House Prices Project

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Introduction

This project aims to predict the final price of houses using the Ames housing dataset.

Data description

The Ames Housing dataset was compiled by Dean De Cock for use in data science education. It's an alternative to the Boston Housing dataset and is for data scientists looking for a modernized and expanded version of the often cited Boston Housing dataset.

The Ames housing data contains With 79 explanatory variables describing (almost) every aspect of residential homes in Ames, Iowa.

Data Processing

Install packages

```
#install.packages(c("Amelia","purrr","tidyr","ggplot2","rpart","plyr","corrplot","RColorBrewer","ggrepel","Desc
```

Load data

```
df <- read.table("../data/raw/train.csv", sep = ",",header = T)
head(df)
```

```
##   Id MSSubClass MSZoning LotFrontage LotArea Street Alley LotShape LandContour
## 1  1         60       RL          65    8450   Pave  <NA>      Reg         Lvl
## 2  2         20       RL          80    9600   Pave  <NA>      Reg         Lvl
## 3  3         60       RL          68   11250   Pave  <NA>      IR1         Lvl
## 4  4         70       RL          60    9550   Pave  <NA>      IR1         Lvl
## 5  5         60       RL          84   14260   Pave  <NA>      IR1         Lvl
## 6  6         50       RL          85   14115   Pave  <NA>      IR1         Lvl
##   Utilities LotConfig LandSlope Neighborhood Condition1 Condition2 BldgType
## 1    AllPub    Inside       Gtl      CollgCr       Norm       Norm     1Fam
## 2    AllPub       FR2       Gtl      Veenker      Feedr       Norm     1Fam
## 3    AllPub    Inside       Gtl      CollgCr       Norm       Norm     1Fam
## 4    AllPub    Corner       Gtl      Crawfor       Norm       Norm     1Fam
## 5    AllPub       FR2       Gtl      NoRidge       Norm       Norm     1Fam
## 6    AllPub    Inside       Gtl      Mitchel       Norm       Norm     1Fam
##   HouseStyle OverallQual OverallCond YearBuilt YearRemodAdd RoofStyle RoofMatl
## 1     2Story           7           5      2003         2003     Gable  CompShg
## 2     1Story           6           8      1976         1976     Gable  CompShg
```

```
## 3     2Story           7           5      2001         2002     Gable  CompShg
## 4     2Story           7           5      1915         1970     Gable  CompShg
## 5     2Story           8           5      2000         2000     Gable  CompShg
## 6     1.5Fin           5           5      1993         1995     Gable  CompShg
##   Exterior1st Exterior2nd MasVnrType MasVnrArea ExterQual ExterCond Foundation
## 1     VinylSd     VinylSd    BrkFace        196        Gd        TA      PConc
## 2     MetalSd     MetalSd       None          0        TA        TA     CBlock
## 3     VinylSd     VinylSd    BrkFace        162        Gd        TA      PConc
## 4     Wd Sdng     Wd Shng       None          0        TA        TA     BrkTil
## 5     VinylSd     VinylSd    BrkFace        350        Gd        TA      PConc
## 6     VinylSd     VinylSd       None          0        TA        TA       Wood
##   BsmtQual BsmtCond BsmtExposure BsmtFinType1 BsmtFinSF1 BsmtFinType2
## 1       Gd       TA           No          GLQ        706          Unf
## 2       Gd       TA           Gd          ALQ        978          Unf
## 3       Gd       TA           Mn          GLQ        486          Unf
## 4       TA       Gd           No          ALQ        216          Unf
## 5       Gd       TA           Av          GLQ        655          Unf
## 6       Gd       TA           No          GLQ        732          Unf
##   BsmtFinSF2 BsmtUnfSF TotalBsmtSF Heating HeatingQC CentralAir Electrical
## 1          0       150         856    GasA        Ex          Y      SBrkr
## 2          0       284        1262    GasA        Ex          Y      SBrkr
## 3          0       434         920    GasA        Ex          Y      SBrkr
## 4          0       540         756    GasA        Gd          Y      SBrkr
## 5          0       490        1145    GasA        Ex          Y      SBrkr
## 6          0        64         796    GasA        Ex          Y      SBrkr
##   X1stFlrSF X2ndFlrSF LowQualFinSF GrLivArea BsmtFullBath BsmtHalfBath FullBath
## 1       856       854            0      1710            1            0        2
## 2      1262         0            0      1262            0            1        2
## 3       920       866            0      1786            1            0        2
## 4       961       756            0      1717            1            0        1
## 5      1145      1053            0      2198            1            0        2
## 6       796       566            0      1362            1            0        1
##   HalfBath BedroomAbvGr KitchenAbvGr KitchenQual TotRmsAbvGrd Functional
## 1        1            3            1          Gd            8        Typ
## 2        0            3            1          TA            6        Typ
## 3        1            3            1          Gd            6        Typ
## 4        0            3            1          Gd            7        Typ
## 5        1            4            1          Gd            9        Typ
## 6        1            1            1          TA            5        Typ
##   Fireplaces FireplaceQu GarageType GarageYrBlt GarageFinish GarageCars
## 1          0       <NA>     Attchd        2003          RFn          2
## 2          1         TA     Attchd        1976          RFn          2
## 3          1         TA     Attchd        2001          RFn          2
## 4          1         Gd     Detchd        1998          Unf          3
## 5          1         TA     Attchd        2000          RFn          3
## 6          0       <NA>     Attchd        1993          Unf          2
##   GarageArea GarageQual GarageCond PavedDrive WoodDeckSF OpenPorchSF
## 1        548         TA         TA          Y          0          61
## 2        460         TA         TA          Y        298           0
## 3        608         TA         TA          Y          0          42
## 4        642         TA         TA          Y          0          35
## 5        836         TA         TA          Y        192          84
## 6        480         TA         TA          Y         40          30
##   EnclosedPorch X3SsnPorch ScreenPorch PoolArea PoolQC Fence MiscFeature
## 1             0          0           0        0   <NA>  <NA>        <NA>
## 2             0          0           0        0   <NA>  <NA>        <NA>
## 3             0          0           0        0   <NA>  <NA>        <NA>
## 4           272          0           0        0   <NA>  <NA>        <NA>
## 5             0          0           0        0   <NA>  <NA>        <NA>
## 6             0        320           0        0   <NA> MnPrv        Shed
##   MiscVal MoSold YrSold SaleType SaleCondition SalePrice
```

```
## 1       0      2   2008       WD        Normal    208500
## 2       0      5   2007       WD        Normal    181500
## 3       0      9   2008       WD        Normal    223500
## 4       0      2   2006       WD       Abnorml    140000
## 5       0     12   2008       WD        Normal    250000
## 6     700     10   2009       WD        Normal    143000
```

```
combined <- df

combined <- combined[,!names(combined) %in% "Id"]
str(combined)
```

```
## '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 ...
```

Missing values

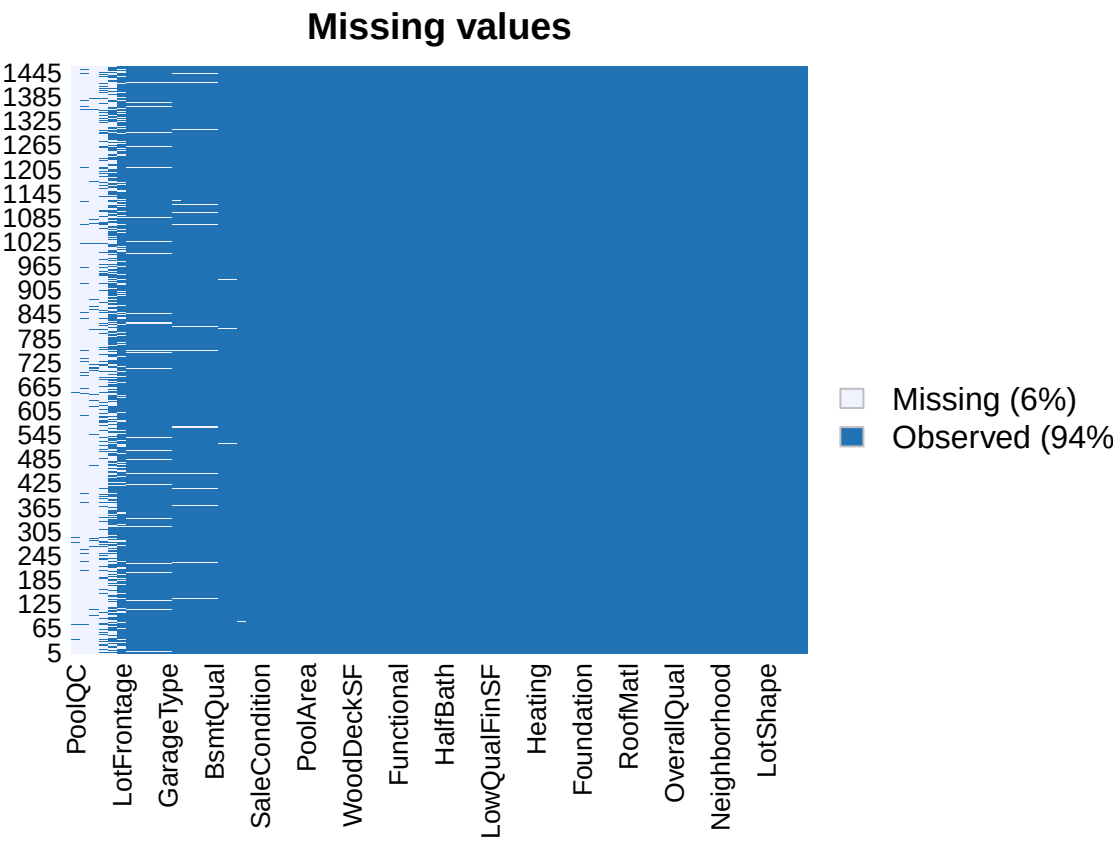
```
library(Amelia)
```

```
## Warning: package 'Amelia' was built under R version 4.0.3
```

```
## Loading required package: Rcpp
```

```
## ##
## ## Amelia II: Multiple Imputation
## ## (Version 1.7.6, built: 2019-11-24)
## ## Copyright (C) 2005-2020 James Honaker, Gary King and Matthew Blackwell
## ## Refer to http://gking.harvard.edu/amelia/ for more information
## ##
```

```
misscounts <- sapply(combined,function(x) sum(is.na(x)))
missmap(combined, main = "Missing values")
```




```
sort(colSums(sapply(combined, is.na)), decreasing = T)
```

```
##        PoolQC   MiscFeature         Alley         Fence   FireplaceQu
##          1453          1406          1369          1179           690
##   LotFrontage    GarageType   GarageYrBlt  GarageFinish    GarageQual
##           259            81            81            81            81
##    GarageCond  BsmtExposure  BsmtFinType2      BsmtQual      BsmtCond
##            81            38            38            37            37
##  BsmtFinType1    MasVnrType    MasVnrArea    Electrical    MSSubClass
##            37             8             8             1             0
##      MSZoning       LotArea        Street      LotShape   LandContour
##             0             0             0             0             0
##     Utilities     LotConfig     LandSlope  Neighborhood    Condition1
##             0             0             0             0             0
##    Condition2      BldgType    HouseStyle   OverallQual   OverallCond
##             0             0             0             0             0
##     YearBuilt  YearRemodAdd     RoofStyle     RoofMatl   Exterior1st
##             0             0             0             0             0
##   Exterior2nd     ExterQual     ExterCond    Foundation    BsmtFinSF1
##             0             0             0             0             0
##    BsmtFinSF2     BsmtUnfSF   TotalBsmtSF       Heating     HeatingQC
##             0             0             0             0             0
##    CentralAir     X1stFlrSF     X2ndFlrSF  LowQualFinSF     GrLivArea
##             0             0             0             0             0
##  BsmtFullBath  BsmtHalfBath      FullBath      HalfBath  BedroomAbvGr
##             0             0             0             0             0
##  KitchenAbvGr   KitchenQual  TotRmsAbvGrd    Functional    Fireplaces
##             0             0             0             0             0
##    GarageCars    GarageArea    PavedDrive    WoodDeckSF   OpenPorchSF
##             0             0             0             0             0
## EnclosedPorch    X3SsnPorch   ScreenPorch      PoolArea       MiscVal
##             0             0             0             0             0
##        MoSold        YrSold      SaleType SaleCondition     SalePrice
```

```
##             0             0             0             0             0
```

pool variables

The PoolQC has the most missing values. Pool area does not have missing values but it is related to PoolQC as it does not make sense to have a pool quality data when there is zero pool area or no pool. Its description from the data description document is.

PoolQC: Pool quality

```
   Ex   Excellent
   Gd   Good
   TA   Average/Typical
   Fa   Fair
   NA   No Pool
```

Since a house with no pool has NA they are not really missing values. we can check with other pool related variables to see if there are any actual missing values in our data.

```
table(is.na(combined$PoolQC))
```

```
##
## FALSE  TRUE
##     7  1453
```

```
table(combined$PoolArea, combined$PoolQC, useNA = 'ifany')
```

```
##
##         Ex   Fa   Gd <NA>
##   0      0    0    0 1453
##   480    0    0    1    0
##   512    1    0    0    0
##   519    0    1    0    0
##   555    1    0    0    0
##   576    0    0    1    0
##   648    0    1    0    0
##   738    0    0    1    0
```

Here we have some actual missing values. We have 13 houses with pool area data but we have only 10 PoolQC data available.

```
library(plyr)
```

```
## Warning: package 'plyr' was built under R version 4.0.3
```

```
library(ggplot2)
```

```
## Warning: package 'ggplot2' was built under R version 4.0.3
```

```
combined[combined$PoolArea==0,]$PoolQC <- "None"

# convert all NA's in PoolQC to none except for the 3 actual missing values.

combined[is.na(combined$PoolQC),c("OverallQual","PoolArea")]
```

```
## [1] OverallQual PoolArea
## <0 rows> (or 0-length row.names)
```

```
# imputing the values of poolQC according to overall quality and pool area.

combined[is.na(combined$PoolQC),"PoolQC"] <- c("TA","Gd","TA")

# label encoding as the values are ordinal.

quality <- c("None" = 0, 'Po' = 1 , 'Fa' = 2, 'TA'=3 , 'Gd'=4, 'Ex'=5 )

combined$PoolQC <- as.integer(revalue(combined$PoolQC, quality))
```

```
## The following `from` values were not present in `x`: Po, TA
```

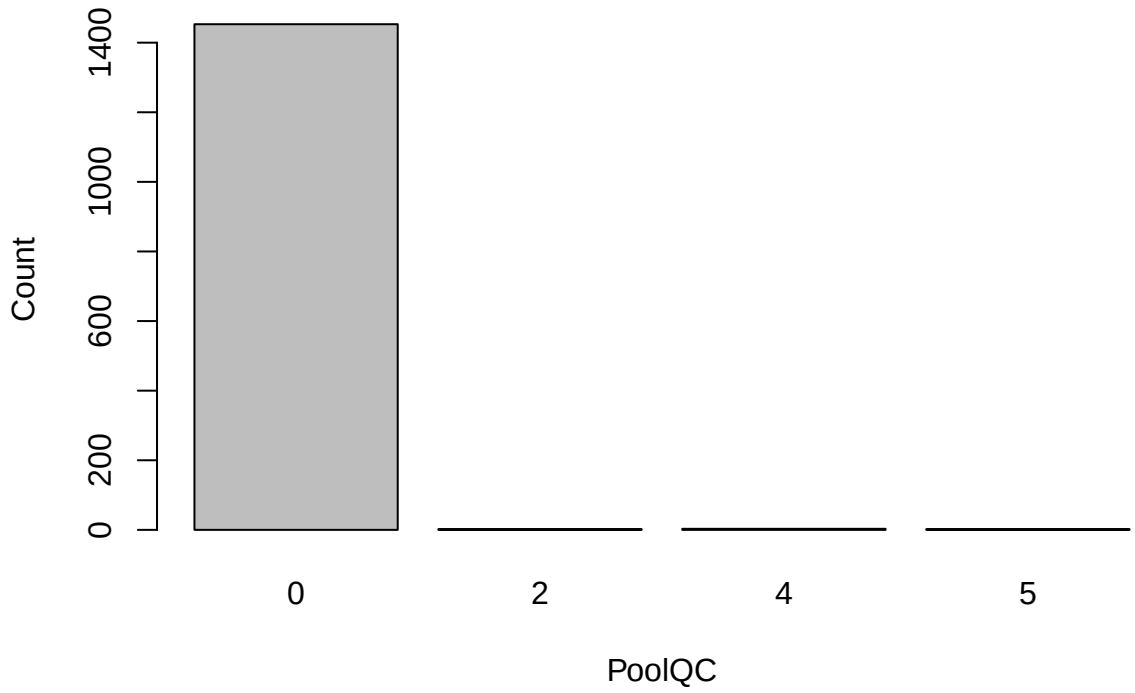
```
table(combined$PoolQC)
```

```
##
##    0    2    4    5
## 1453    2    3    2
```

```
str(combined$PoolQC)
```

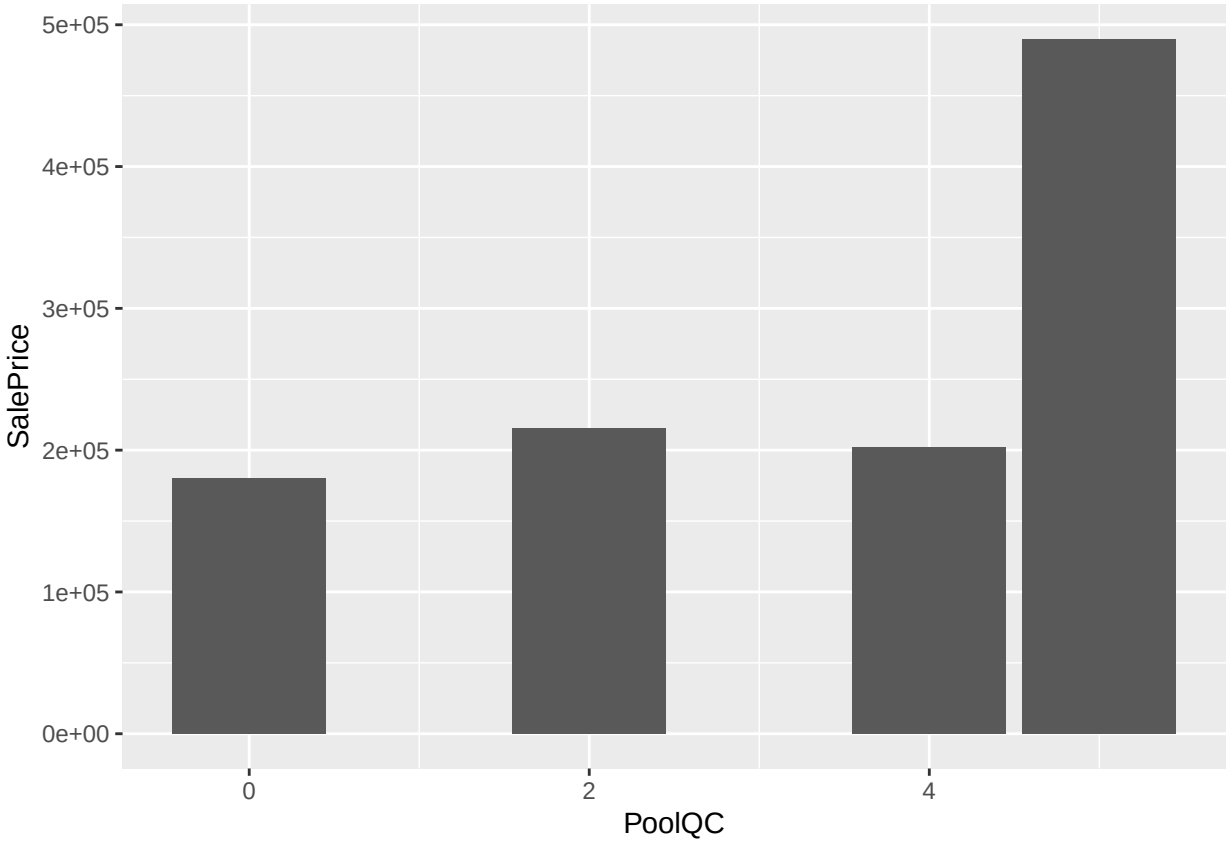
```
##  int [1:1460] 0 0 0 0 0 0 0 0 0 0 ...
```

```
barplot(table(combined$PoolQC), xlab = "PoolQC", ylab = "Count")
```




```
ggplot(combined, aes(x=PoolQC, y = SalePrice)) + geom_bar(stat = 'summary')
```

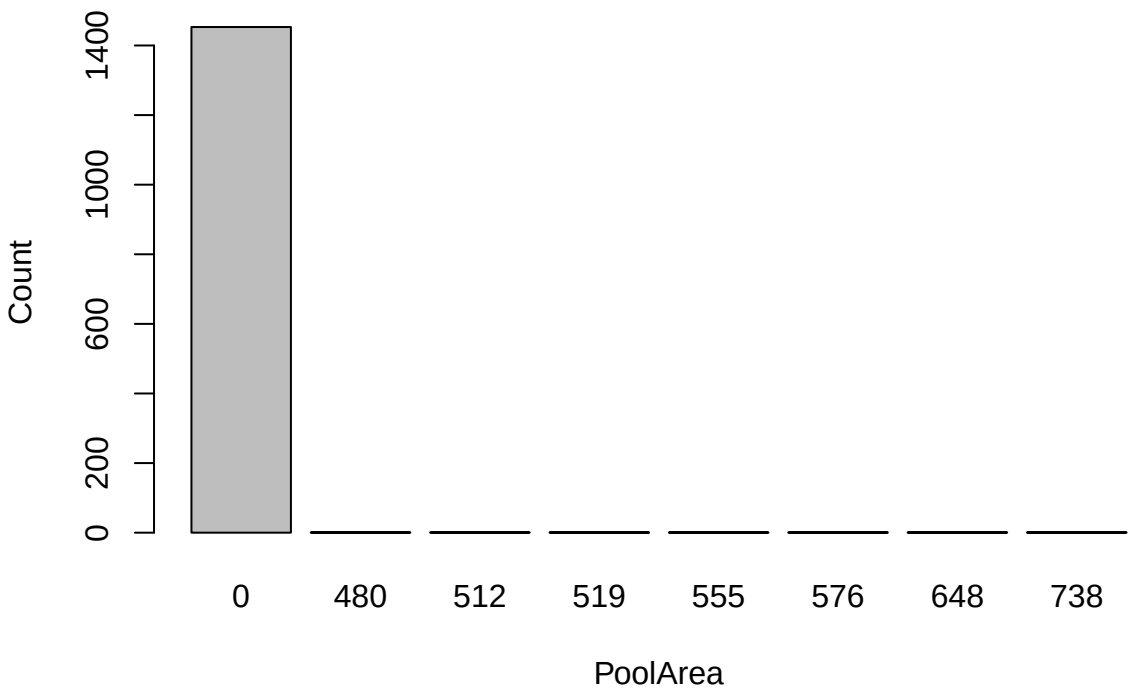
```
## No summary function supplied, defaulting to `mean_se()`
```



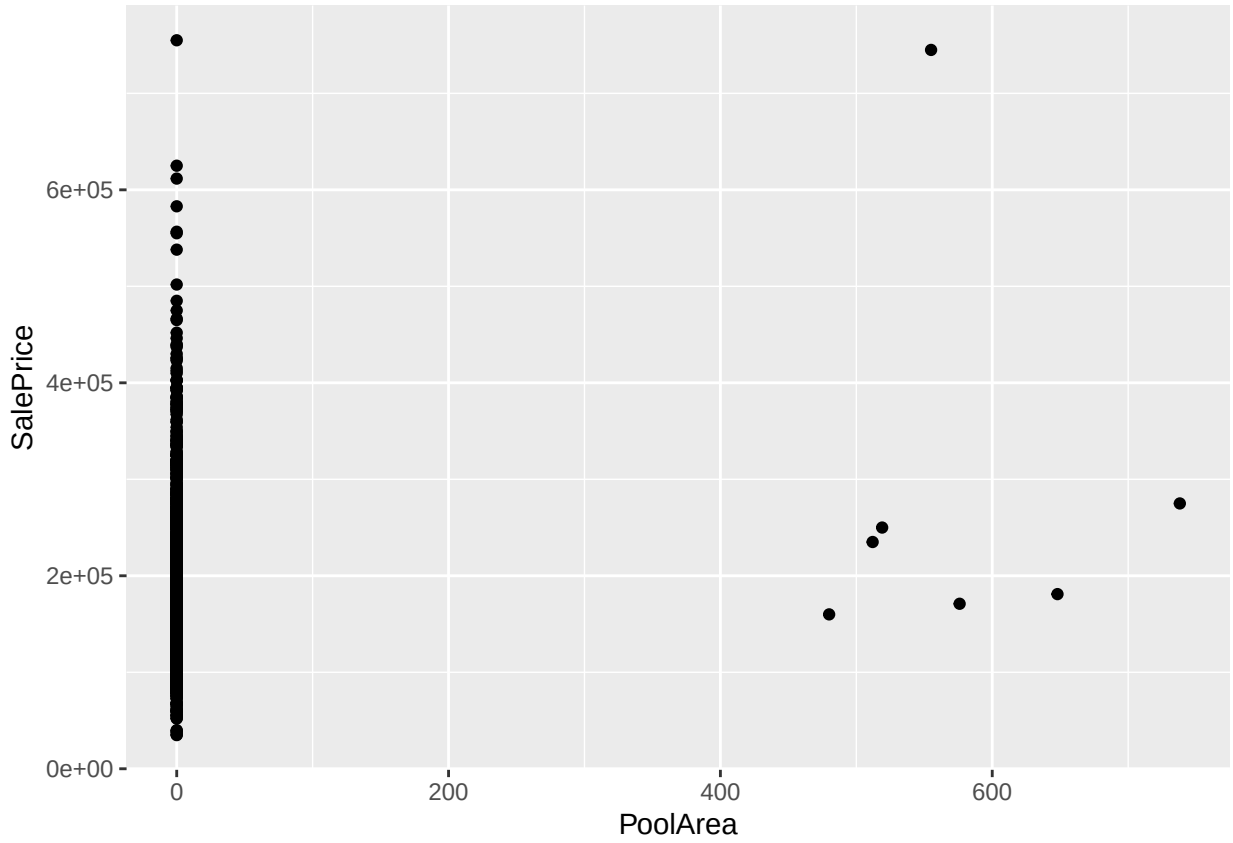

```
table(combined$PoolArea)
```

```
##
##    0  480  512  519  555  576  648  738
## 1453    1    1    1    1    1    1    1
```

```
barplot(table(combined$PoolArea), xlab = "PoolArea", ylab = "Count")
```




```
ggplot(combined, aes(x=PoolArea, y = SalePrice)) + geom_point()
```



MiscFeature variable

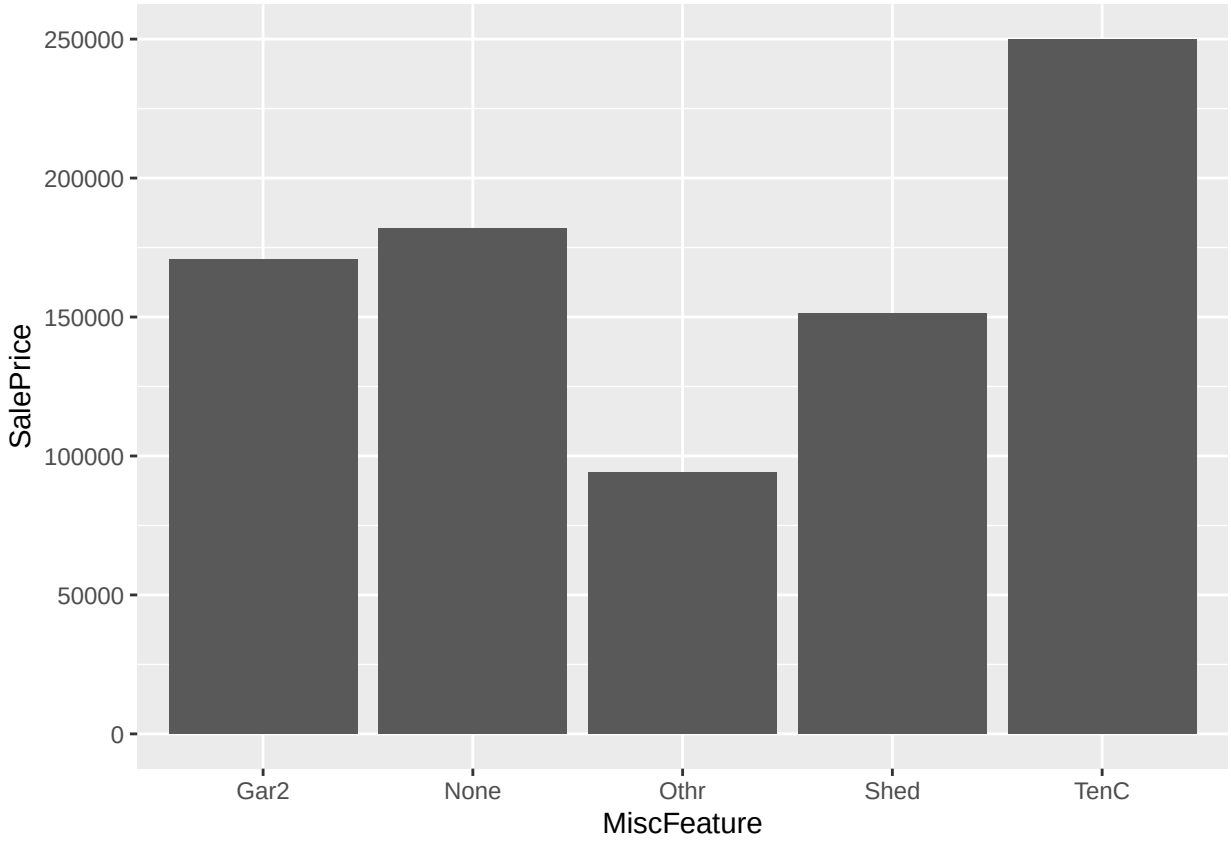
```
table(combined$MiscFeature, useNA = "ifany")
```

```
##
## Gar2 Othr Shed TenC <NA>
##    2    2   49    1 1406
```

In MiscFeature variable, there are 1406 missing values that have to be replaced by none.

```
library(ggplot2)

# convert all NA's in MiscFeature to none.
combined[is.na(combined$MiscFeature),"MiscFeature"] <- "None"

# convert to factor
combined$MiscFeature <- as.factor(combined$MiscFeature)

ggplot(combined, aes(x=MiscFeature, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



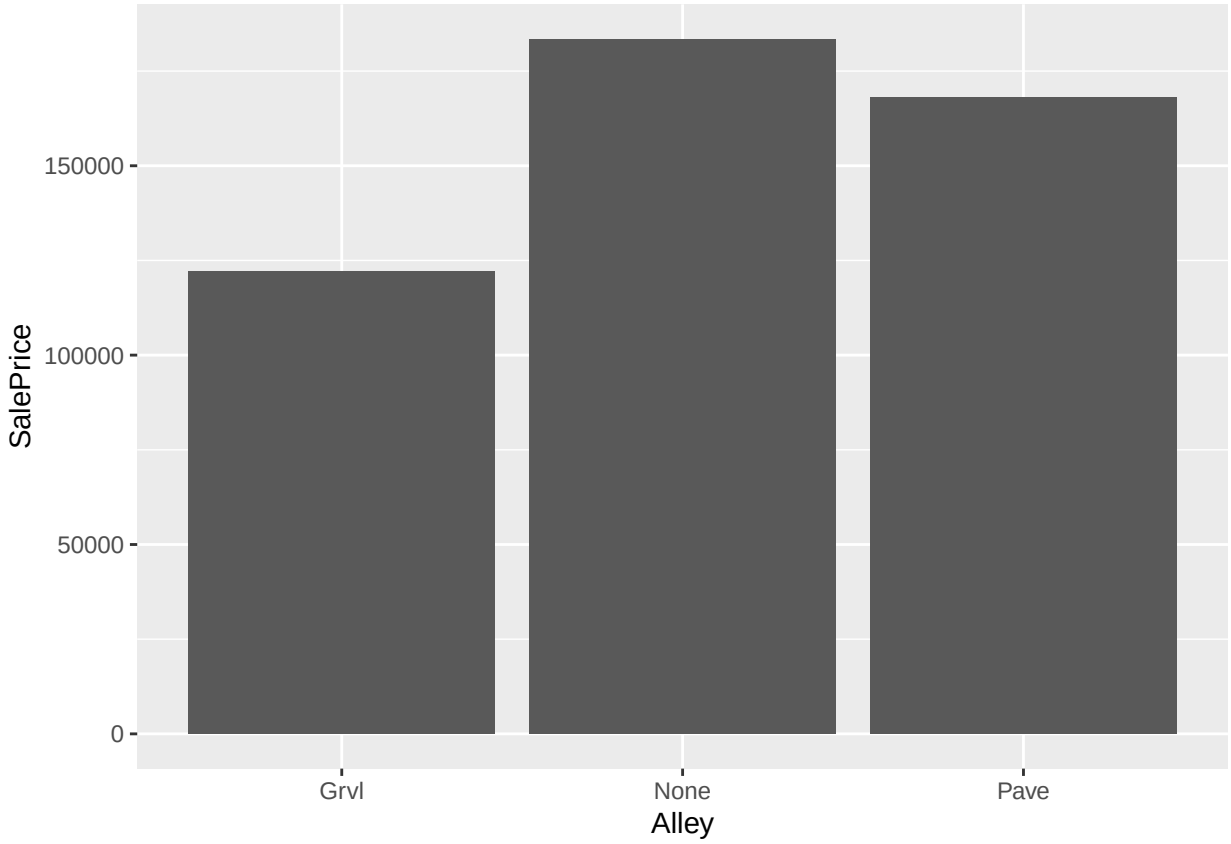
Alley Predictor

```
table(combined$Alley, useNA = "ifany")
```

```
##
## Grvl Pave <NA>
##   50   41 1369
```

```
# convert all NA's in Alley to none.
combined[is.na(combined$Alley),"Alley"] <- "None"

# convert to factor
combined$Alley <- as.factor(combined$Alley)

ggplot(combined, aes(x=Alley, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



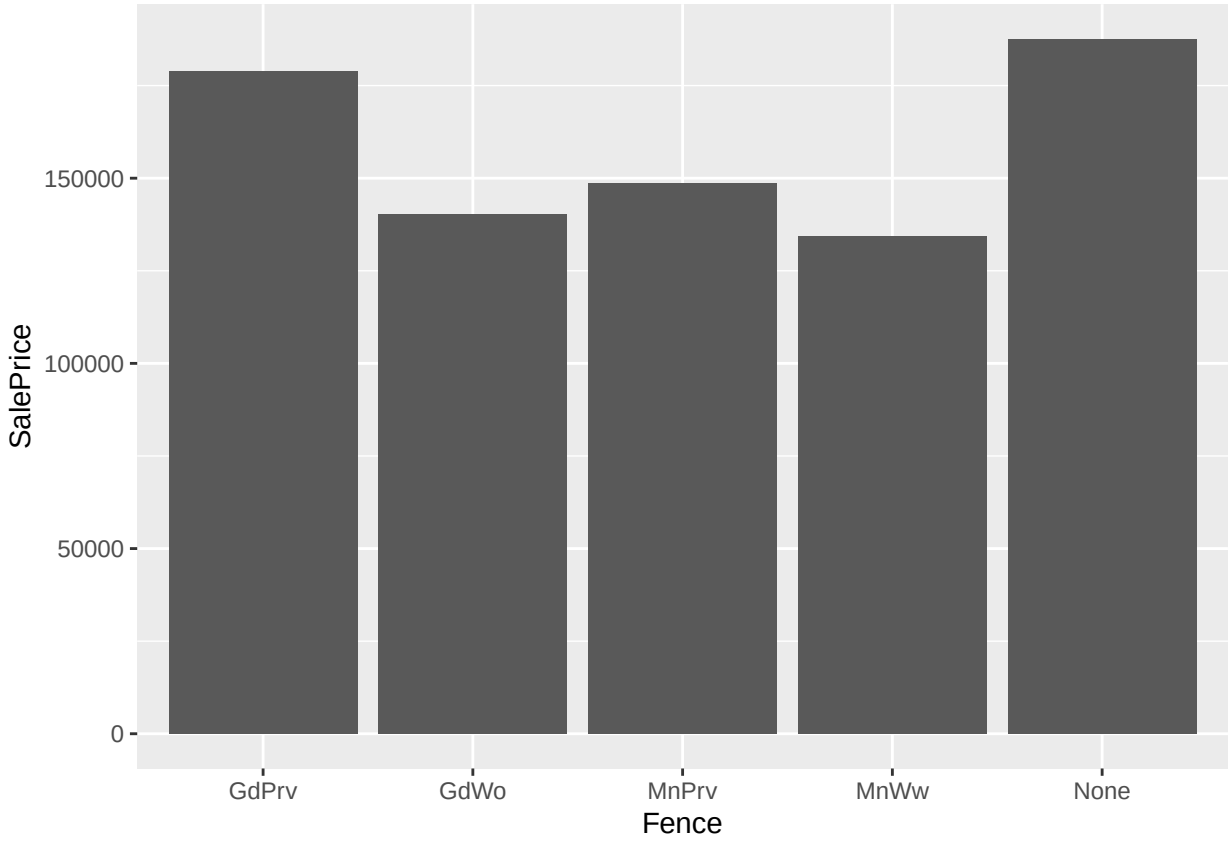
Fence predictor

```
table(combined$Fence, useNA = "ifany")
```

```
##
## GdPrv  GdWo MnPrv  MnWw  <NA>
##    59    54   157    11  1179
```

```
# convert all NA's in Fence to none.
combined[is.na(combined$Fence),"Fence"] <- "None"

# convert to factor
combined$Fence <- as.factor(combined$Fence)

ggplot(combined, aes(x=Fence, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Fireplace variables

Fireplace quality

```
table(combined$FireplaceQu, useNA = "ifany")
```

```
##
##   Ex   Fa   Gd   Po   TA <NA>
##   24   33  380   20  313  690
```

```
# convert all NA's in FireplaceQu to none.

combined[is.na(combined$FireplaceQu),"FireplaceQu"] <- "None"

# Changing and converting to factor levels from character.


combined$FireplaceQu <- as.integer(revalue(combined$FireplaceQu, quality))

table(combined$FireplaceQu, useNA = "ifany")
```

```
##
##   0   1   2   3   4   5
## 690  20  33 313 380  24
```

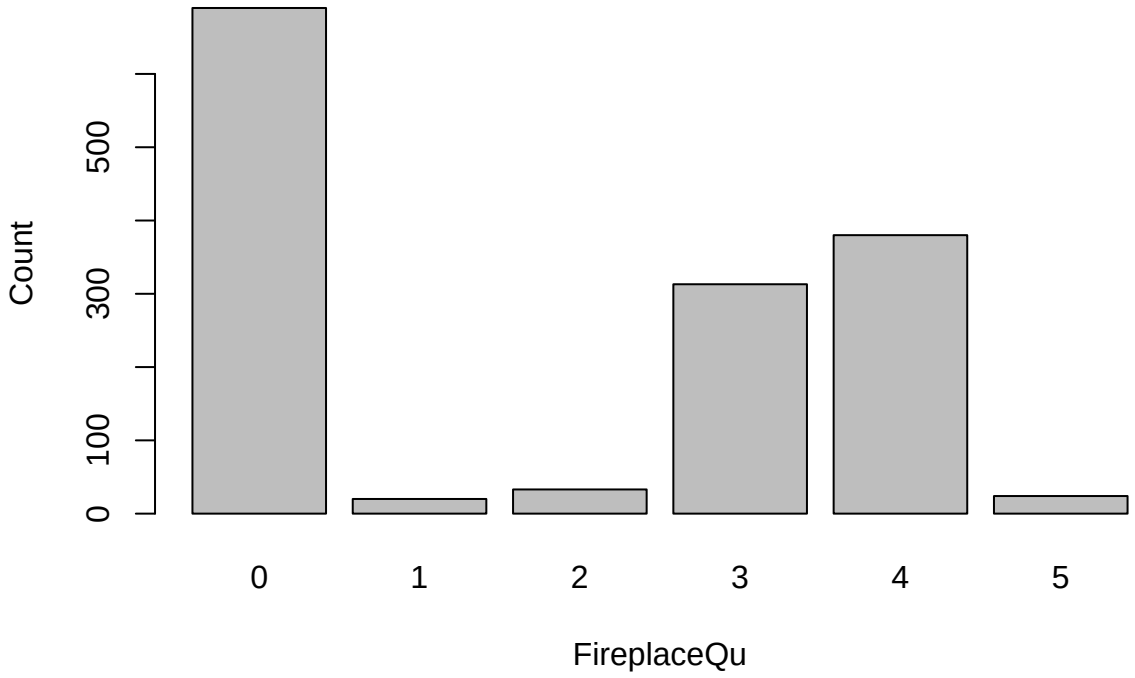
```
str(combined$FireplaceQu)
```

```
##  int [1:1460] 0 3 3 4 3 0 4 3 3 3 ...
```

```
anyNA(combined$FireplaceQu)
```

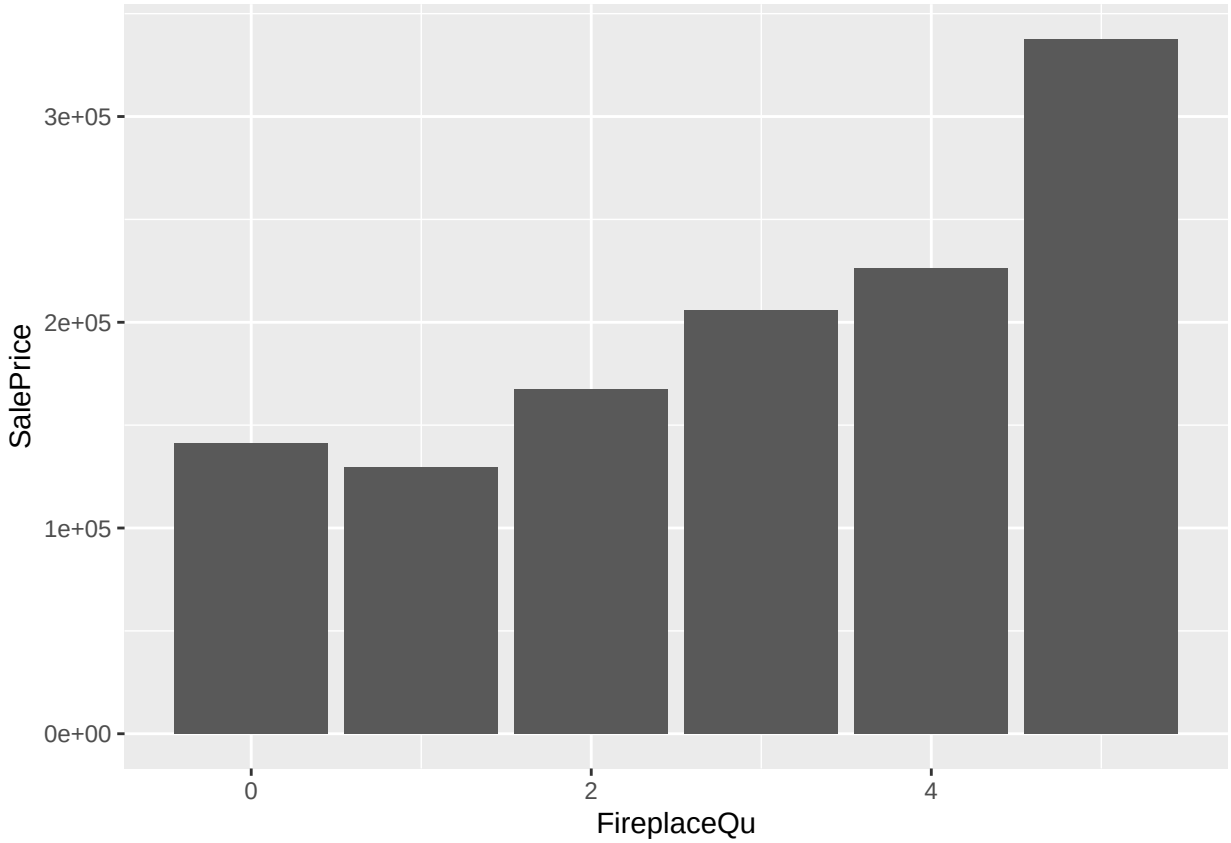
```
## [1] FALSE
```

```
barplot(table(combined$FireplaceQu), xlab = "FireplaceQu", ylab = "Count")
```




```
ggplot(combined, aes(x=FireplaceQu, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Lot variables

LotFrontage LotShape LotConfig LotArea

```
table(is.na(combined$LotFrontage))
```

```
##
## FALSE  TRUE
##  1201   259
```

Here we have 259 missing values which cannot be replaced by none as it is a numerical variable. So we predict using rpart.

http://r-statistics.co/Missing-Value-Treatment-With-R.html

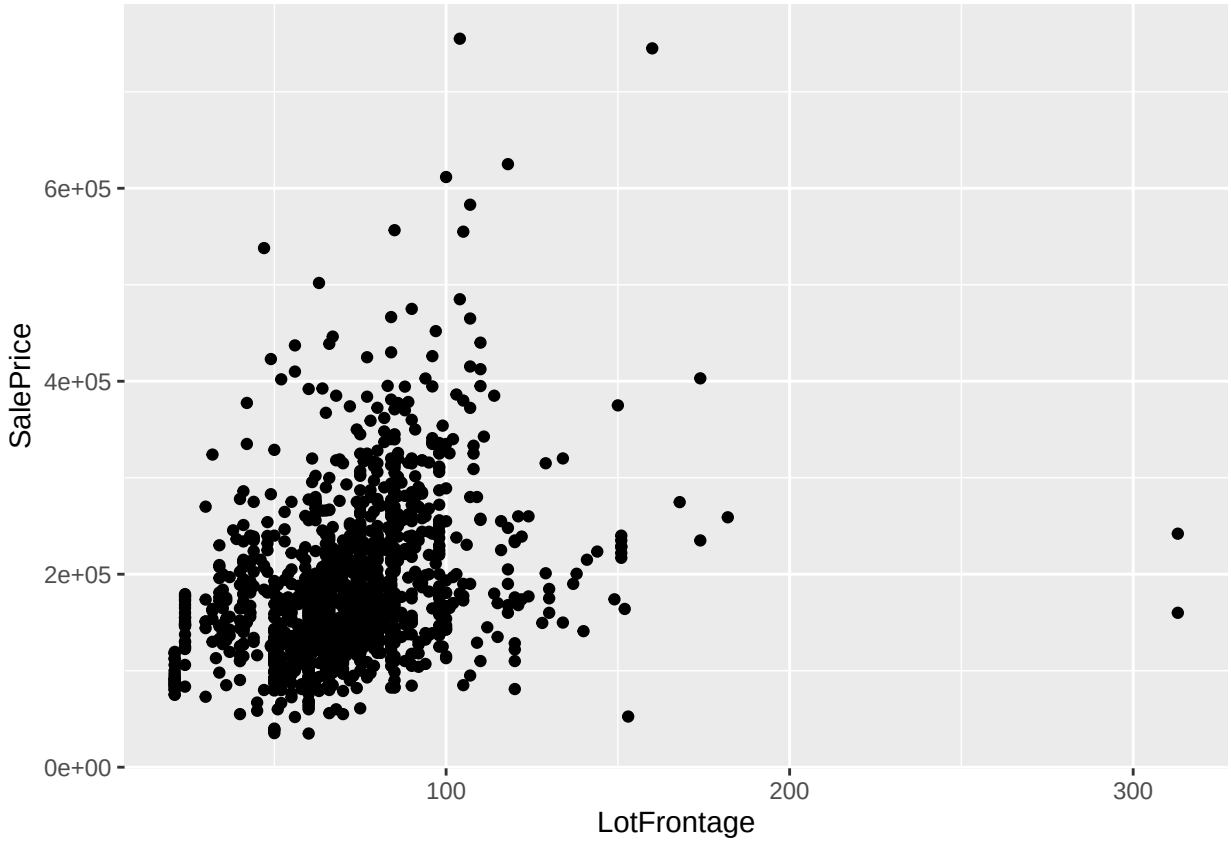
```
# predictors that lotfrontage variable might depend on.
predictors <- c("MSSubClass", "MSZoning", "LotFrontage", "LotArea", "Street", "Alley", "LotShape", "LandContour"
library(rpart)
```

```
## Warning: package 'rpart' was built under R version 4.0.3
```

```
mod <- rpart(LotFrontage~., data = combined[!is.na(combined$LotFrontage),predictors], method = "anova", na.actio

pred <- predict(mod, combined[is.na(combined$LotFrontage),predictors])
pred <- round(pred)
combined$LotFrontage[is.na(combined$LotFrontage)] <- pred
anyNA(combined$LotFrontage)
```

```
## [1] FALSE
```

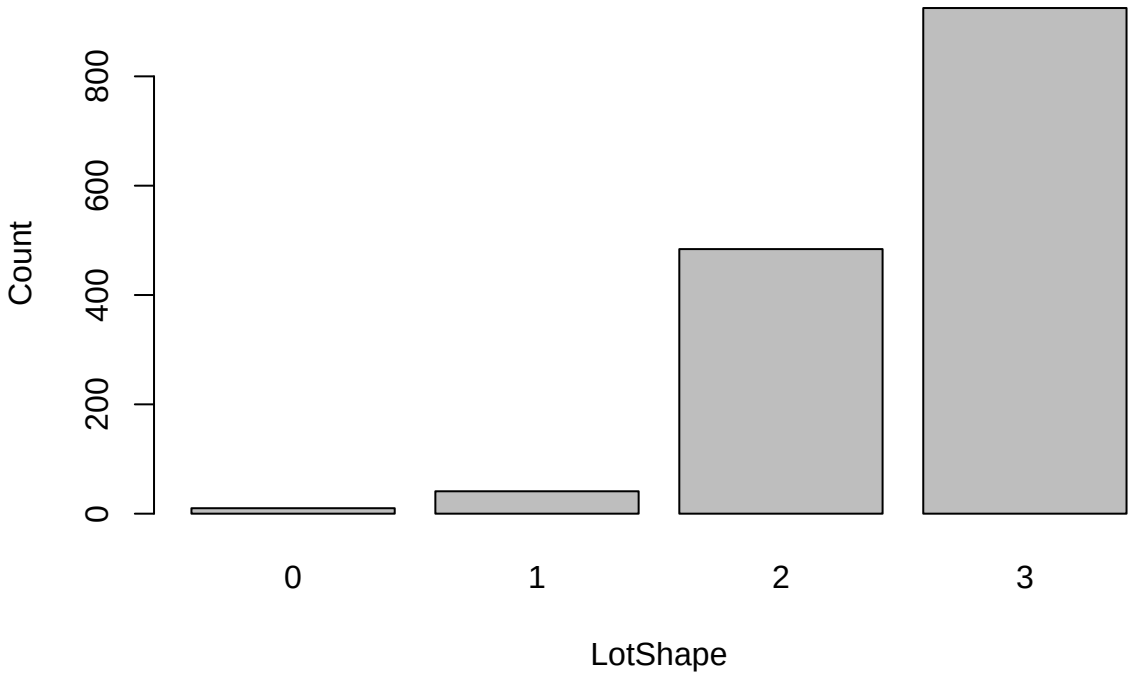
```
ggplot(combined, aes(x=LotFrontage, y = SalePrice)) + geom_point()
```




```
table(combined$LotShape, useNA = "ifany")
```

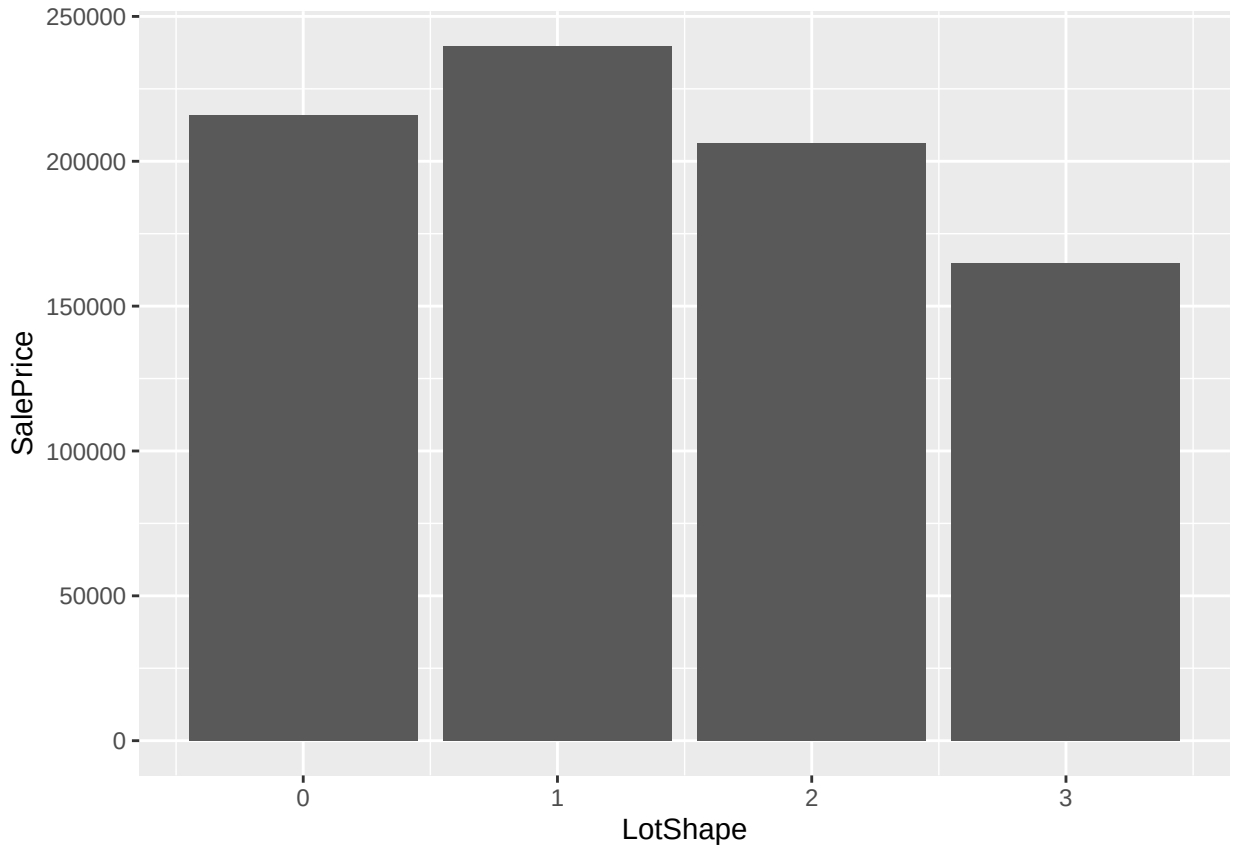
```
##
## IR1 IR2 IR3 Reg
## 484  41  10 925
```

```
combined$LotShape <- as.integer(revalue(combined$LotShape,  c("IR3"=0 , "IR2"=1 , "IR1"=2 , "Reg"=3 )))
barplot(table(combined$LotShape), xlab = "LotShape", ylab = "Count")
```




```
ggplot(combined, aes(x=LotShape, y = SalePrice)) + geom_bar(stat = 'summary')
```

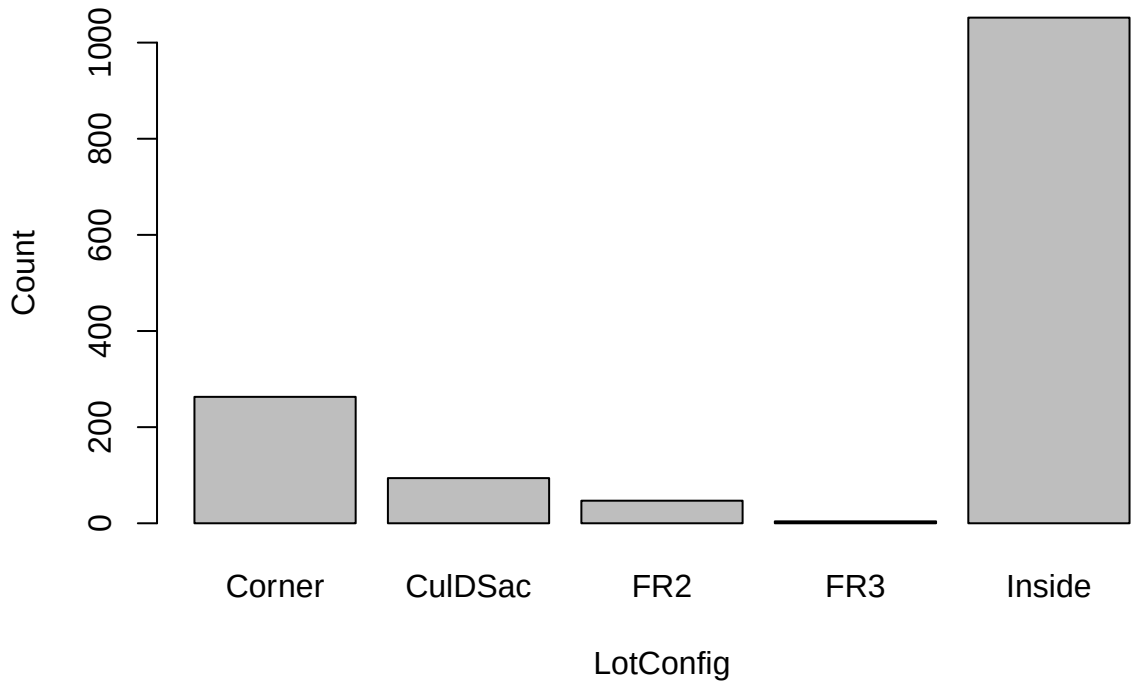
```
## No summary function supplied, defaulting to `mean_se()`
```



```
table(combined$LotConfig, useNA = "ifany")
```

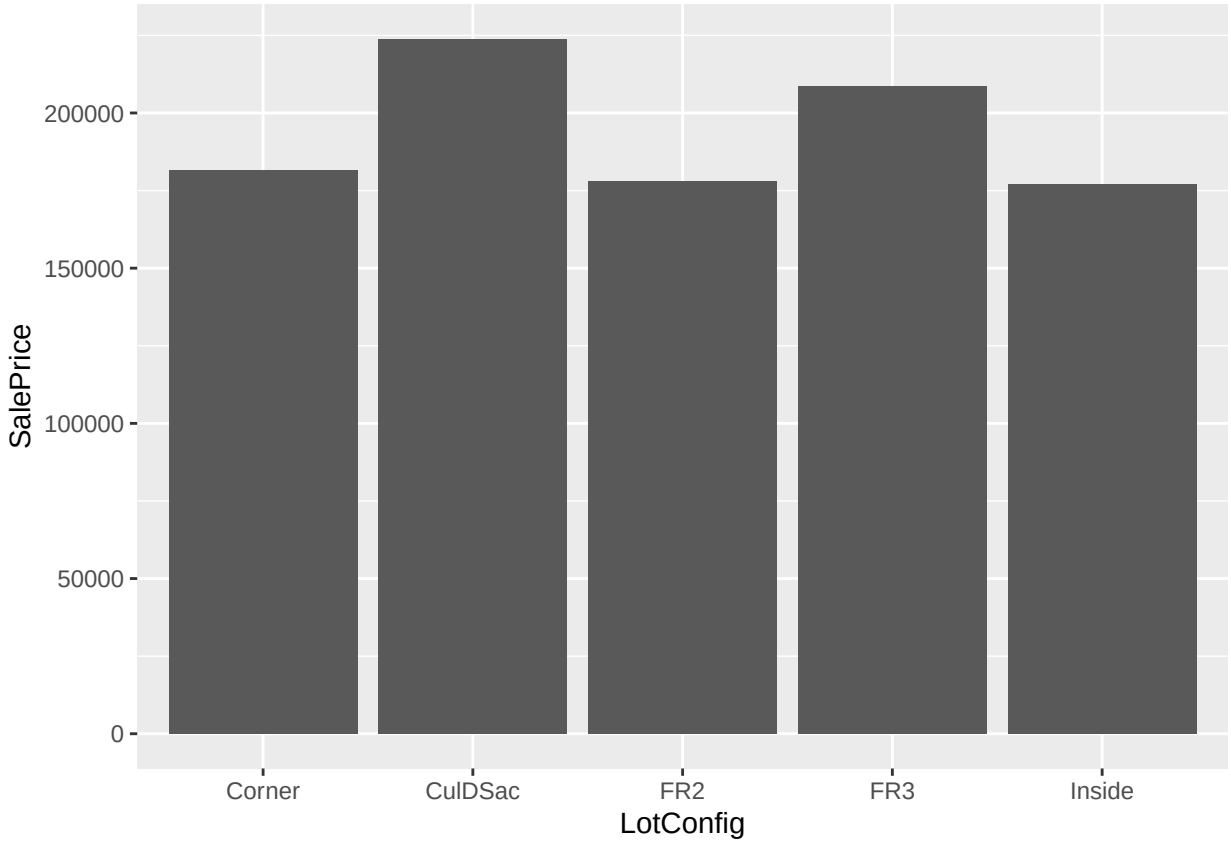
```
##
##  Corner CulDSac     FR2     FR3  Inside
##     263      94      47       4    1052
```

```
combined$LotConfig <- as.factor(combined$LotConfig)
barplot(table(combined$LotConfig), xlab = "LotConfig", ylab = "Count")
```




```
ggplot(combined, aes(x=LotConfig, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Garage variables

GarageYrBlt GarageType GarageFinish, GarageQual, GarageCond, GarageCars, GarageArea

```
garage <- c("GarageYrBlt","GarageType","GarageFinish","GarageQual","GarageCond","GarageCars","GarageArea")
sort(colSums(sapply(combined[,garage], is.na)), decreasing = T)
```

```
##  GarageYrBlt   GarageType GarageFinish   GarageQual   GarageCond   GarageCars
##           81           81           81           81           81            0
##   GarageArea
##            0
```

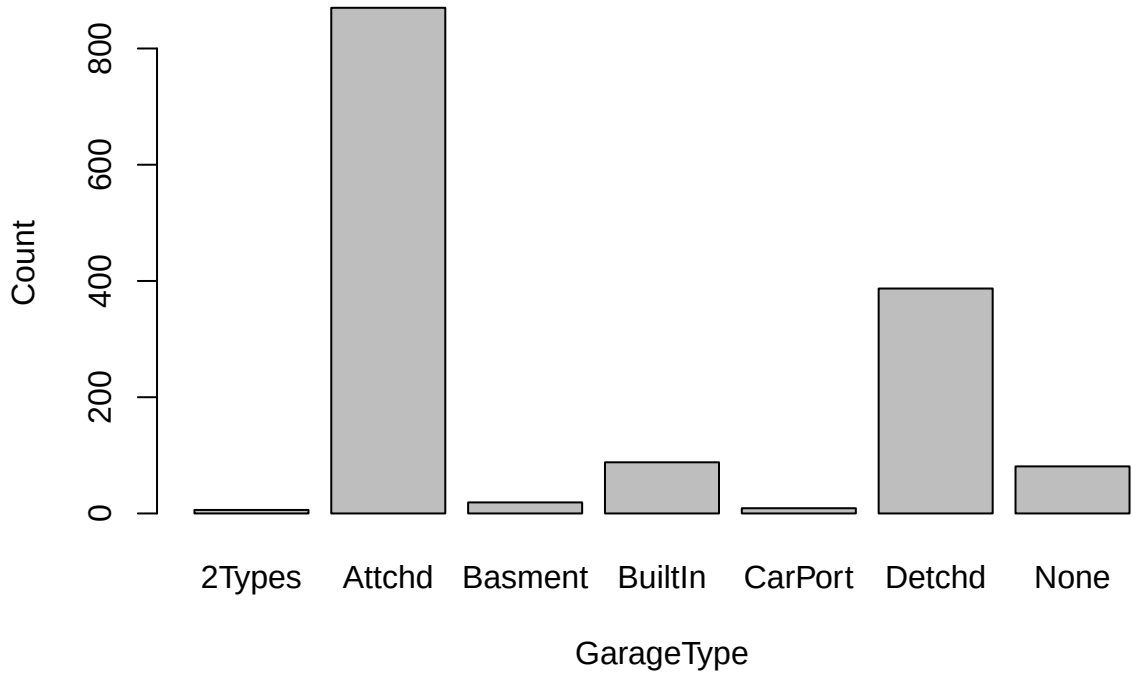
```
combined$GarageYrBlt[is.na(combined$GarageYrBlt)] <- combined$YearBuilt[is.na(combined$GarageYrBlt)]

combined$GarageType[is.na(combined$GarageType)] <- "None"
combined$GarageFinish[is.na(combined$GarageFinish)] <- "None"
combined$GarageCond[is.na(combined$GarageCond)] <- "None"
combined$GarageQual[is.na(combined$GarageQual)] <- "None"
sort(colSums(sapply(combined[,garage], is.na)), decreasing = T)
```

```
##  GarageYrBlt   GarageType GarageFinish   GarageQual   GarageCond   GarageCars
##            0            0            0            0            0            0
##   GarageArea
##            0
```

```
# convert into factor
combined$GarageType <- as.factor(combined$GarageType)
table(combined$GarageType)
```

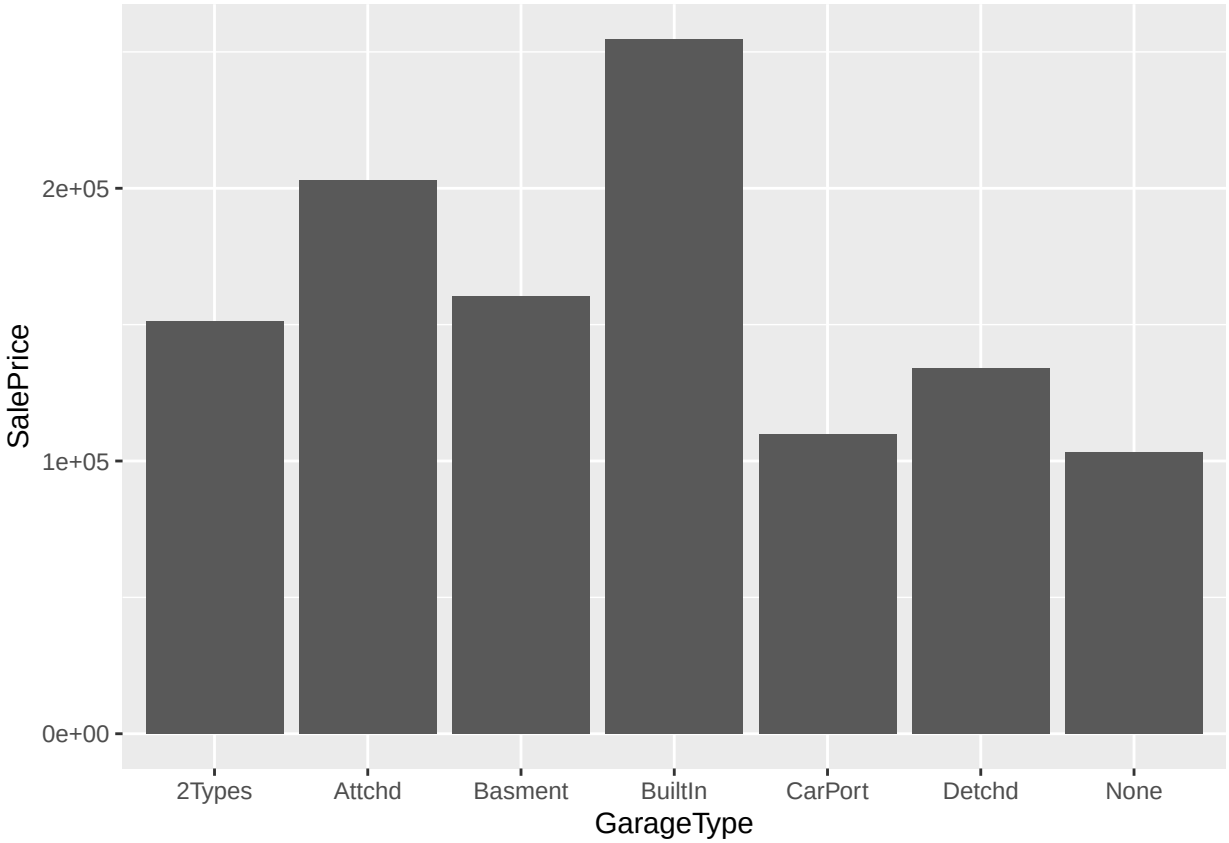
```
##
##  2Types  Attchd Basment BuiltIn CarPort  Detchd    None
##       6     870      19      88       9     387      81
```

```r
barplot(table(combined$GarageType), xlab = "GarageType", ylab = "Count")
```




```r
ggplot(combined, aes(x=GarageType, y = SalePrice)) + geom_bar(stat = 'summary')
```

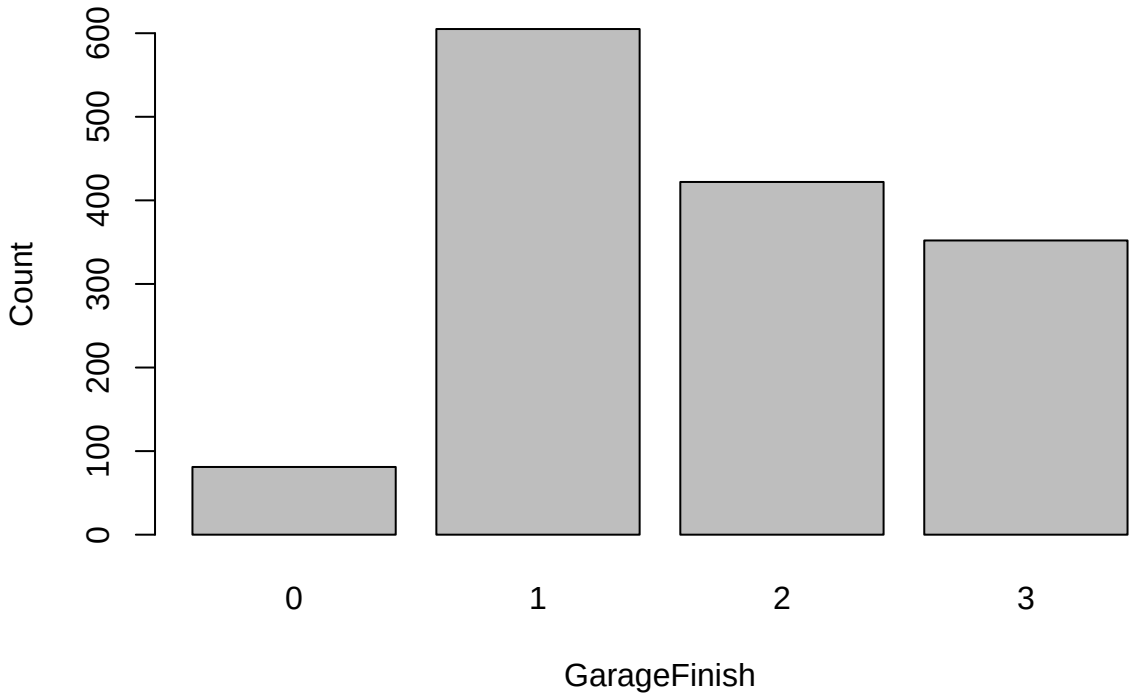
```
## No summary function supplied, defaulting to `mean_se()`
```




```
Finish <- c('None'=0, 'Unf'=1, 'RFn'=2, 'Fin'=3)
combined$GarageFinish<-as.integer(revalue(combined$GarageFinish,  Finish))
table(combined$GarageFinish, useNA = 'ifany')
```

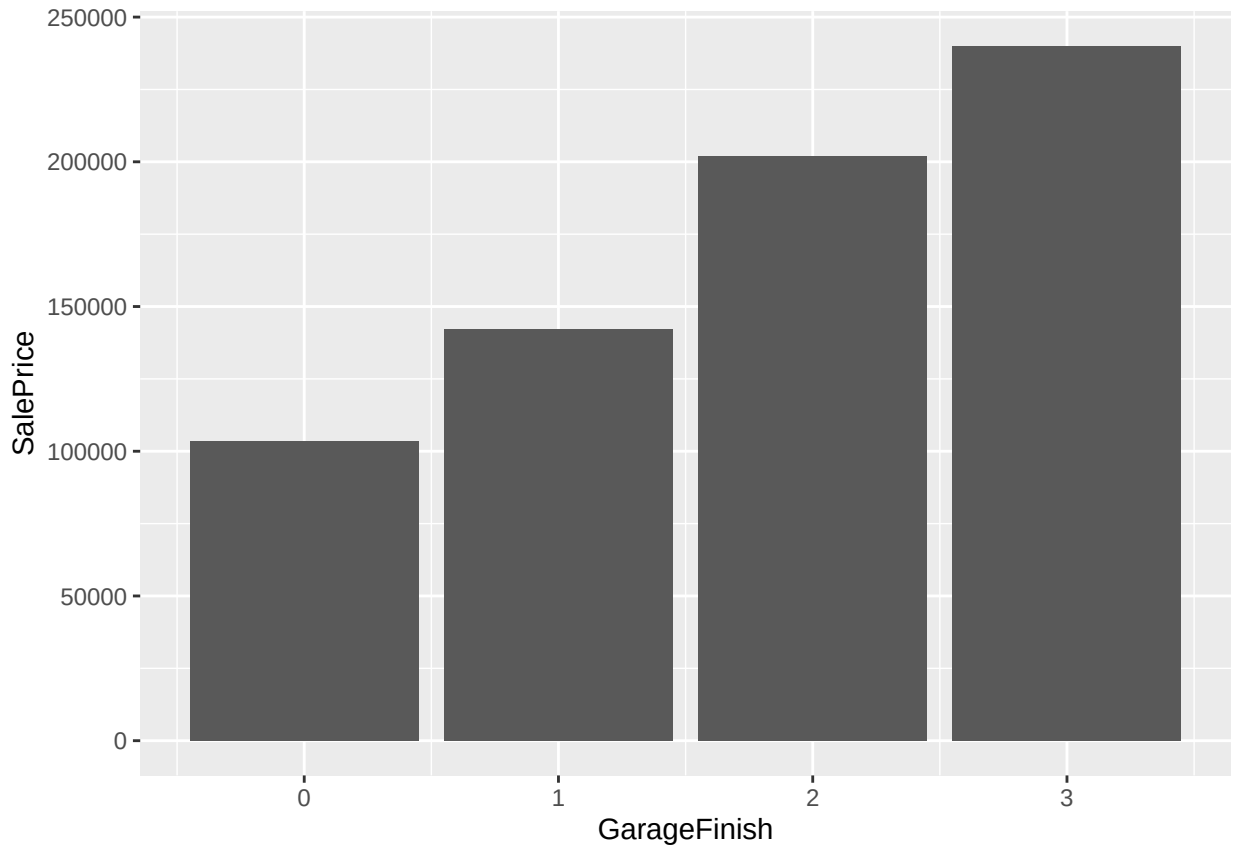
```
##
##   0   1   2   3
##  81 605 422 352
```

```
barplot(table(combined$GarageFinish), xlab = "GarageFinish", ylab = "Count")
```




```
ggplot(combined, aes(x=GarageFinish, y = SalePrice)) + geom_bar(stat = 'summary')
```

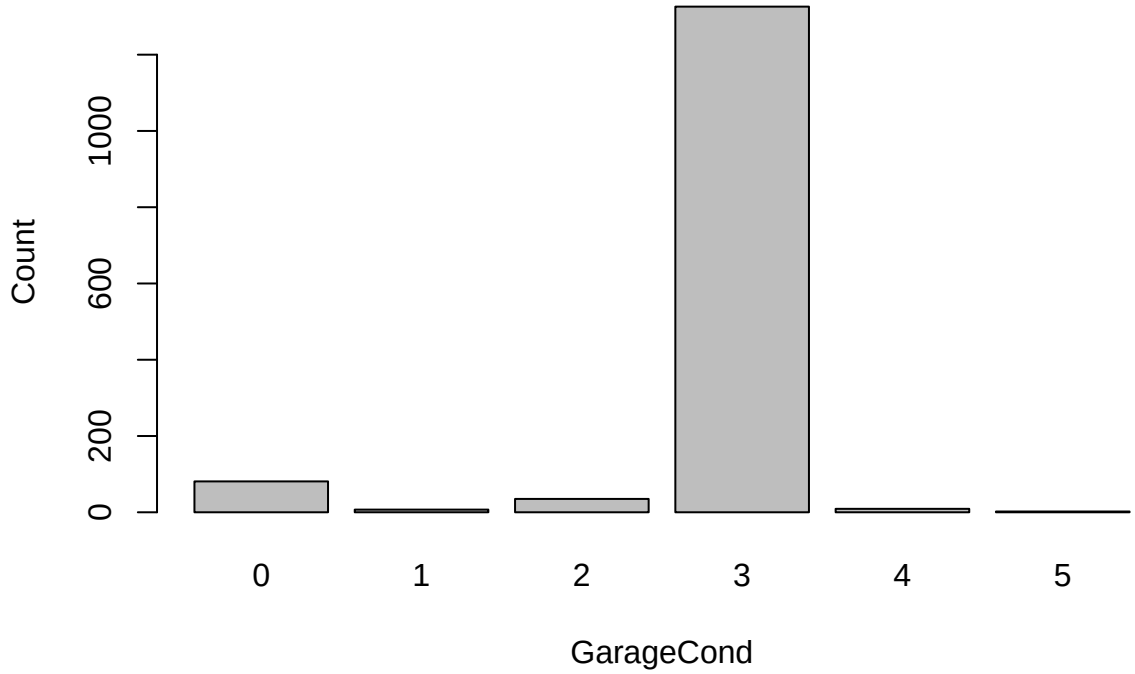
```
## No summary function supplied, defaulting to `mean_se()`
```



```
combined$GarageCond<-as.integer(revalue(combined$GarageCond,  quality))
table(combined$GarageCond, useNA = "ifany")
```

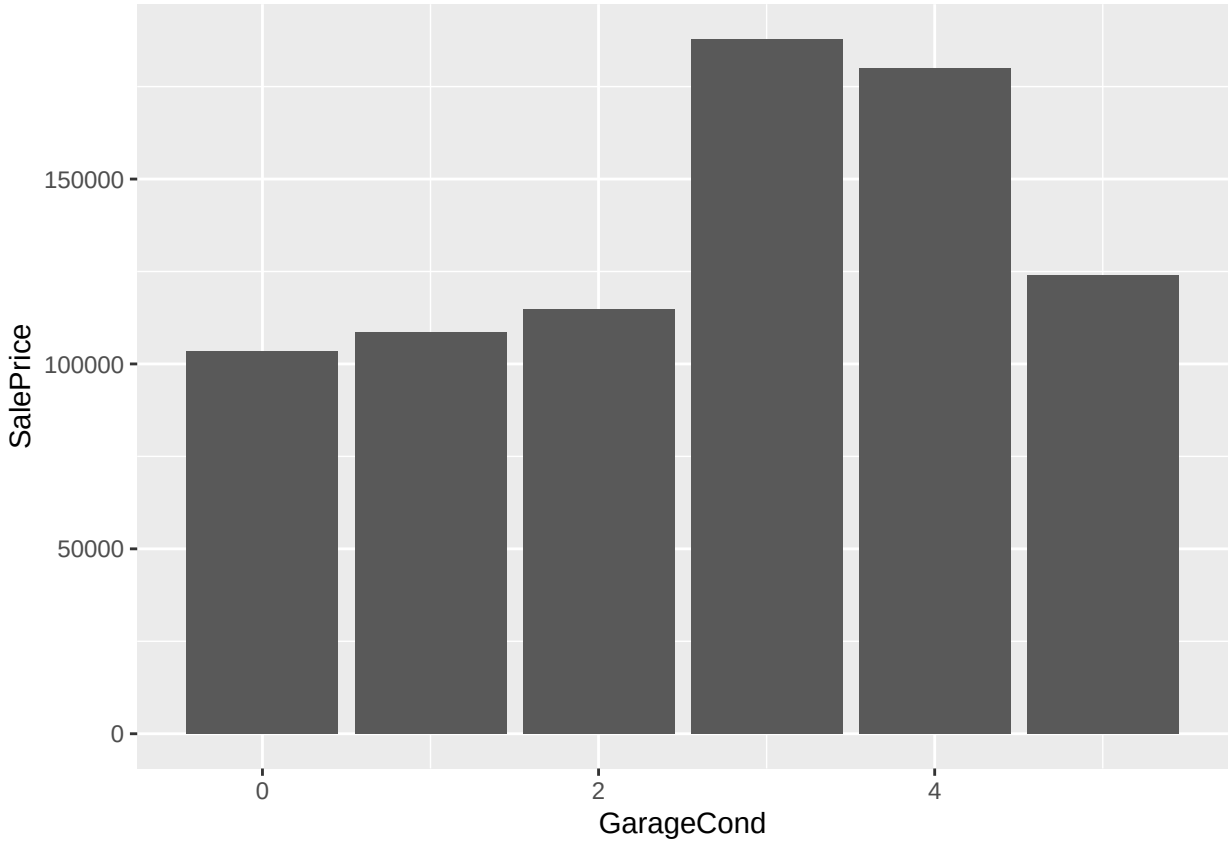
```
##
##    0    1    2    3    4    5
##   81    7   35 1326    9    2
```

```
barplot(table(combined$GarageCond), xlab = "GarageCond", ylab = "Count")
```




```
ggplot(combined, aes(x=GarageCond, y = SalePrice)) + geom_bar(stat = 'summary')
```

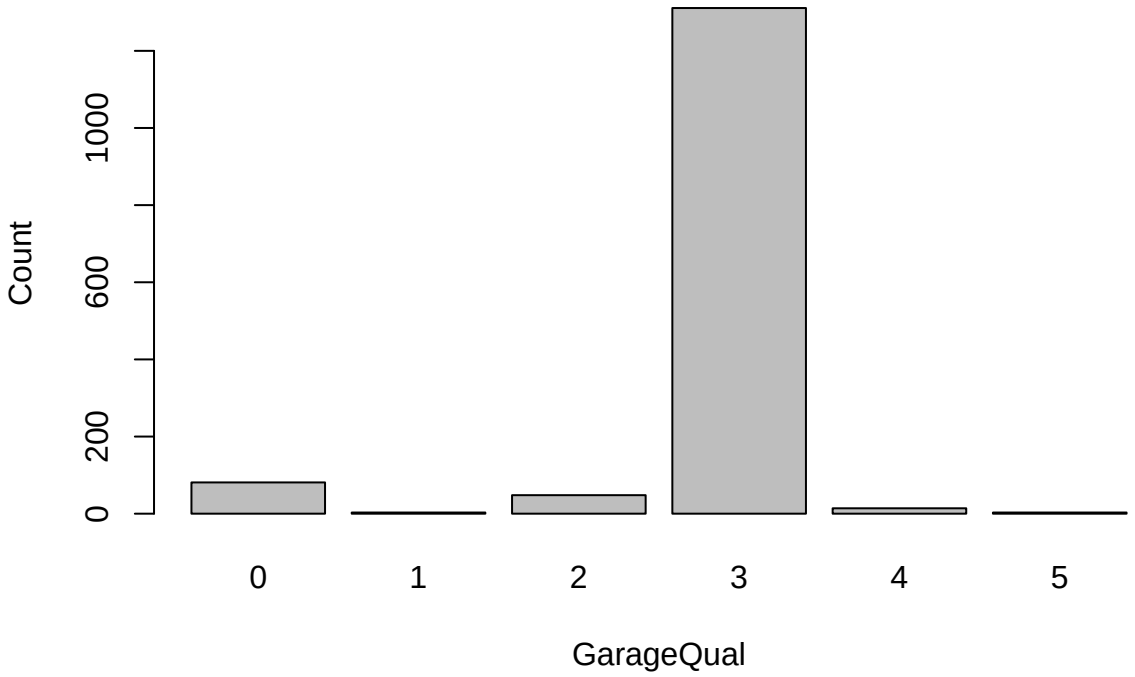
```
## No summary function supplied, defaulting to `mean_se()`
```




```
combined$GarageQual<-as.integer(revalue(combined$GarageQual,  quality))
table(combined$GarageQual, useNA = "ifany")
```

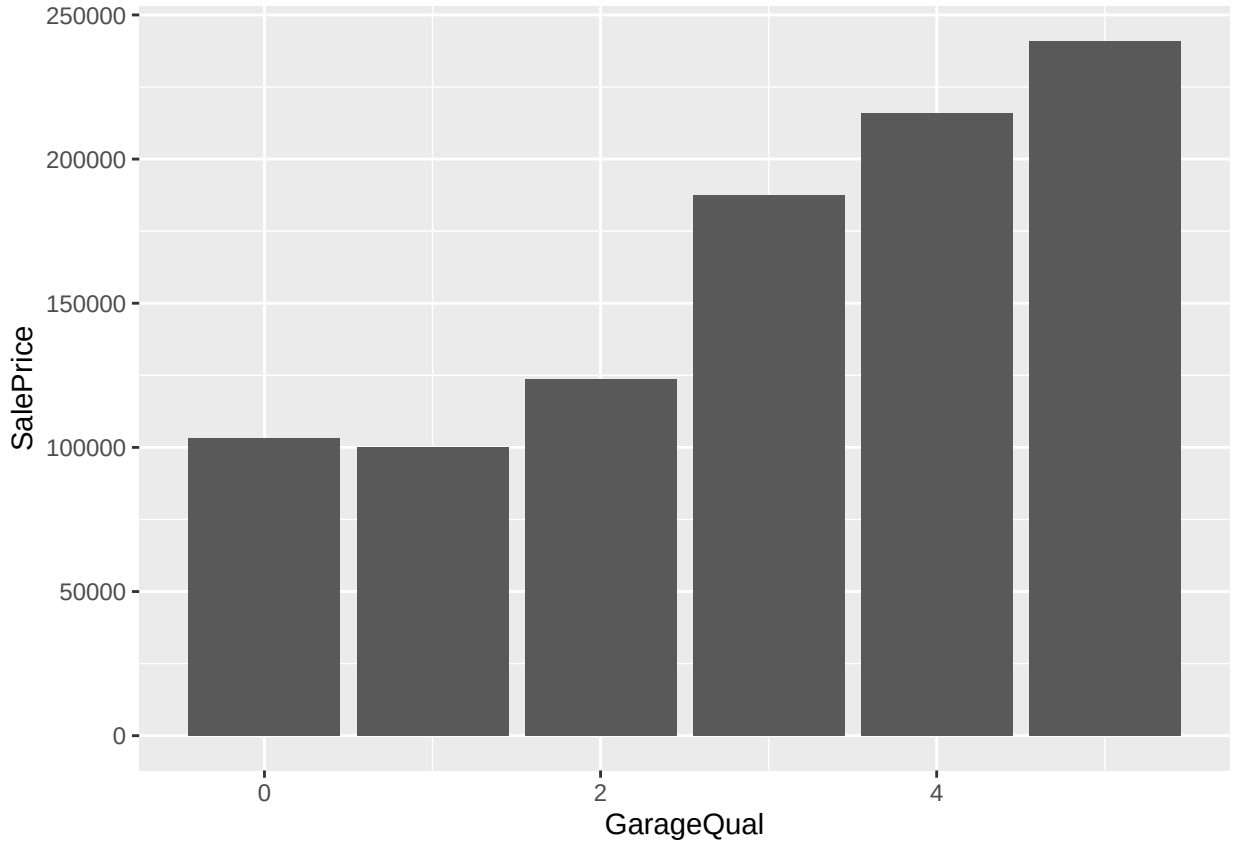
```
##
##    0    1    2    3    4    5
##   81    3   48 1311   14    3
```

```
barplot(table(combined$GarageQual), xlab = "GarageQual", ylab = "Count")
```

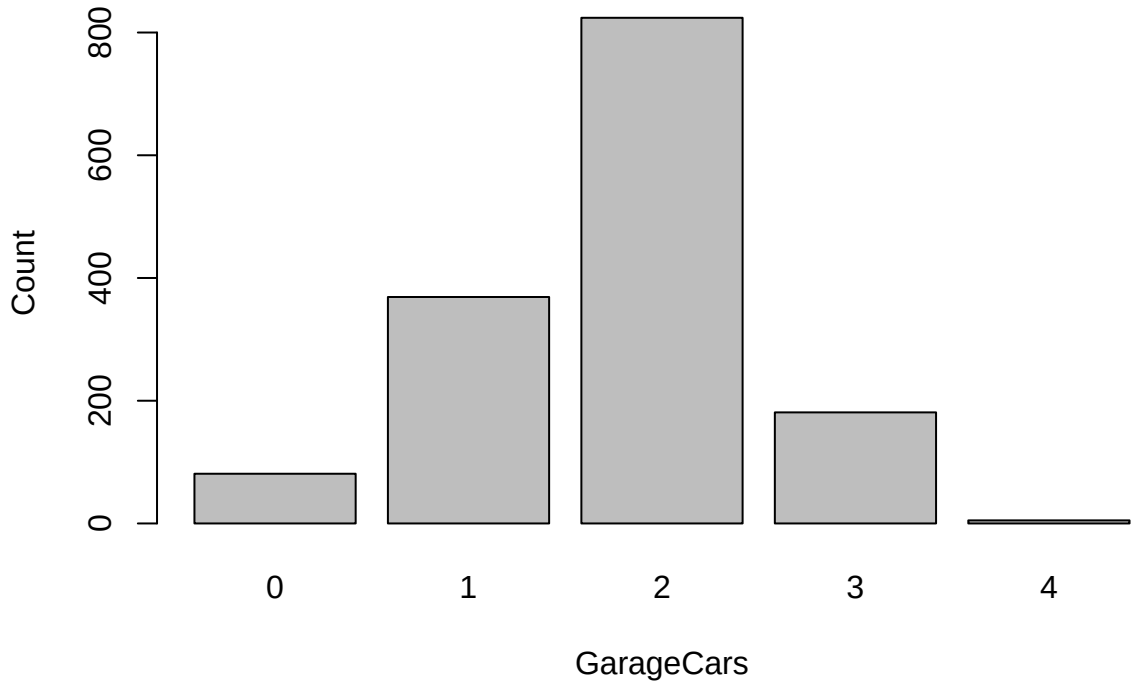



```
ggplot(combined, aes(x=GarageQual, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```

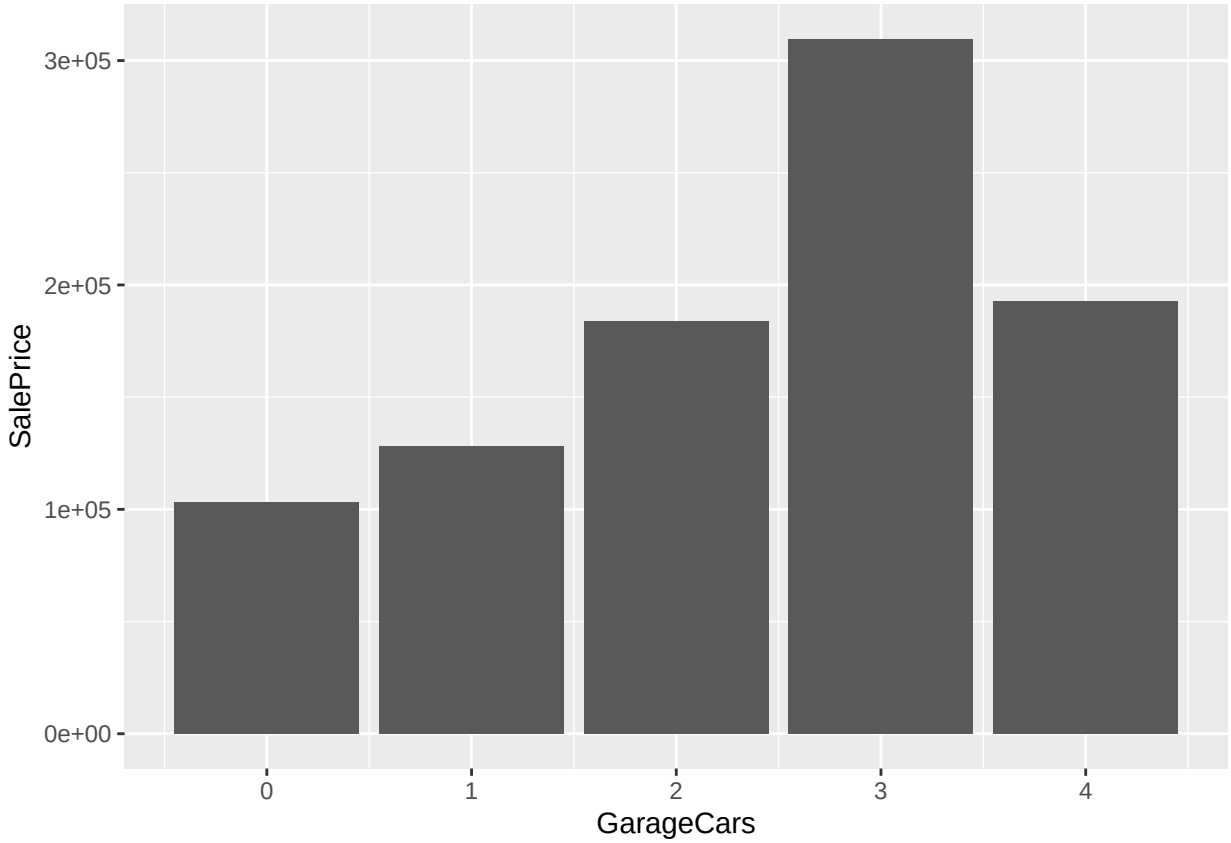


```r
barplot(table(combined$GarageCars), xlab = "GarageCars", ylab = "Count")
```

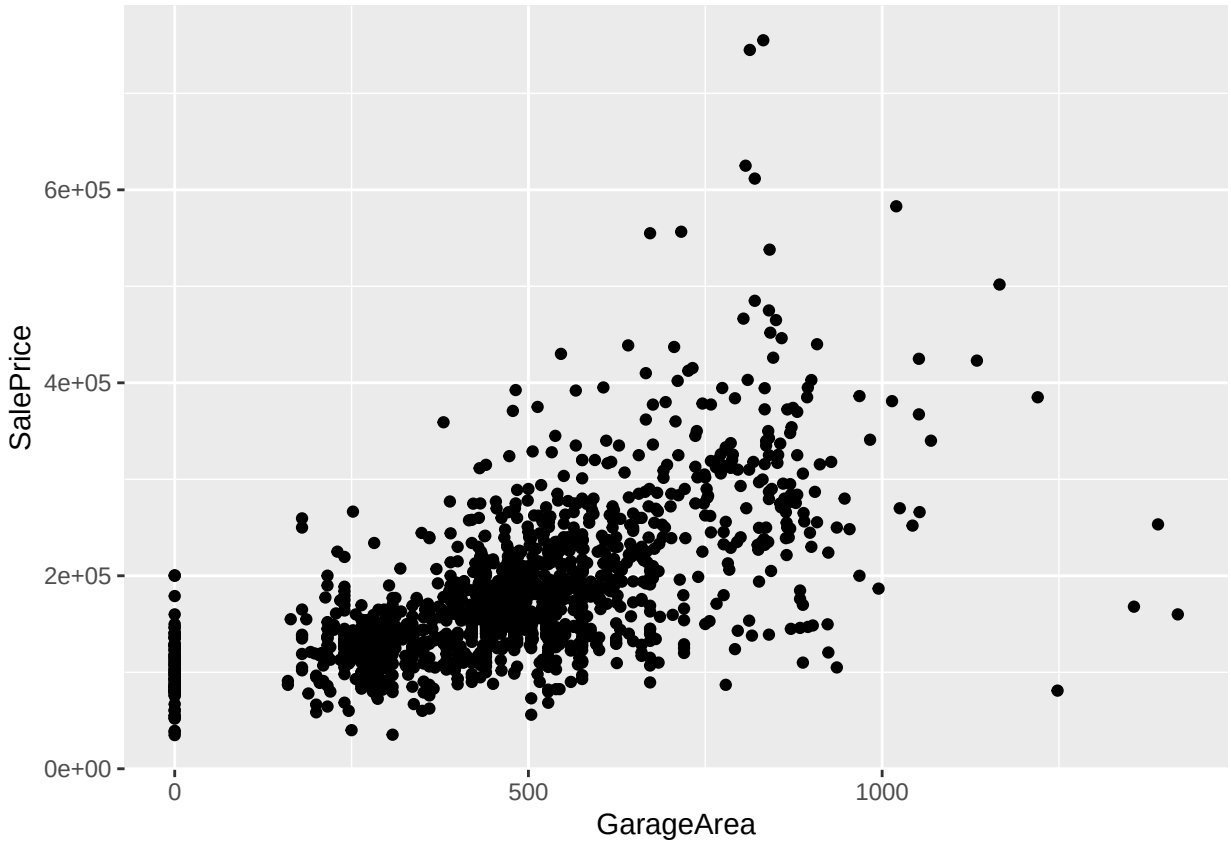



```r
ggplot(combined, aes(x=GarageCars, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```




```
ggplot(combined, aes(x=GarageArea, y = SalePrice)) + geom_point()
```



Basement variables

there are 11 basement variables

BsmtQual, BsmtCond, BsmtExposure, BsmtFinType1, BsmtFinType2, BsmtFullBath, BsmtHalfBath, BsmtFinSF1, BsmtFinSF2, BsmtUnfSF, TotalBsmtSF

```
basement <- c("BsmtQual","BsmtCond","BsmtExposure","BsmtFinType1","BsmtFinType2","BsmtFullBath","BsmtHalfBath","
sort(colSums(sapply(combined[,basement], is.na)), decreasing = T)
```

```
## BsmtExposure BsmtFinType2     BsmtQual     BsmtCond BsmtFinType1 BsmtFullBath
##           38           38           37           37           37            0
## BsmtHalfBath   BsmtFinSF1   BsmtFinSF2    BsmtUnfSF  TotalBsmtSF
##            0            0            0            0            0
```

```
x <- which(!is.na(combined$BsmtFinType1) & (is.na(combined$BsmtCond)|is.na(combined$BsmtExposure)|is.na(combined

combined[x,basement]
```

```
##     BsmtQual BsmtCond BsmtExposure BsmtFinType1 BsmtFinType2 BsmtFullBath
## 333       Gd       TA           No          GLQ         <NA>            1
## 949       Gd       TA         <NA>          Unf          Unf            0
##     BsmtHalfBath BsmtFinSF1 BsmtFinSF2 BsmtUnfSF TotalBsmtSF
## 333            0       1124        479      1603        3206
## 949            0          0          0       936         936
```

```
# impute mode
combined[c(949),"BsmtExposure"] <- names(sort(-table(combined$BsmtExposure)))[1]
combined[c(333),"BsmtFinType2"] <- names(sort(-table(combined$BsmtFinType2)))[1]
combined[x,basement]
```

```
##     BsmtQual BsmtCond BsmtExposure BsmtFinType1 BsmtFinType2 BsmtFullBath
## 333       Gd       TA           No          GLQ          Unf            1
## 949       Gd       TA           No          Unf          Unf            0
##     BsmtHalfBath BsmtFinSF1 BsmtFinSF2 BsmtUnfSF TotalBsmtSF
## 333            0       1124        479      1603        3206
## 949            0          0          0       936         936
```

```
anyNA(combined[x,basement])
```

```
## [1] FALSE
```

```
sort(colSums(sapply(combined[,basement], is.na)), decreasing = T)
```

```
##     BsmtQual     BsmtCond BsmtExposure BsmtFinType1 BsmtFinType2 BsmtFullBath
##           37           37           37           37           37            0
## BsmtHalfBath   BsmtFinSF1   BsmtFinSF2    BsmtUnfSF  TotalBsmtSF
##            0            0            0            0            0
```

```
combined$BsmtQual[is.na(combined$BsmtQual)] <- "None"
combined$BsmtCond[is.na(combined$BsmtCond)] <- "None"
combined$BsmtExposure[is.na(combined$BsmtExposure)] <- "None"
combined$BsmtFinType1[is.na(combined$BsmtFinType1)] <- "None"
combined$BsmtFinType2[is.na(combined$BsmtFinType2)] <- "None"
combined$BsmtFullBath[is.na(combined$BsmtFullBath)] <- 0
combined$BsmtHalfBath[is.na(combined$BsmtHalfBath)] <- 0

sort(colSums(sapply(combined[,basement], is.na)), decreasing = T)
```

```
##     BsmtQual     BsmtCond BsmtExposure BsmtFinType1 BsmtFinType2 BsmtFullBath
##            0            0            0            0            0            0
## BsmtHalfBath   BsmtFinSF1   BsmtFinSF2    BsmtUnfSF  TotalBsmtSF
##            0            0            0            0            0
```

```
# label encoding

combined$BsmtQual<-as.integer(revalue(combined$BsmtQual,  quality))
```

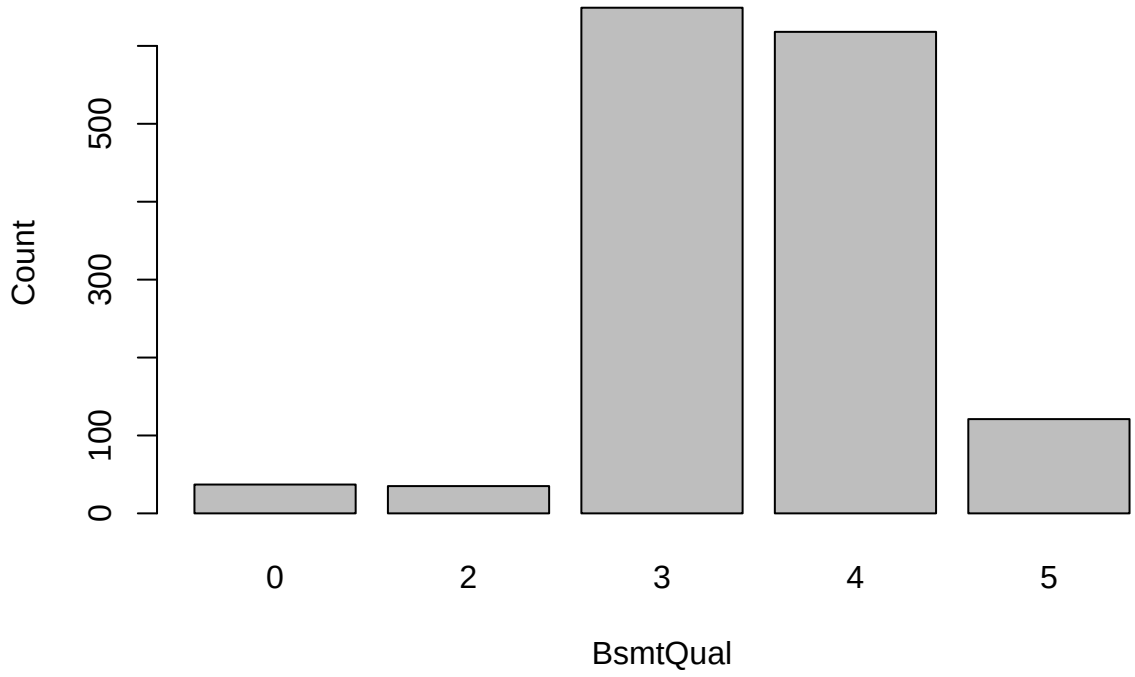
BsmtQual

```
## The following 'from' values were not present in 'x': Po
```

```
table(combined$BsmtQual, useNA = "ifany")
```

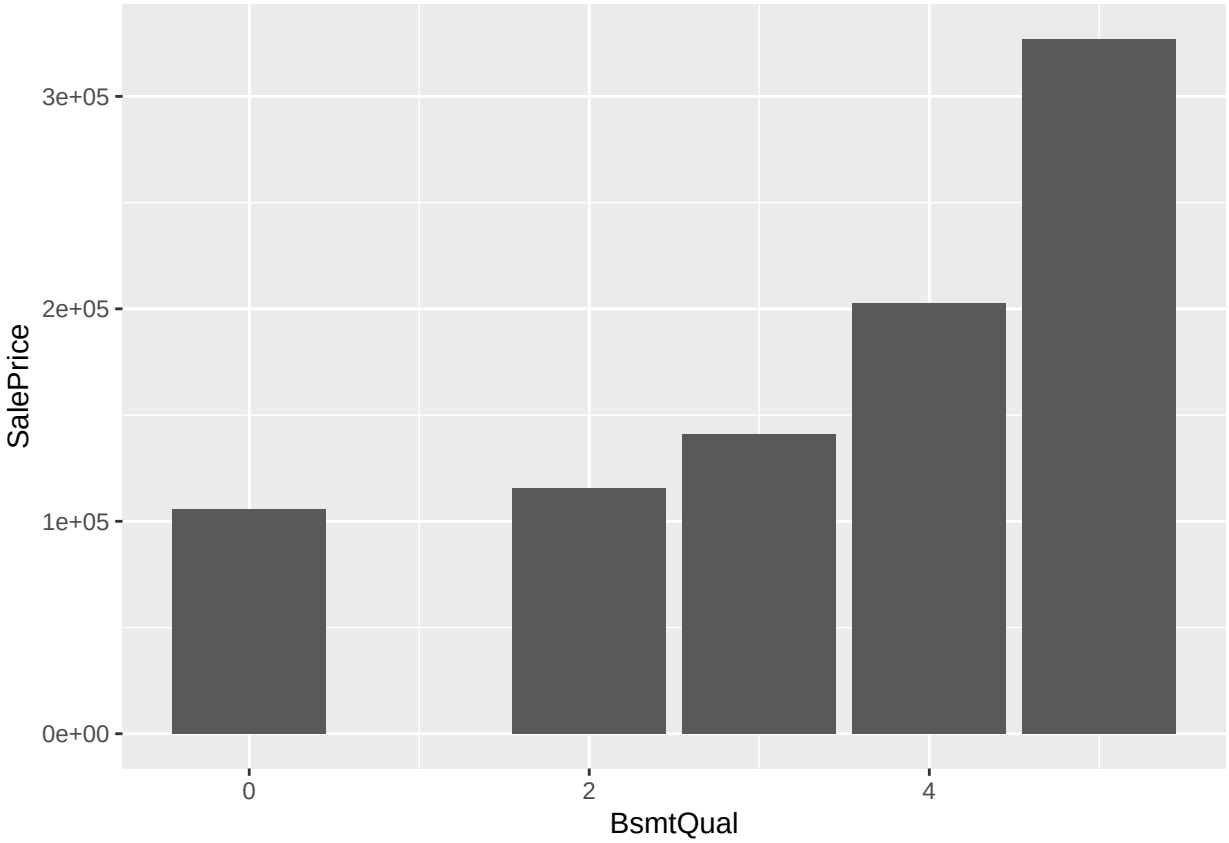
```
##
##   0   2   3   4   5
##  37  35 649 618 121
```

```
barplot(table(combined$BsmtQual), xlab = "BsmtQual", ylab = "Count")
```




```
ggplot(combined, aes(x=BsmtQual, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to 'mean_se()'
```




```
combined$BsmtCond<-as.integer(revalue(combined$BsmtCond,  quality))
```

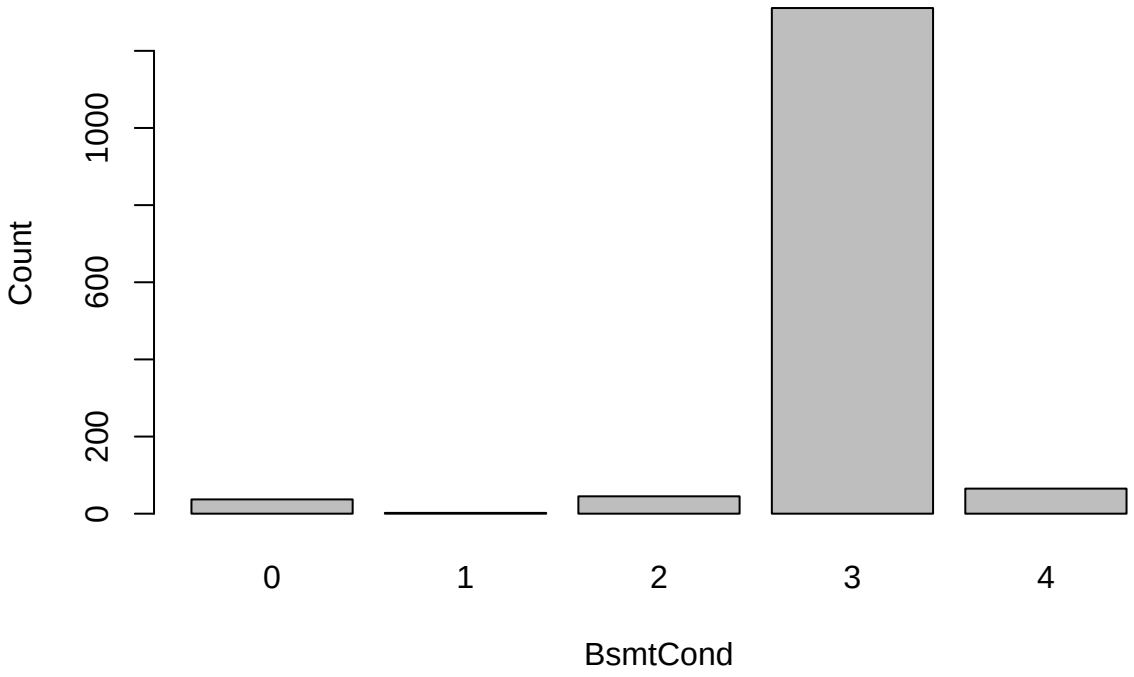
BsmtCond

```
## The following ‘from‘ values were not present in ‘x‘: Ex
```

```
table(combined$BsmtCond, useNA = "ifany")
```

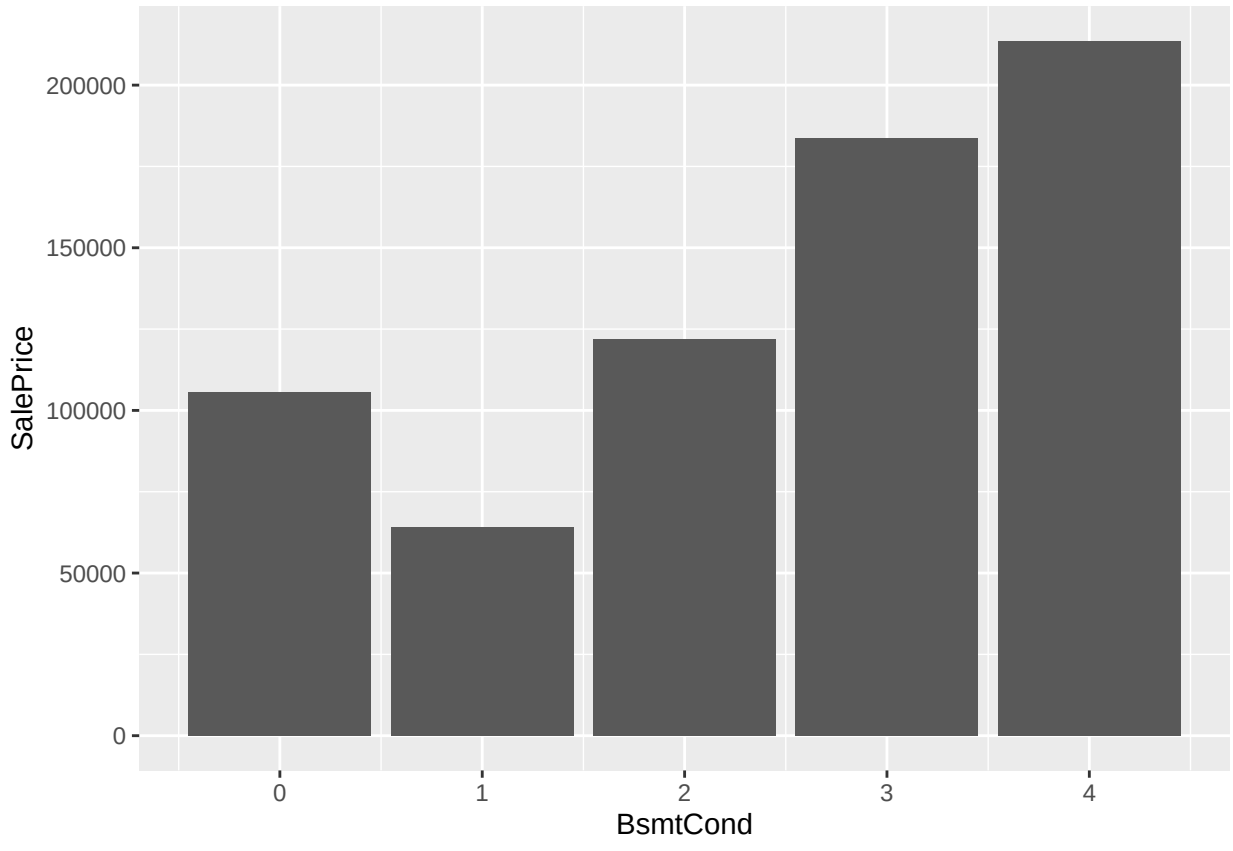
```
##
##    0    1    2    3    4
##   37    2   45 1311   65
```

```
barplot(table(combined$BsmtCond), xlab = "BsmtCond", ylab = "Count")
```




```
ggplot(combined, aes(x=BsmtCond, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```

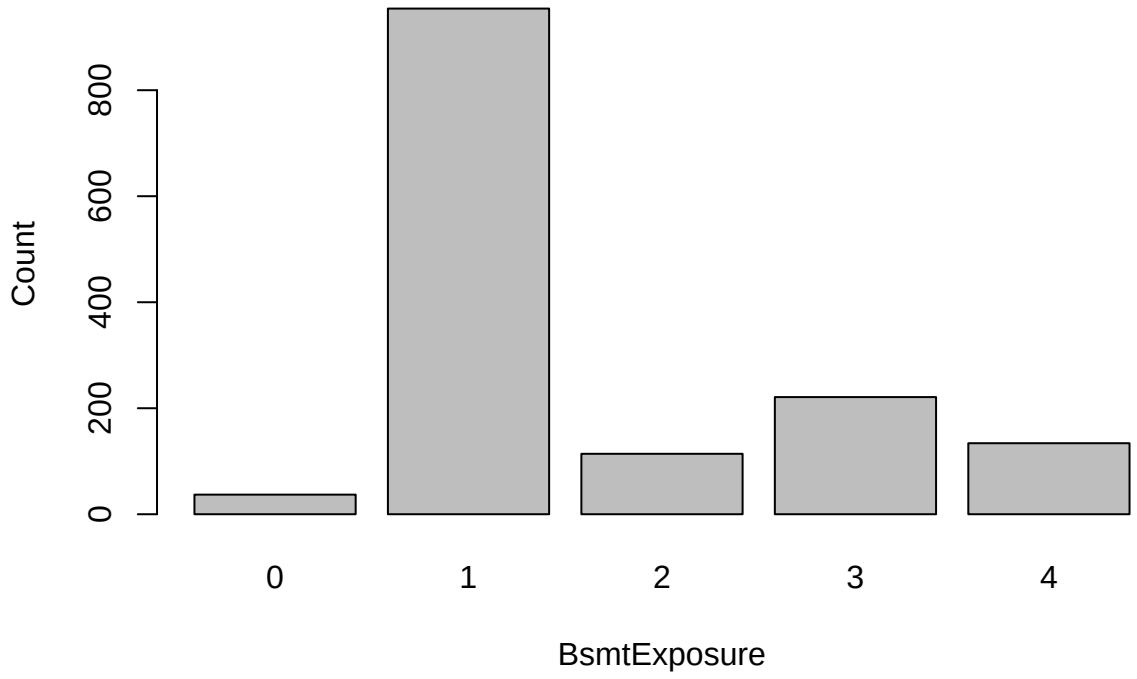


```
exposure <- c('None'=0,'No'=1,'Mn'=2,'Av'=3,'Gd'=4)
combined$BsmtExposure<-as.integer(revalue(combined$BsmtExposure,  exposure))
table(combined$BsmtExposure, useNA = "ifany")
```

BsmtExposure

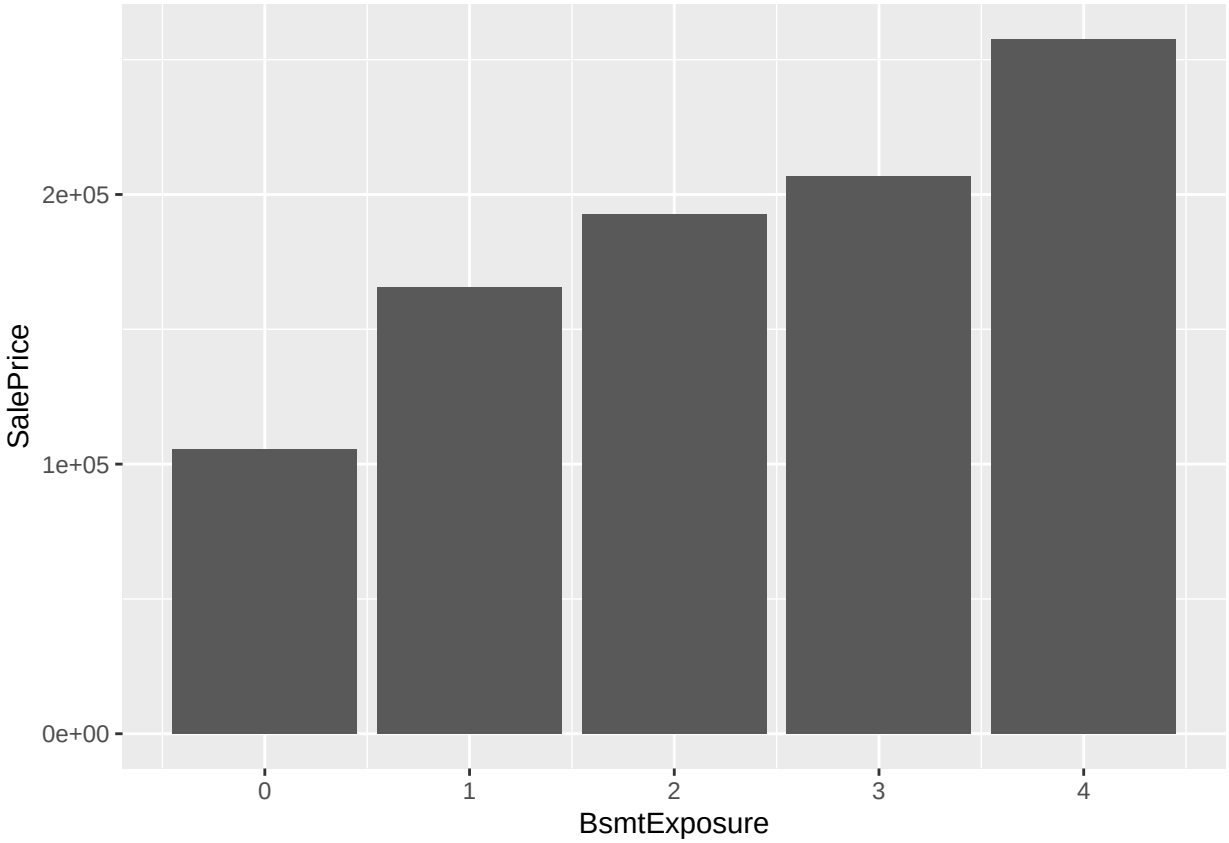
```
##
##   0   1   2   3   4
##  37 954 114 221 134
```

```
barplot(table(combined$BsmtExposure), xlab = "BsmtExposure", ylab = "Count")
```




```
ggplot(combined, aes(x=BsmtExposure, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```

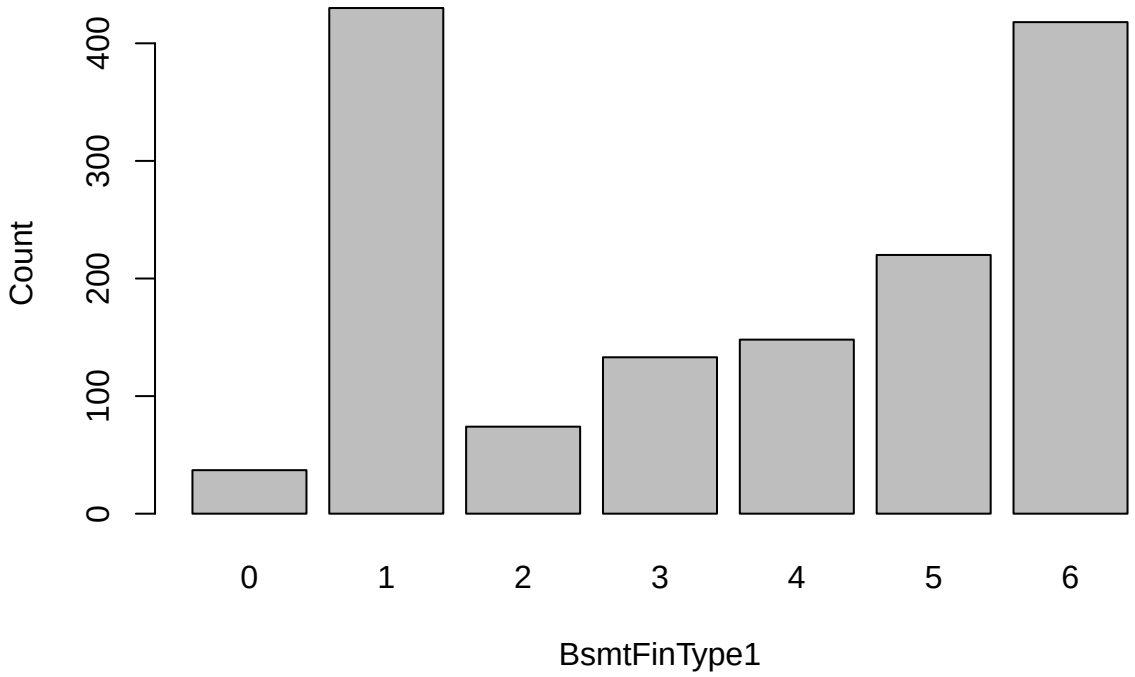



```
rating <- c('None'=0,'Unf'=1,'LwQ'=2,'Rec'=3,'BLQ'=4,'ALQ'=5,'GLQ'=6)
combined$BsmtFinType1<-as.integer(revalue(combined$BsmtFinType1,  rating))
table(combined$BsmtFinType1, useNA = "ifany")
```

BsmtFinType1

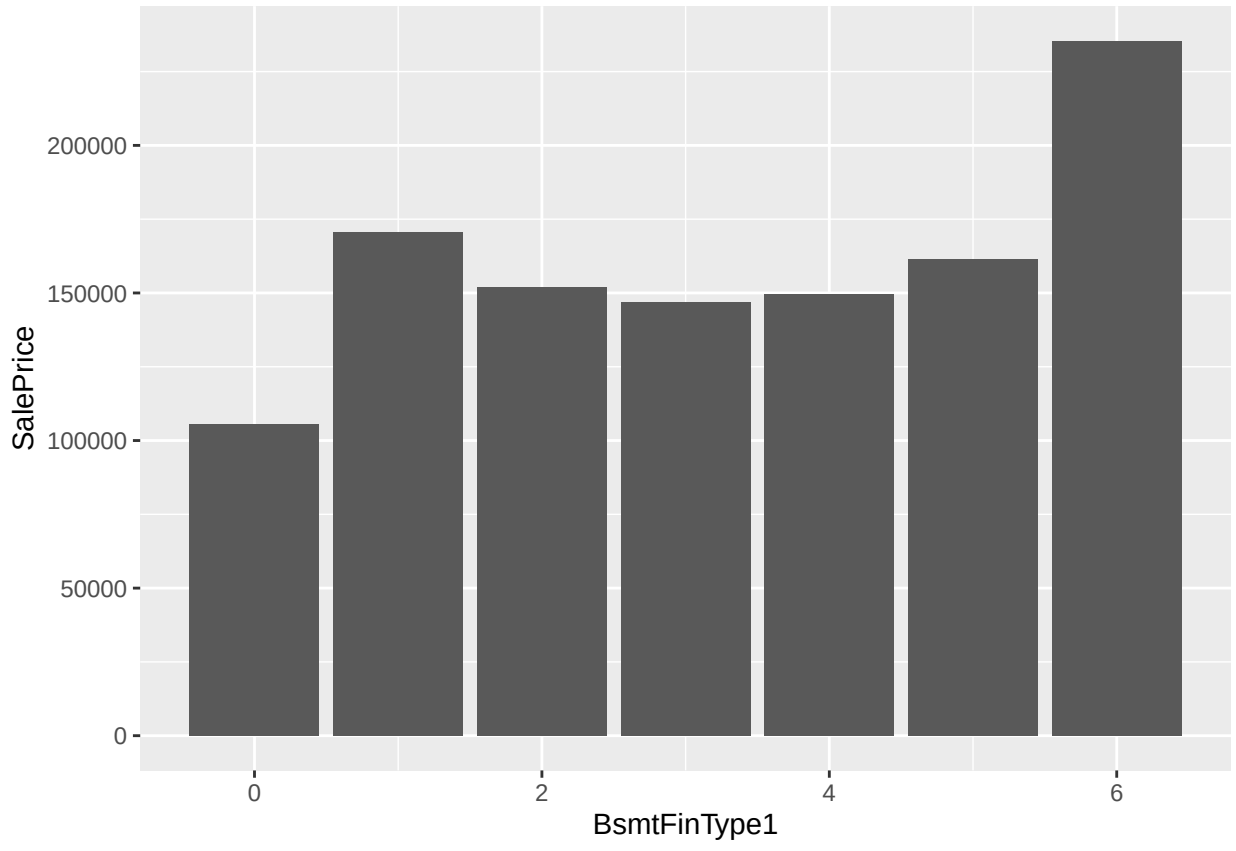
```
##
##   0   1   2   3   4   5   6
##  37 430  74 133 148 220 418
```

```
barplot(table(combined$BsmtFinType1), xlab = "BsmtFinType1", ylab = "Count")
```




```
ggplot(combined, aes(x=BsmtFinType1, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```

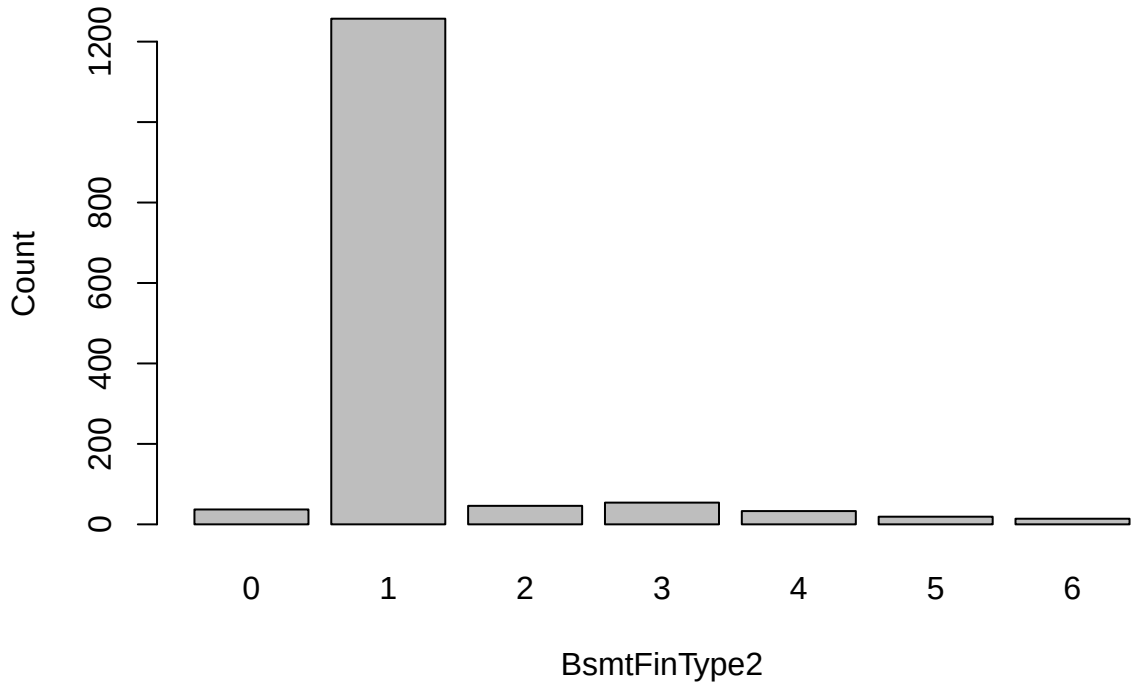


```
combined$BsmtFinType2<-as.integer(revalue(combined$BsmtFinType2,  rating))
table(combined$BsmtFinType2, useNA = "ifany")
```

BsmtFinType2

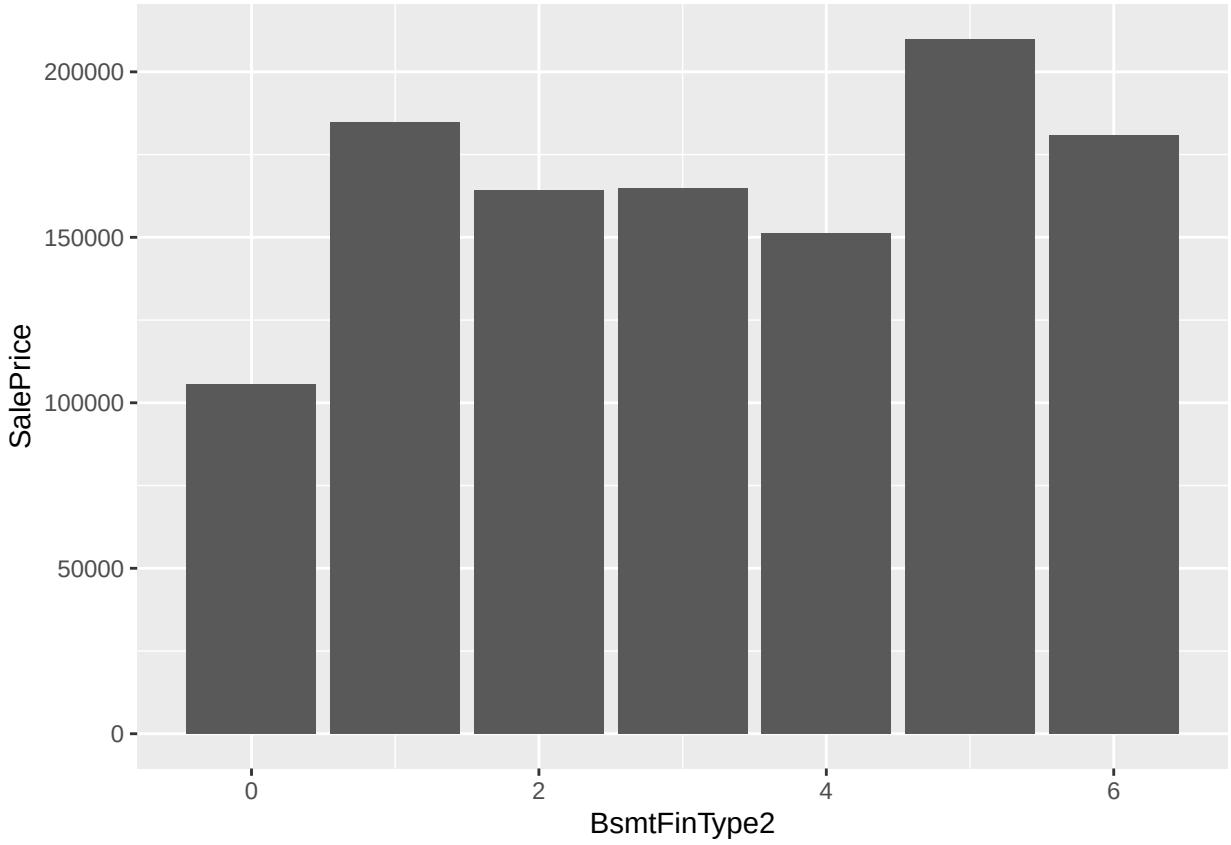
```
##
##    0    1    2    3    4    5    6
##   37 1257   46   54   33   19   14
```

```
barplot(table(combined$BsmtFinType2), xlab = "BsmtFinType2", ylab = "Count")
```

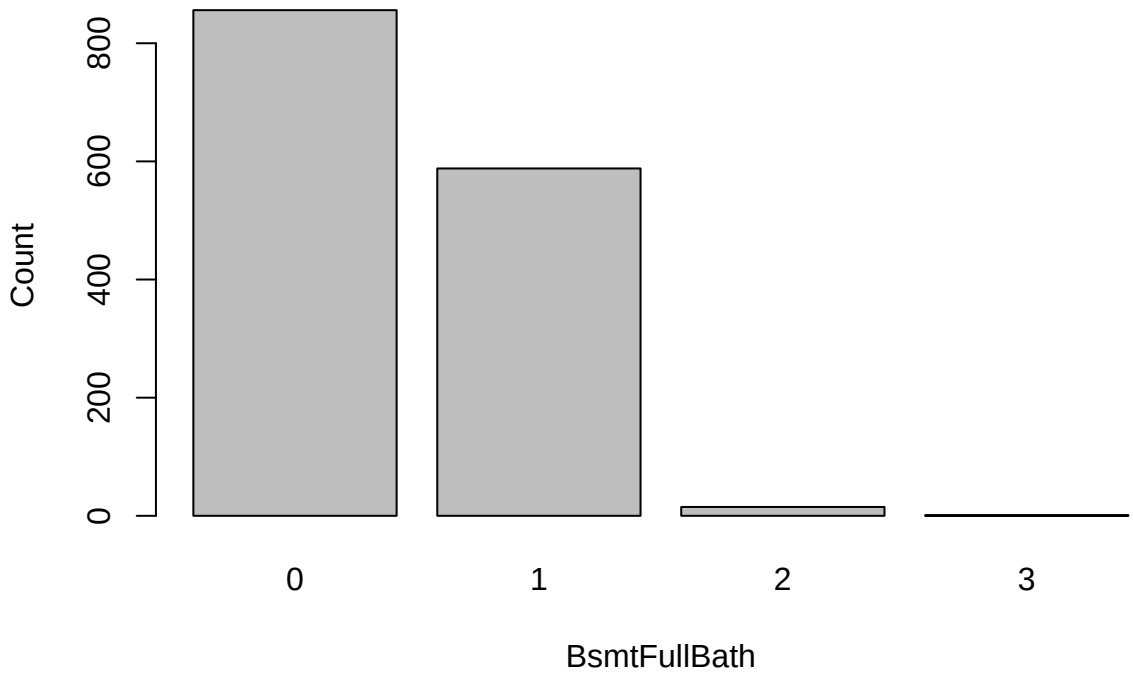



```
ggplot(combined, aes(x=BsmtFinType2, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



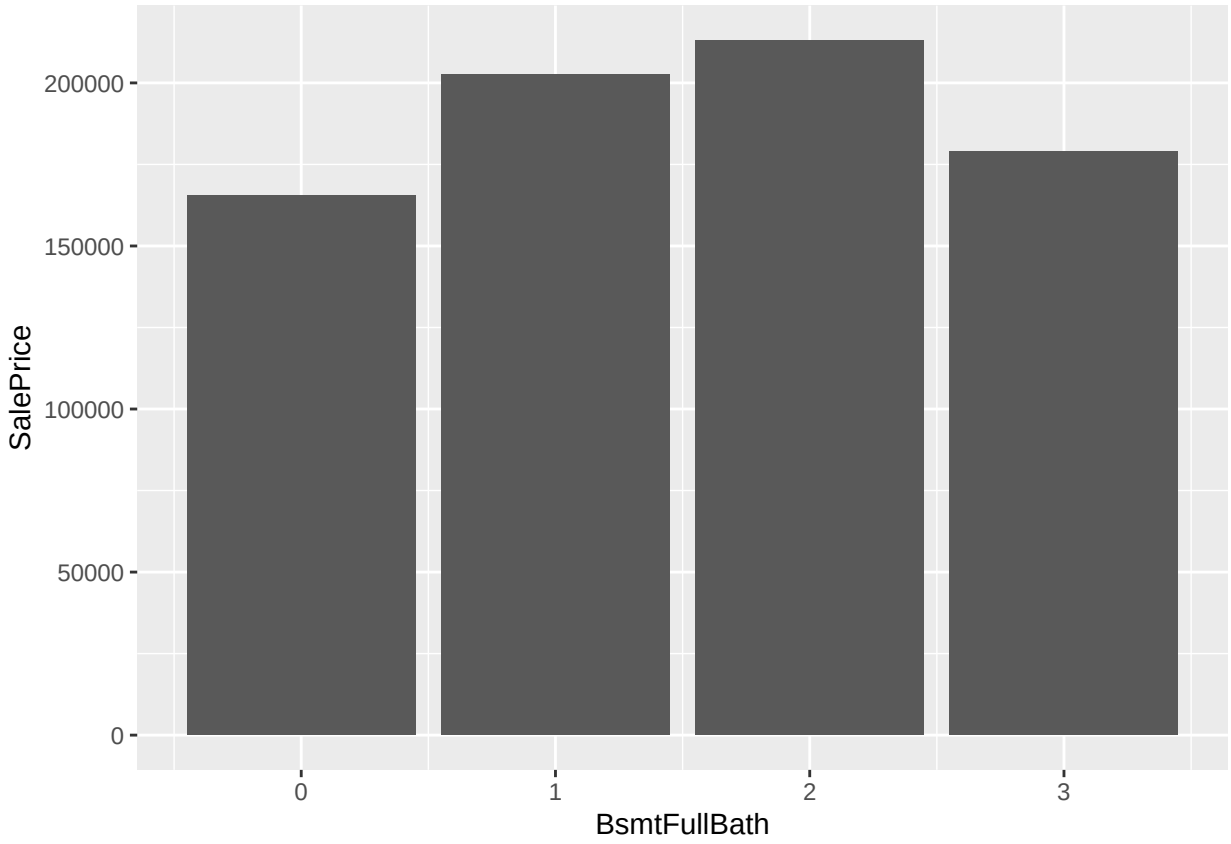

```
barplot(table(combined$BsmtFullBath), xlab = "BsmtFullBath", ylab = "Count")
```



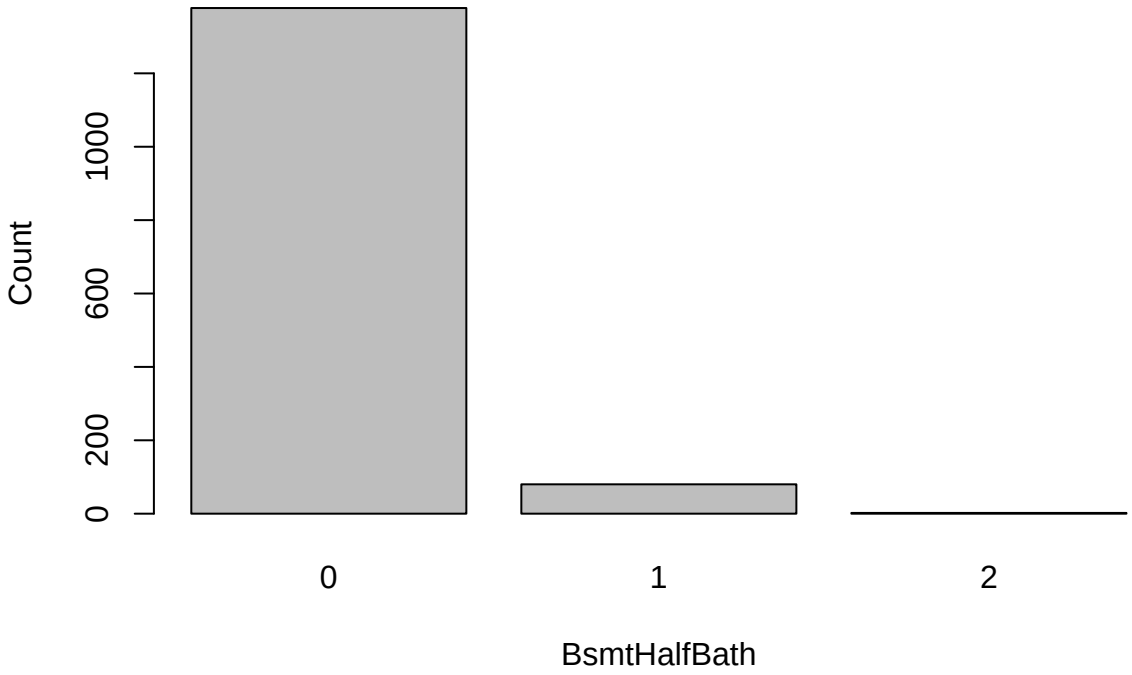
BsmtFullBath

```
ggplot(combined, aes(x=BsmtFullBath, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



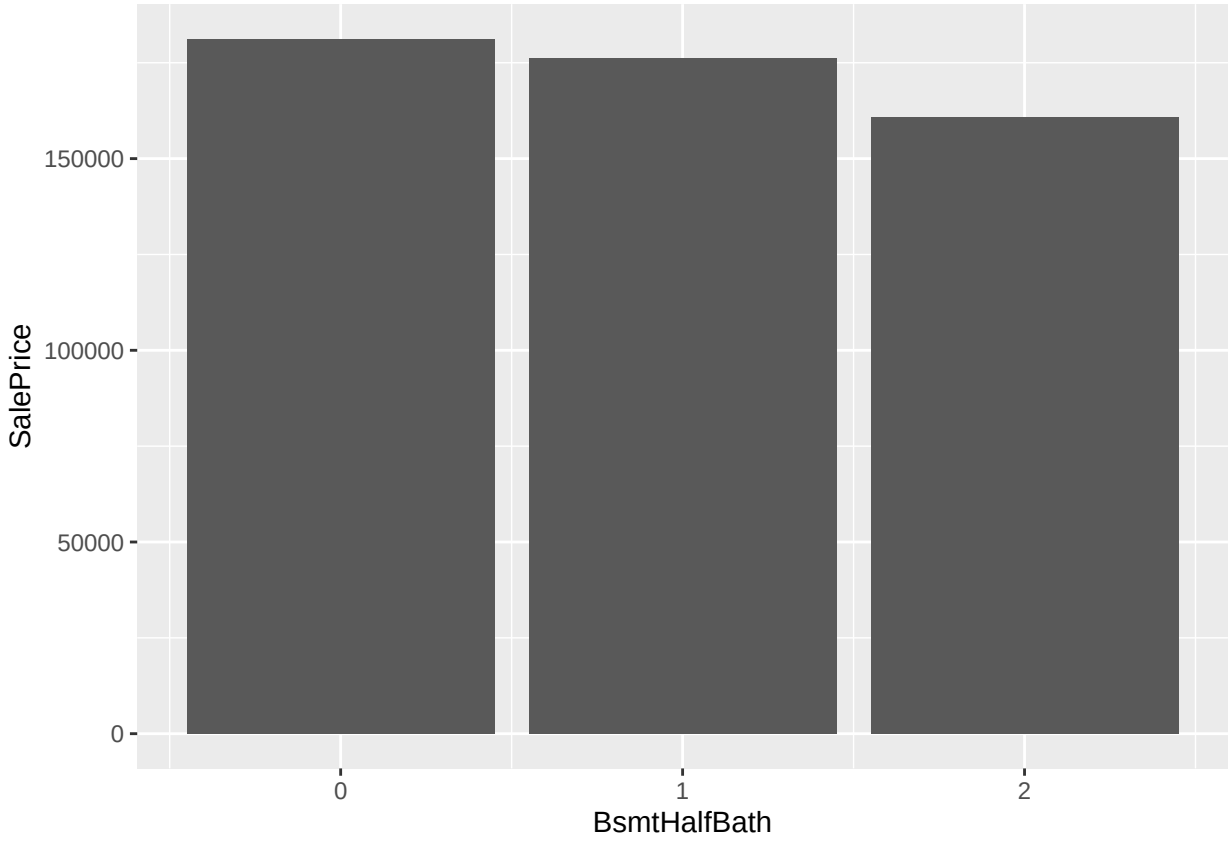

```
barplot(table(combined$BsmtHalfBath), xlab = "BsmtHalfBath", ylab = "Count")
```



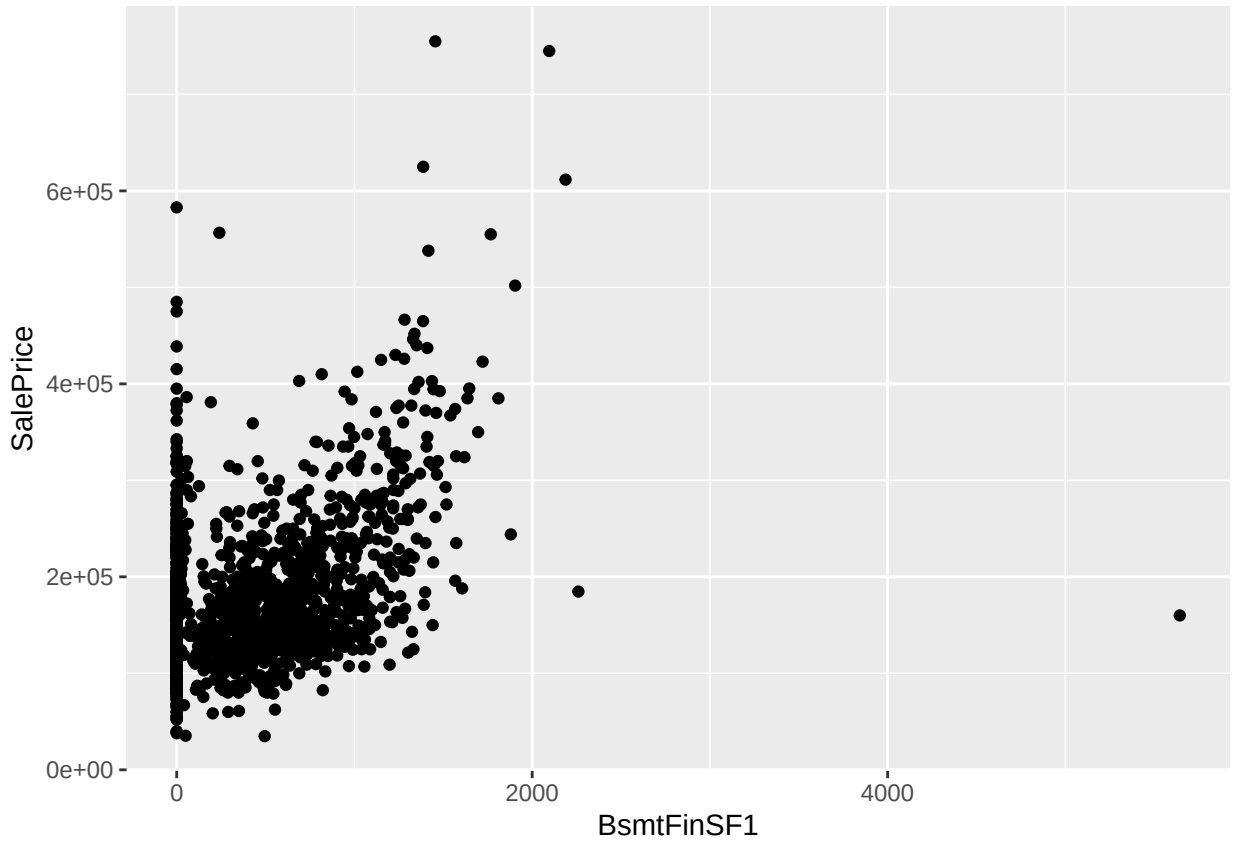
BsmtHalfBath

```
ggplot(combined, aes(x=BsmtHalfBath, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```

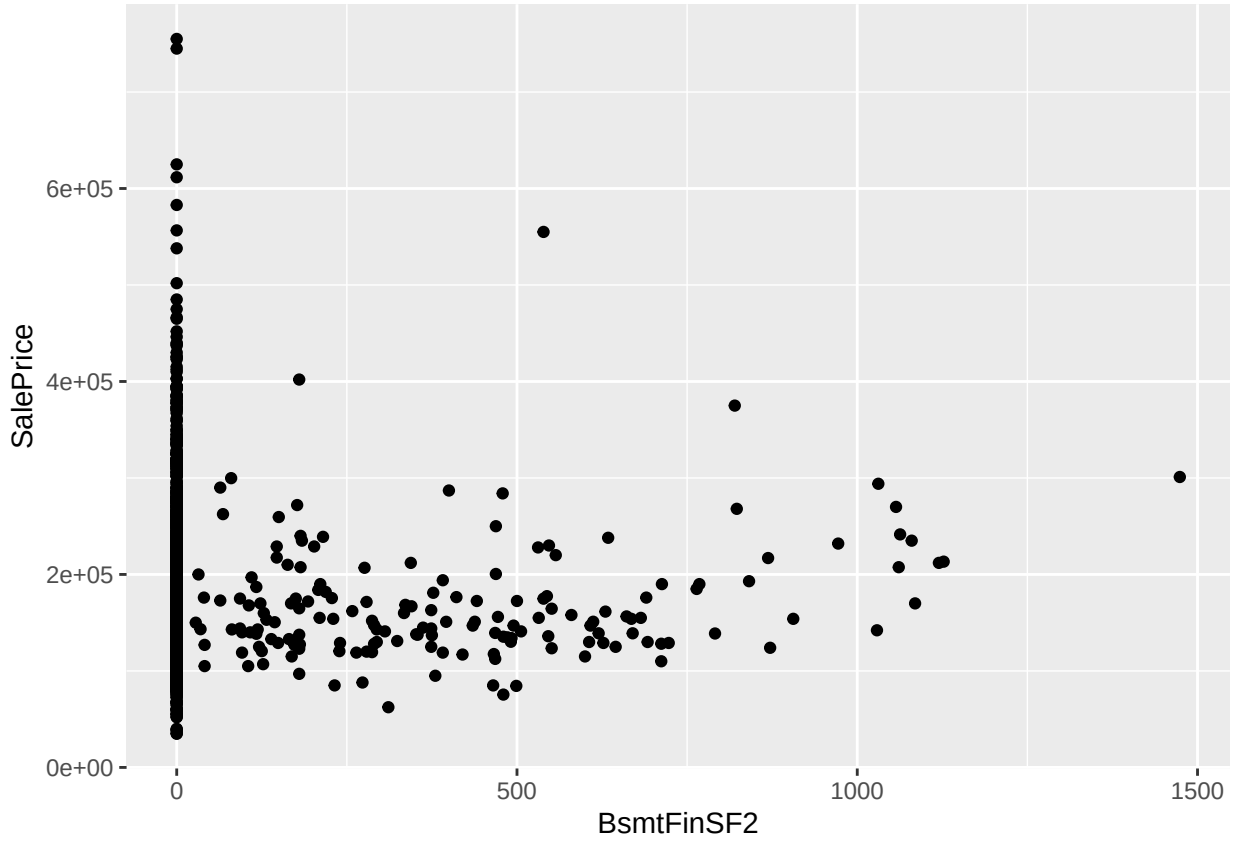


```
ggplot(combined, aes(x=BsmtFinSF1, y = SalePrice)) + geom_point()
```



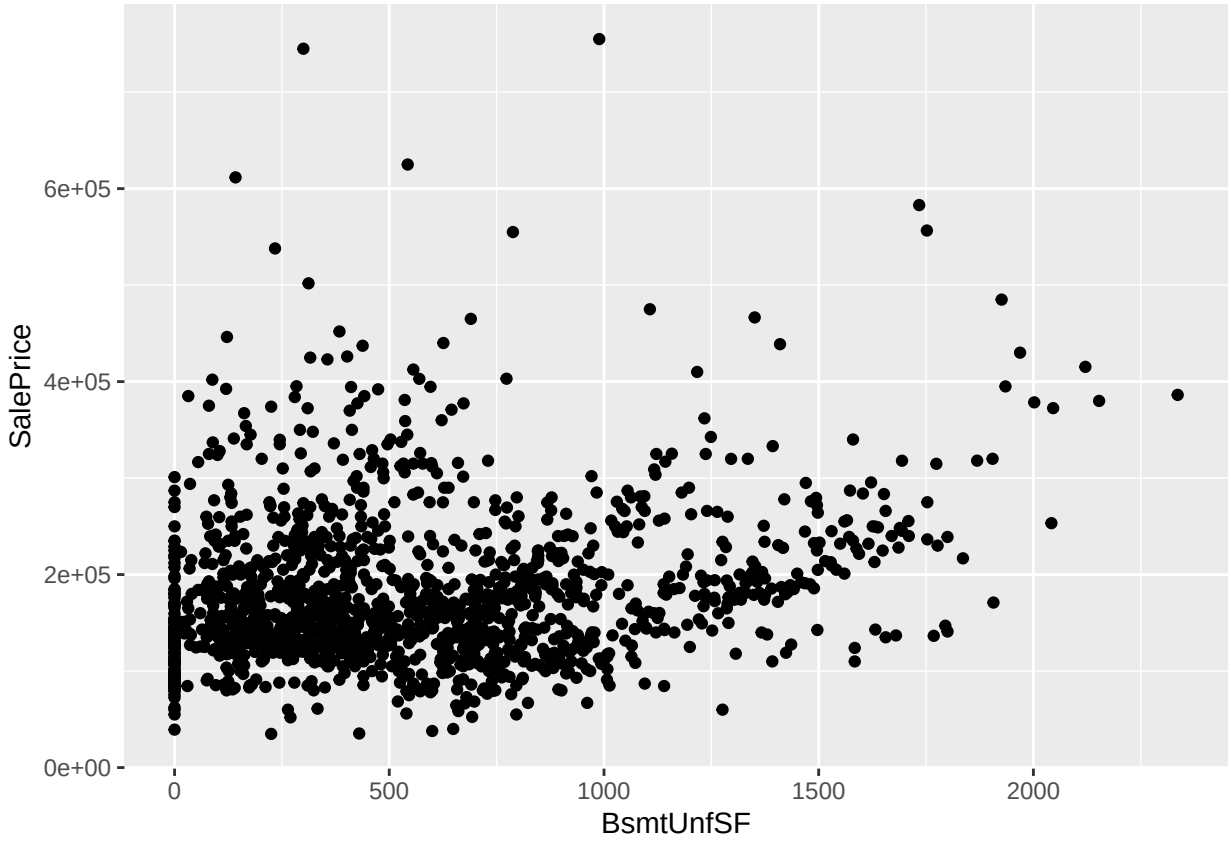
BsmtFinSF1

```
ggplot(combined, aes(x=BsmtFinSF2, y = SalePrice)) + geom_point()
```



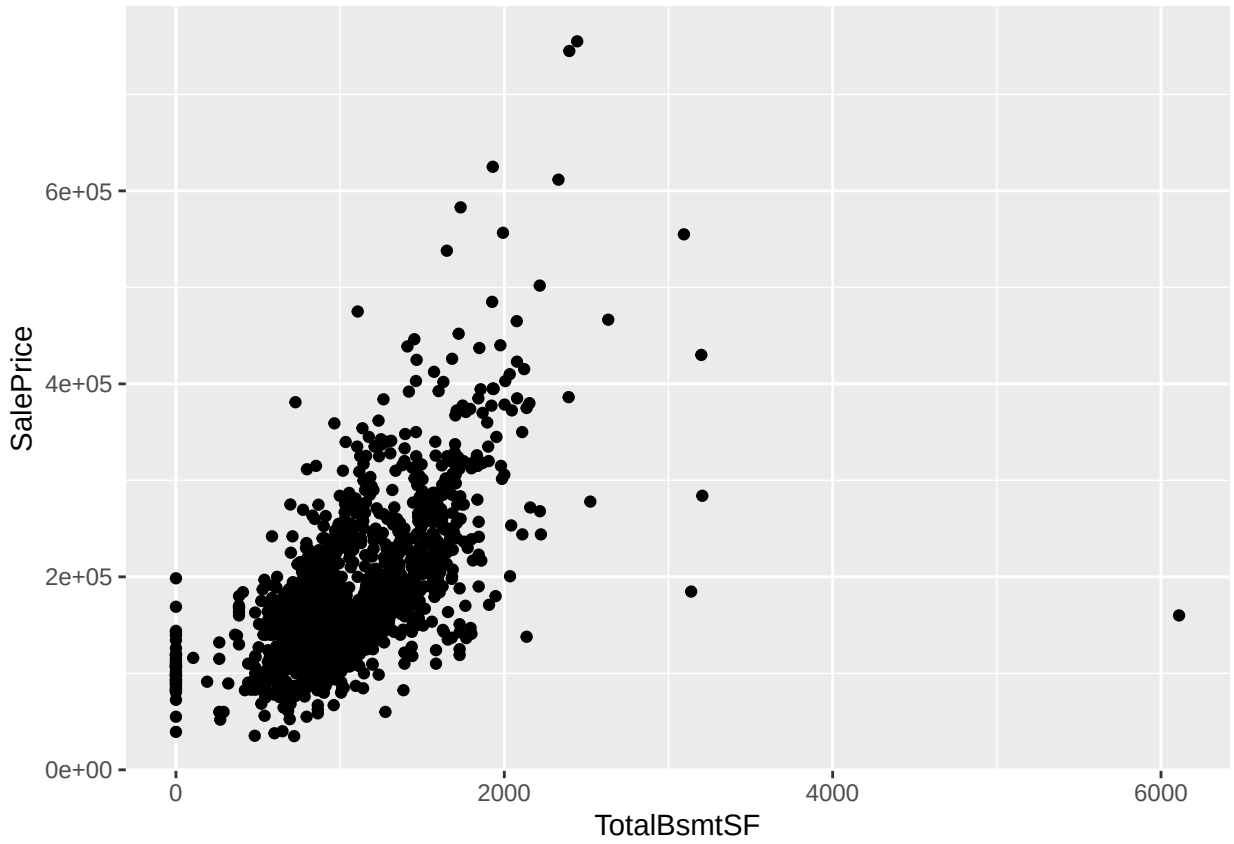
BsmtFinSF2

```
ggplot(combined, aes(x=BsmtUnfSF, y = SalePrice)) + geom_point()
```



BsmtUnfSF

```
ggplot(combined, aes(x=TotalBsmtSF, y = SalePrice)) + geom_point()
```



TotalBsmtSF

masonry variables

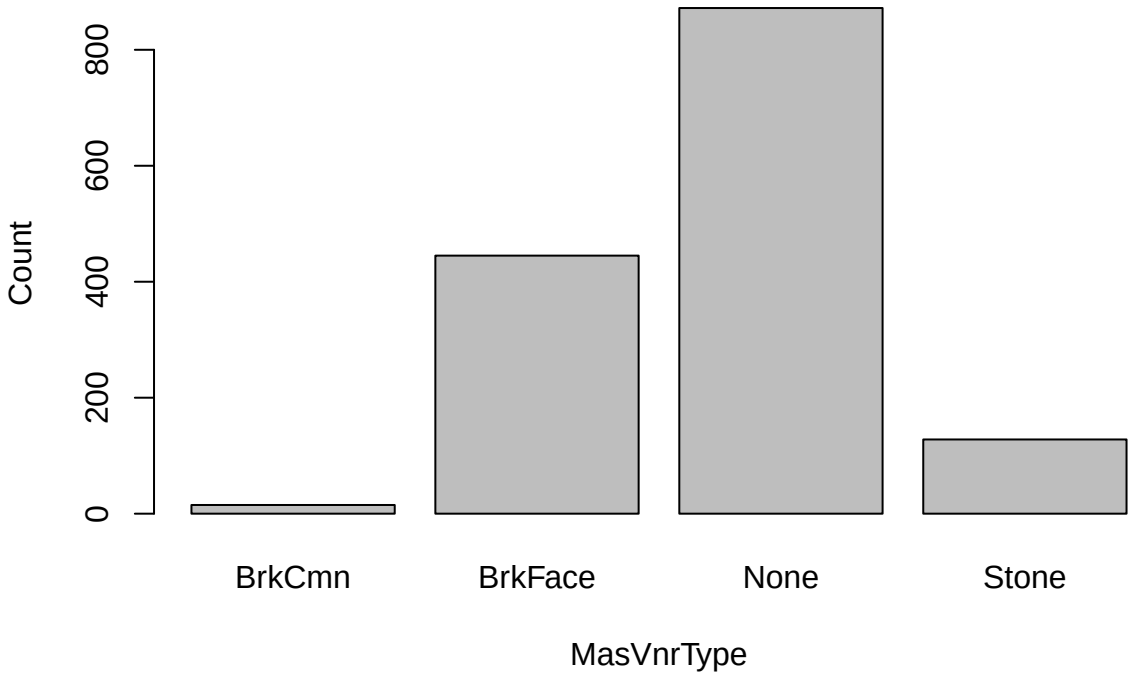
```
table(combined$MasVnrType)
```

```
##
##  BrkCmn BrkFace    None   Stone
##      15     445     864     128
```

```
combined$MasVnrType[is.na(combined$MasVnrType)] <- "None"
combined$MasVnrArea[is.na(combined$MasVnrArea)] <- 0
combined$MasVnrType <- as.factor(combined$MasVnrType)
table(combined$MasVnrType)
```

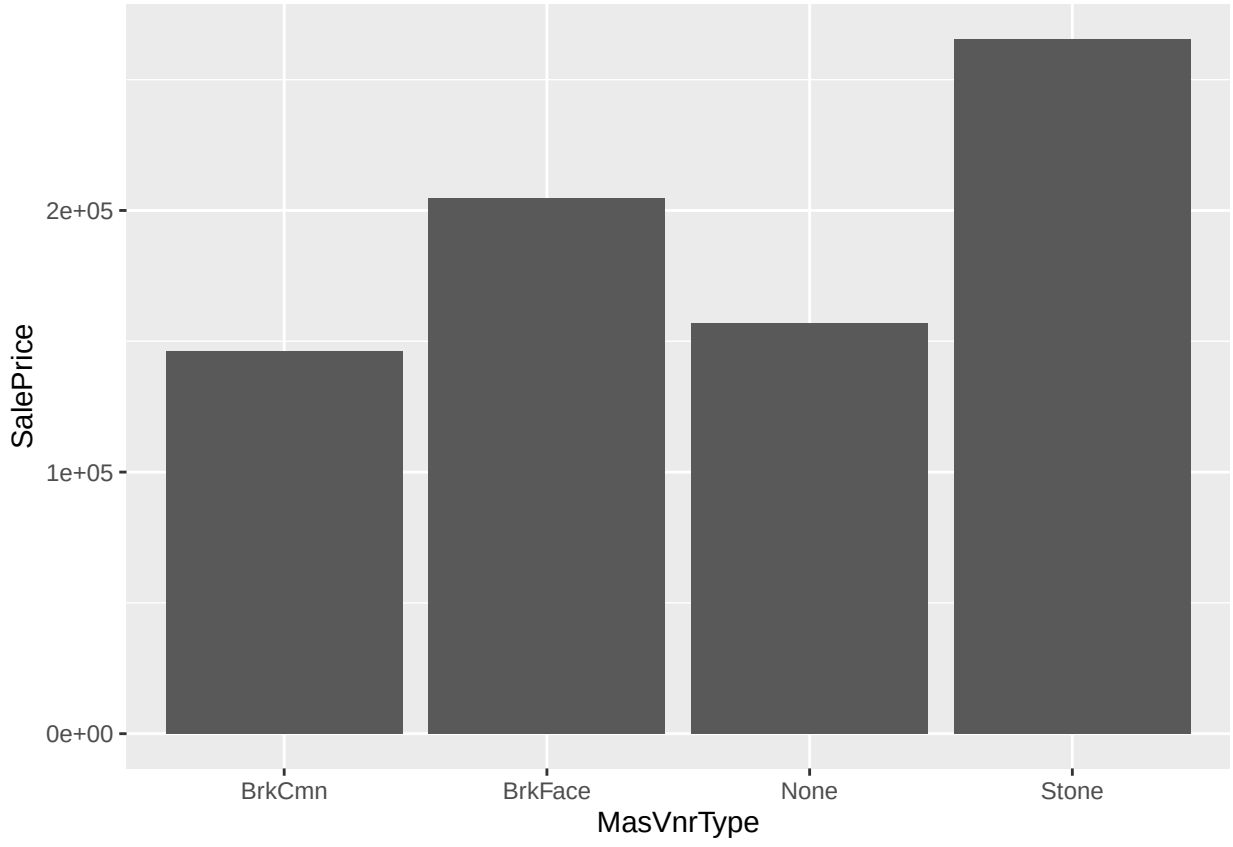
```
##
##  BrkCmn BrkFace    None   Stone
##      15     445     872     128
```

```
barplot(table(combined$MasVnrType), xlab = "MasVnrType", ylab = "Count")
```




```
ggplot(combined, aes(x=MasVnrType, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Electrical variable

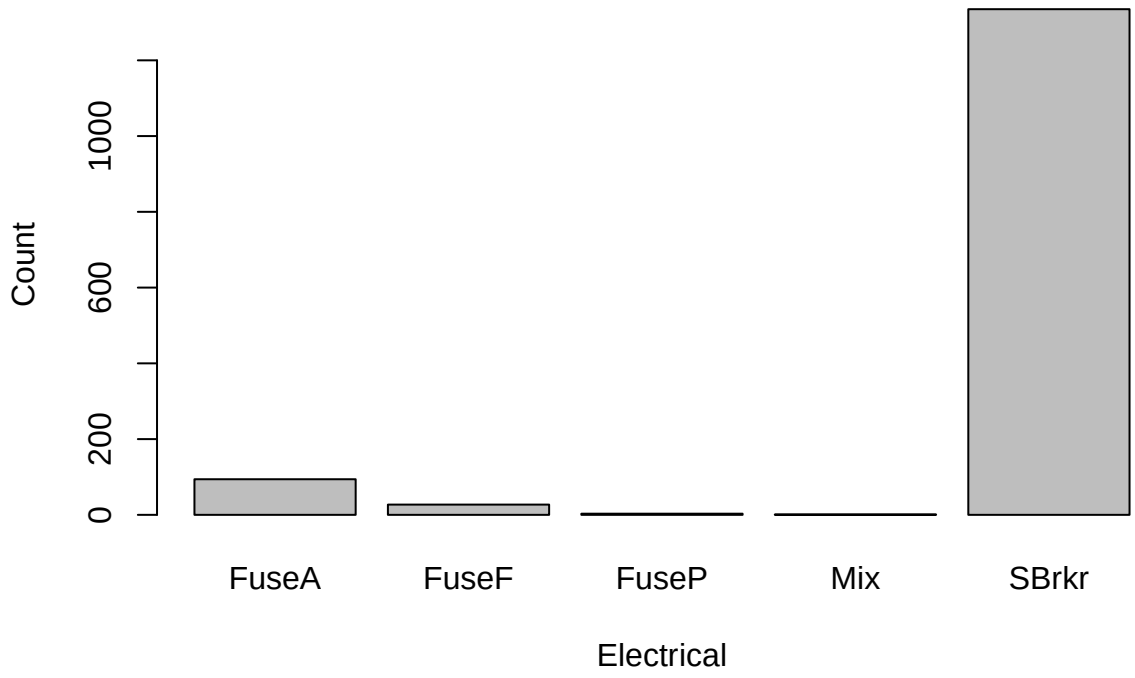
```
table(combined$Electrical)
```

```
##
## FuseA FuseF FuseP   Mix SBrkr
##    94    27     3     1  1334
```

```
combined$Electrical[is.na(combined$Electrical)] <- names(sort(-table(combined$Electrical)))[1]

combined$Electrical <- as.factor(combined$Electrical)
table(combined$Electrical)
```

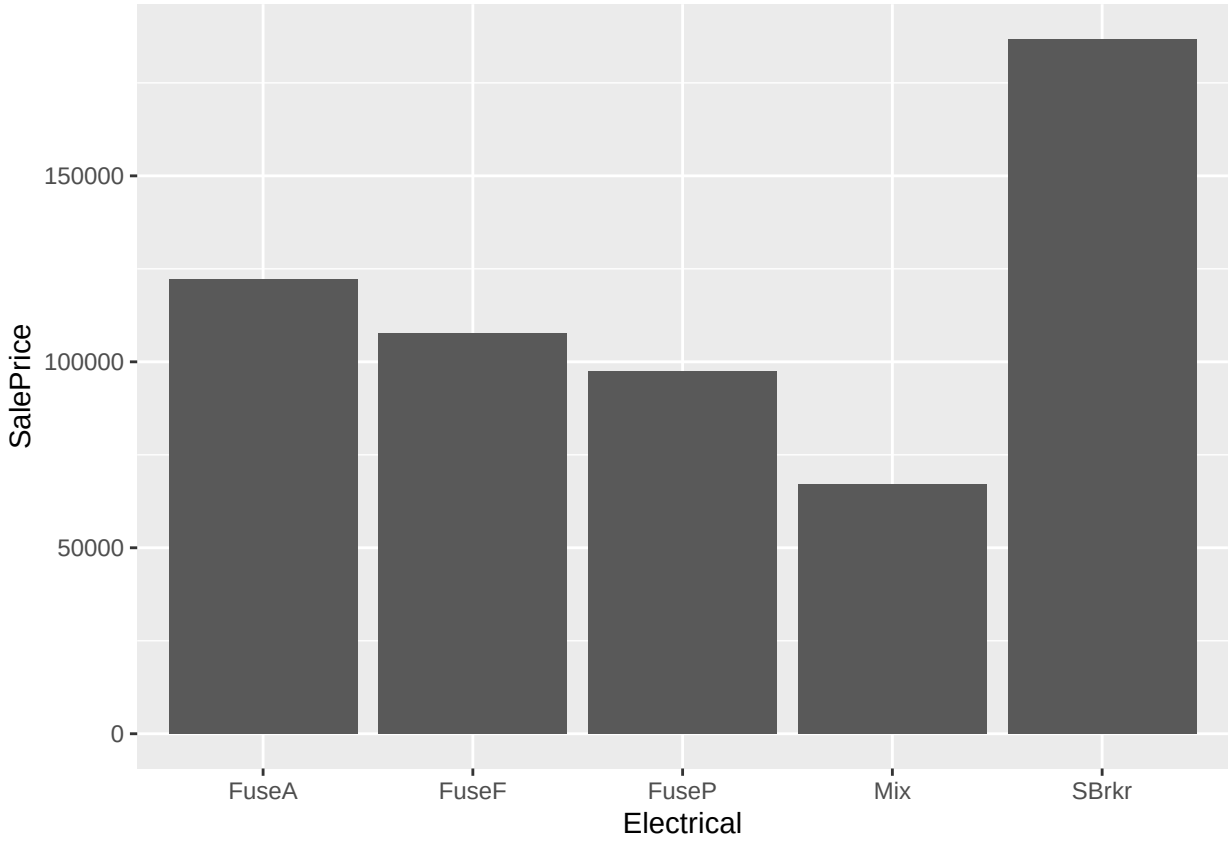
```
##
## FuseA FuseF FuseP   Mix SBrkr
##    94    27     3     1  1335
```

```
barplot(table(combined$Electrical), xlab = "Electrical", ylab = "Count")
```




```
ggplot(combined, aes(x=Electrical, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



MSZoning

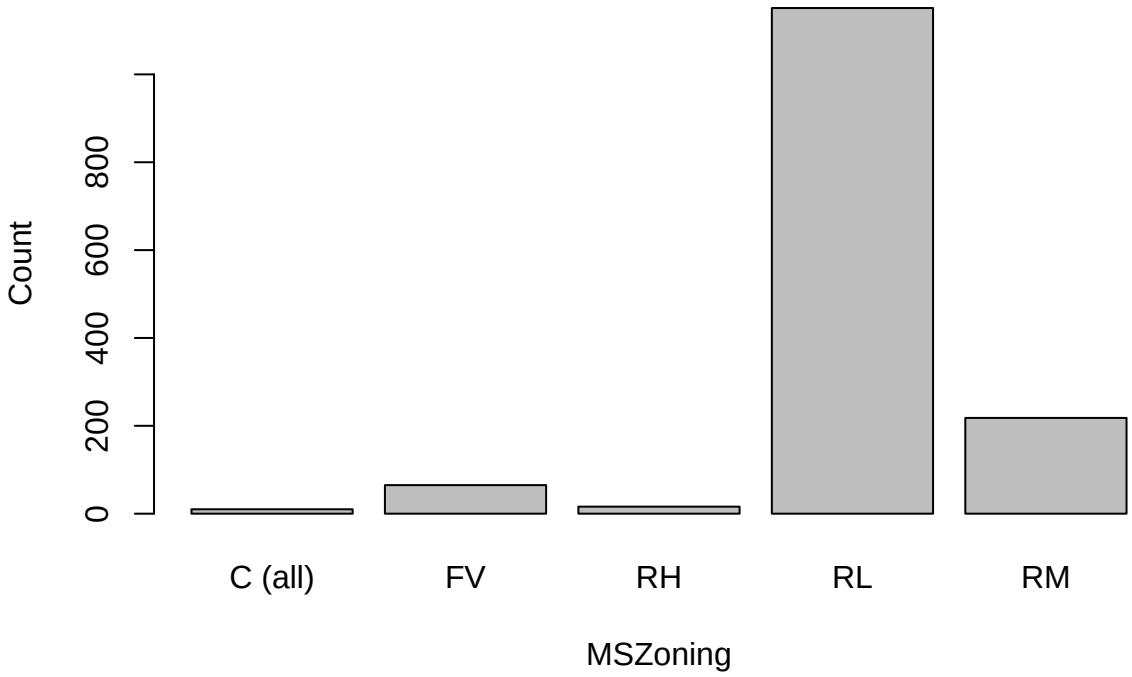
```
table(combined$MSZoning)
```

```
##
## C (all)      FV      RH      RL      RM
##      10      65      16    1151     218
```

```
combined$MSZoning <- as.factor(combined$MSZoning)
table(combined$MSZoning)
```

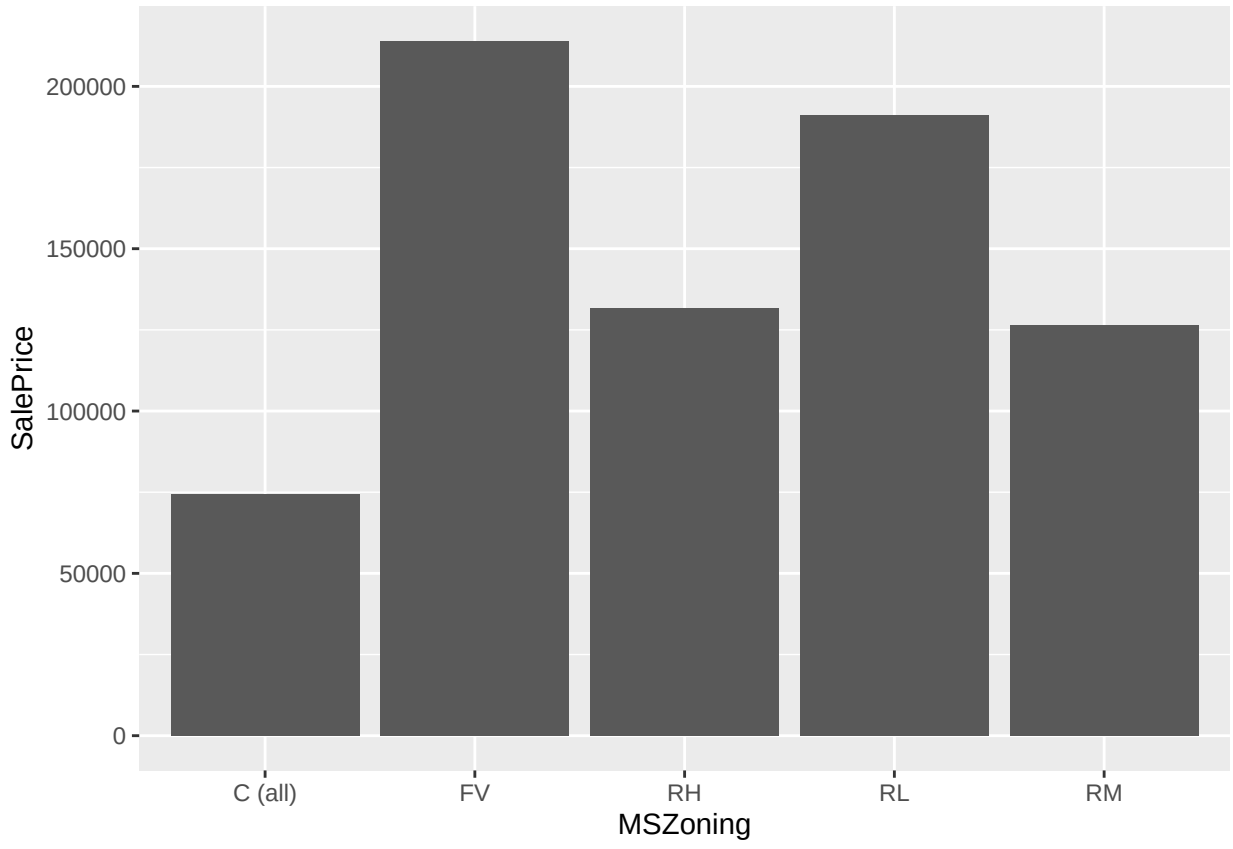
```
##
## C (all)      FV      RH      RL      RM
##      10      65      16    1151     218
```

```
barplot(table(combined$MSZoning), xlab = "MSZoning", ylab = "Count")
```




```
ggplot(combined, aes(x=MSZoning, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Street

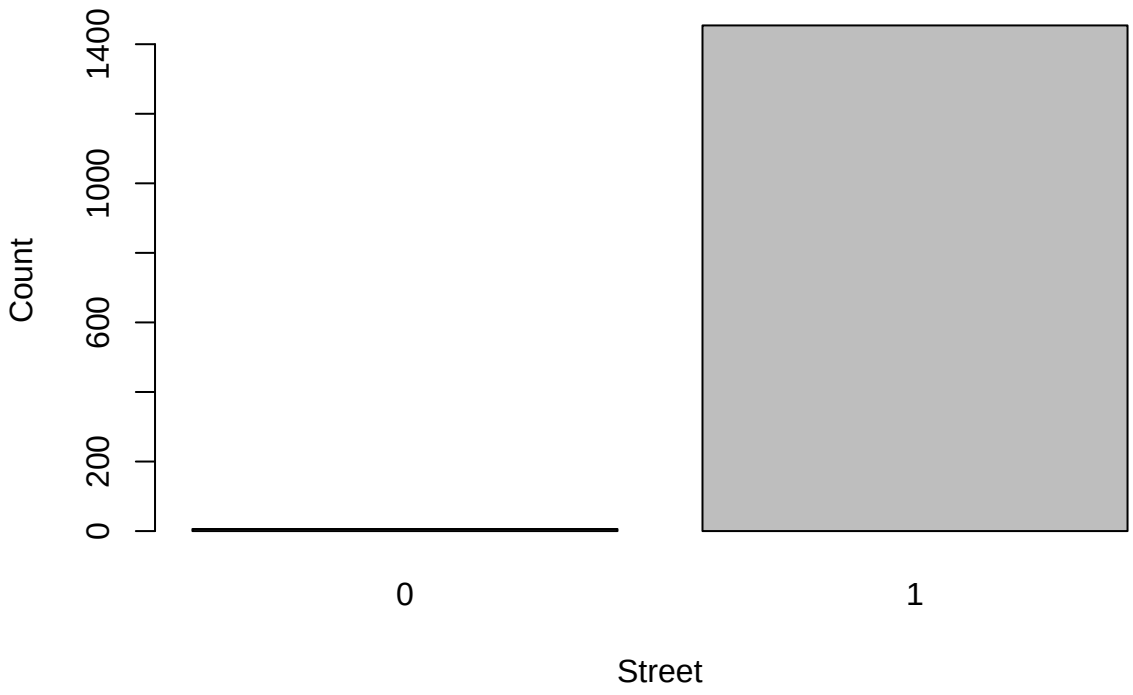
```
table(combined$Street)
```

```
##
## Grvl Pave
##    6 1454
```

```
combined$Street<-as.integer(revalue(combined$Street, c('Grvl'=0, 'Pave'=1)))
table(combined$Street)
```

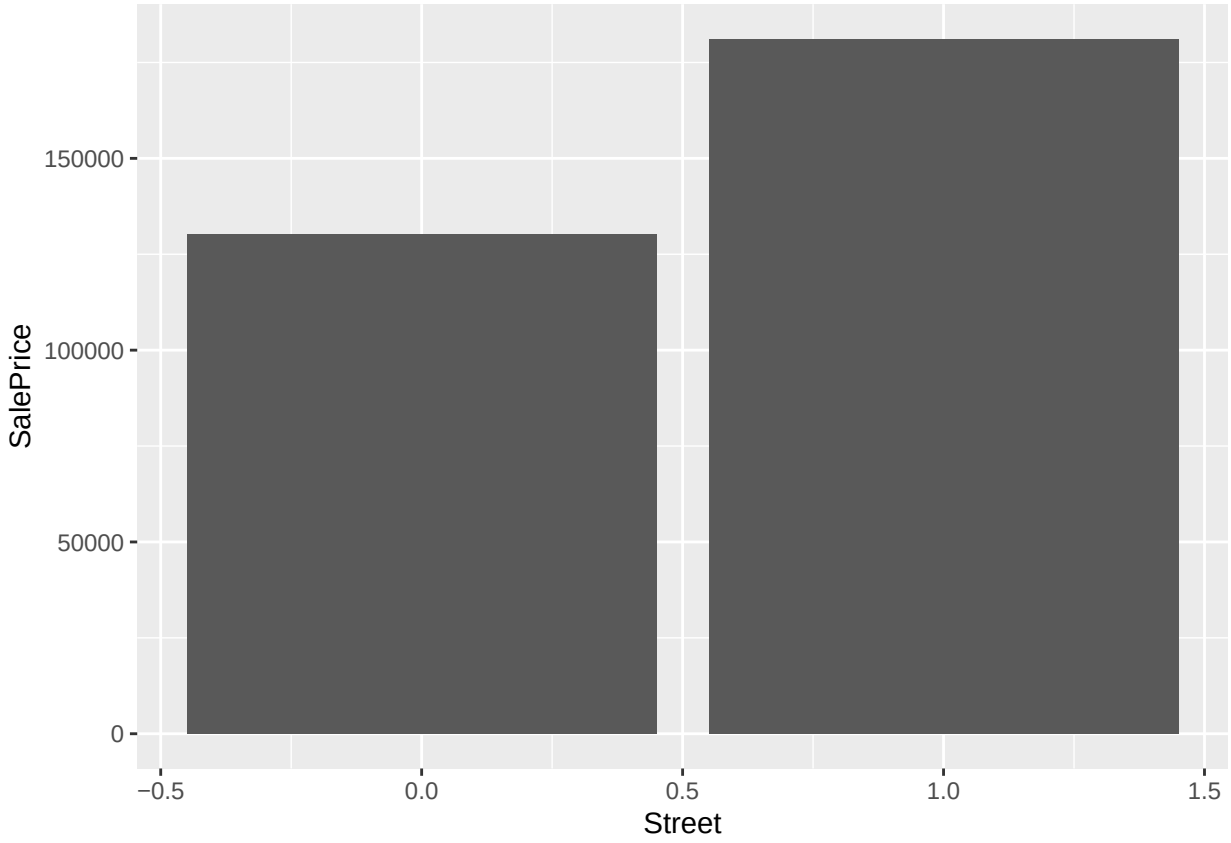
```
##
##    0    1
##    6 1454
```

```
barplot(table(combined$Street), xlab = "Street", ylab = "Count")
```




```
ggplot(combined, aes(x=Street, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



LandContour

Lvl Near Flat/Level Bnk Banked - Quick and significant rise from street grade to building HLS Hillside - Significant slope from side to side Low Depression

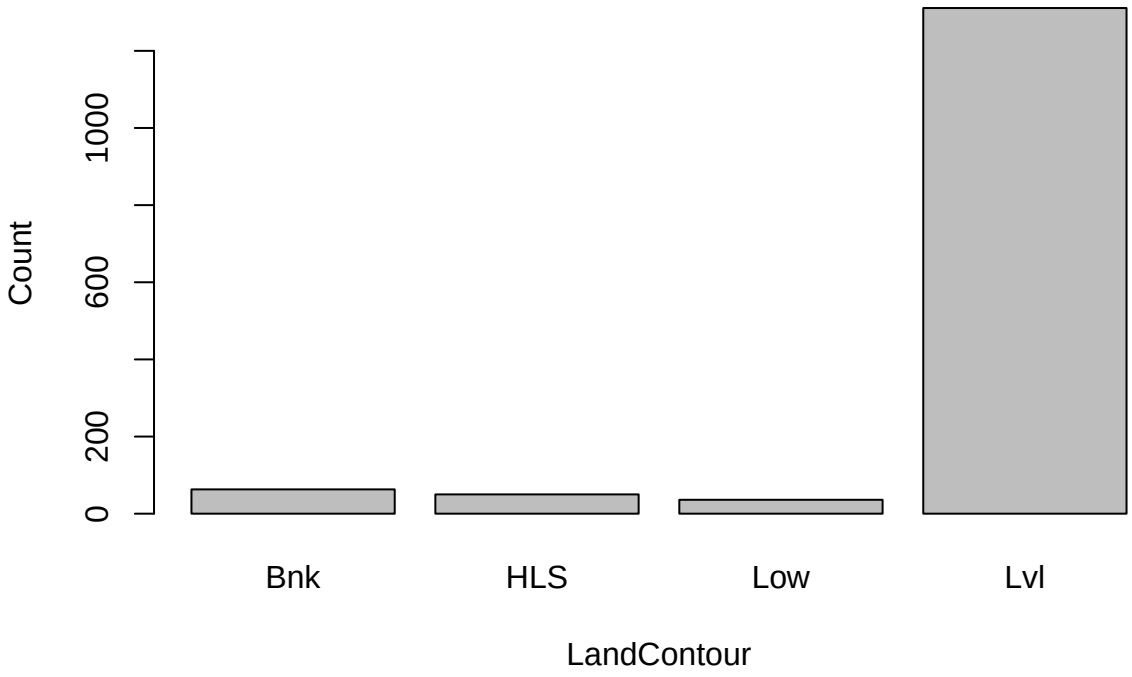
```
table(combined$LandContour)
```

```
##
##  Bnk  HLS  Low  Lvl
##   63   50   36 1311
```

```
combined$LandContour <- as.factor(combined$LandContour)
table(combined$LandContour)
```

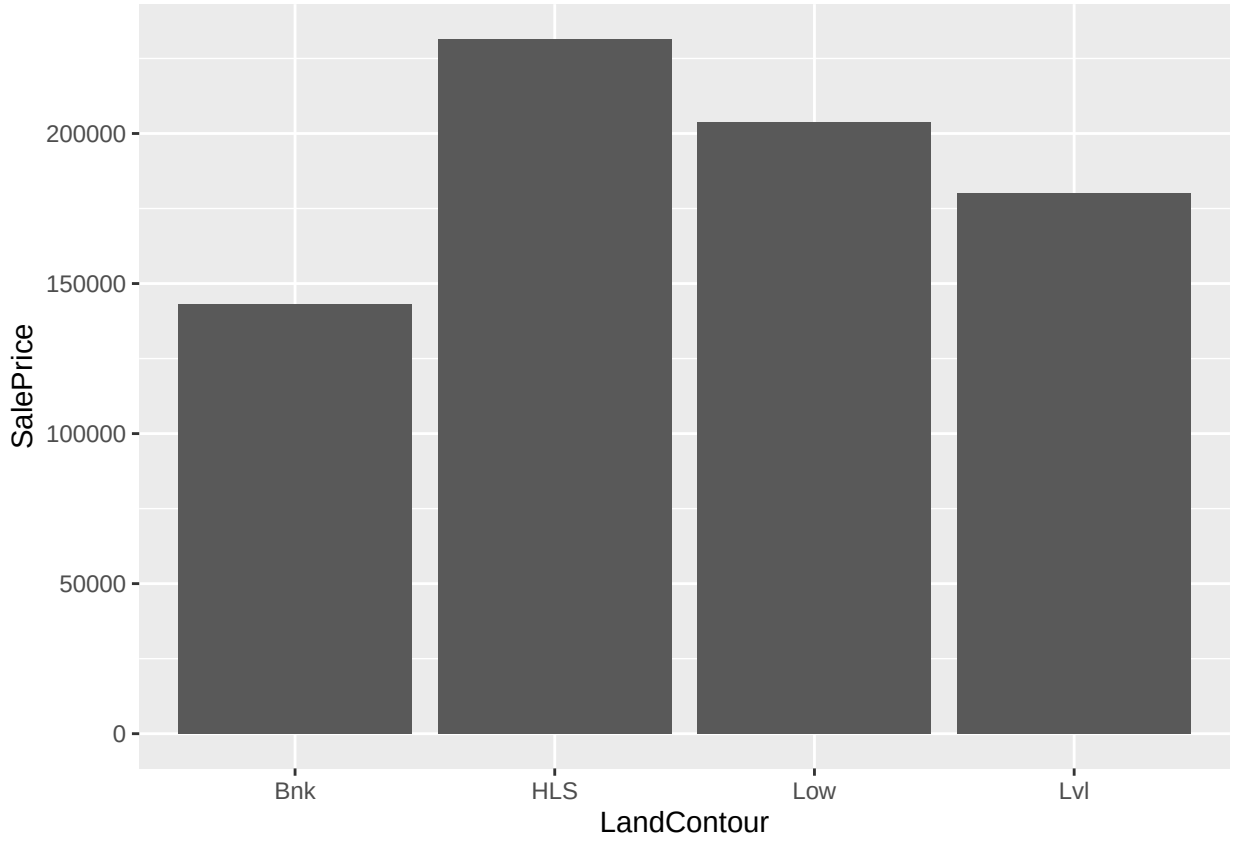
```
##
##  Bnk  HLS  Low  Lvl
##   63   50   36 1311
```

```
barplot(table(combined$LandContour), xlab = "LandContour", ylab = "Count")
```




```
ggplot(combined, aes(x=LandContour, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



LandSlope

Gtl Gentle slope Mod Moderate Slope
Sev Severe Slope

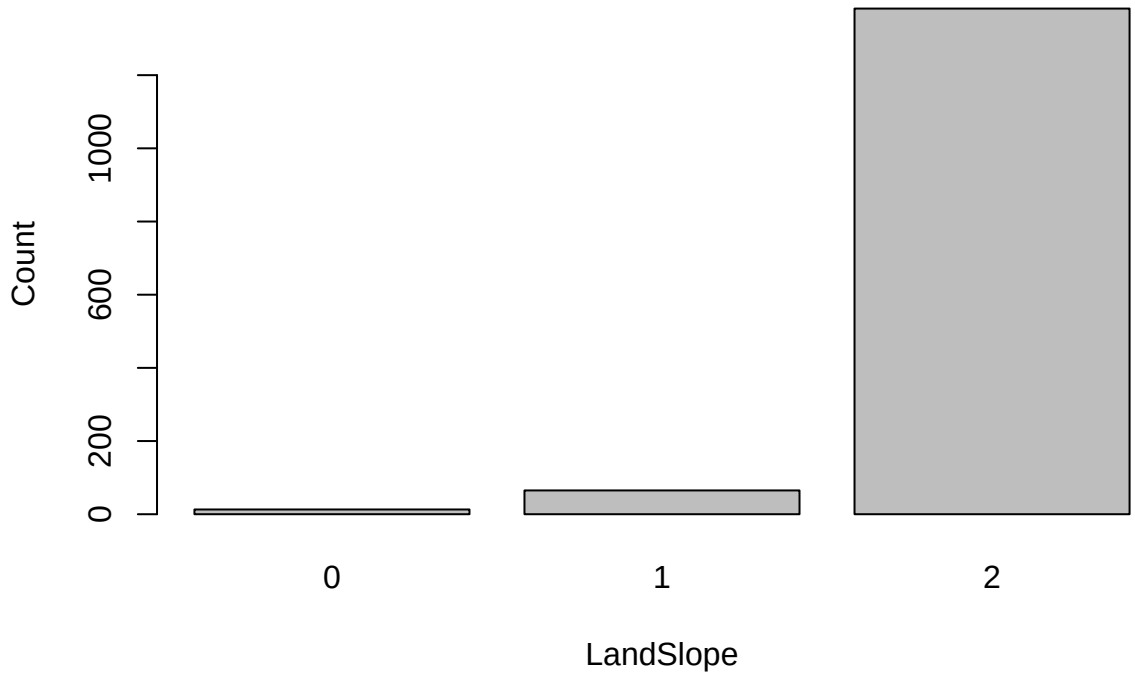
```
table(combined$LandSlope)
```

```
##
##  Gtl  Mod  Sev
## 1382   65   13
```

```
combined$LandSlope<-as.integer(revalue(combined$LandSlope, c('Sev'=0, 'Mod'=1, 'Gtl'=2)))
table(combined$LandSlope)
```

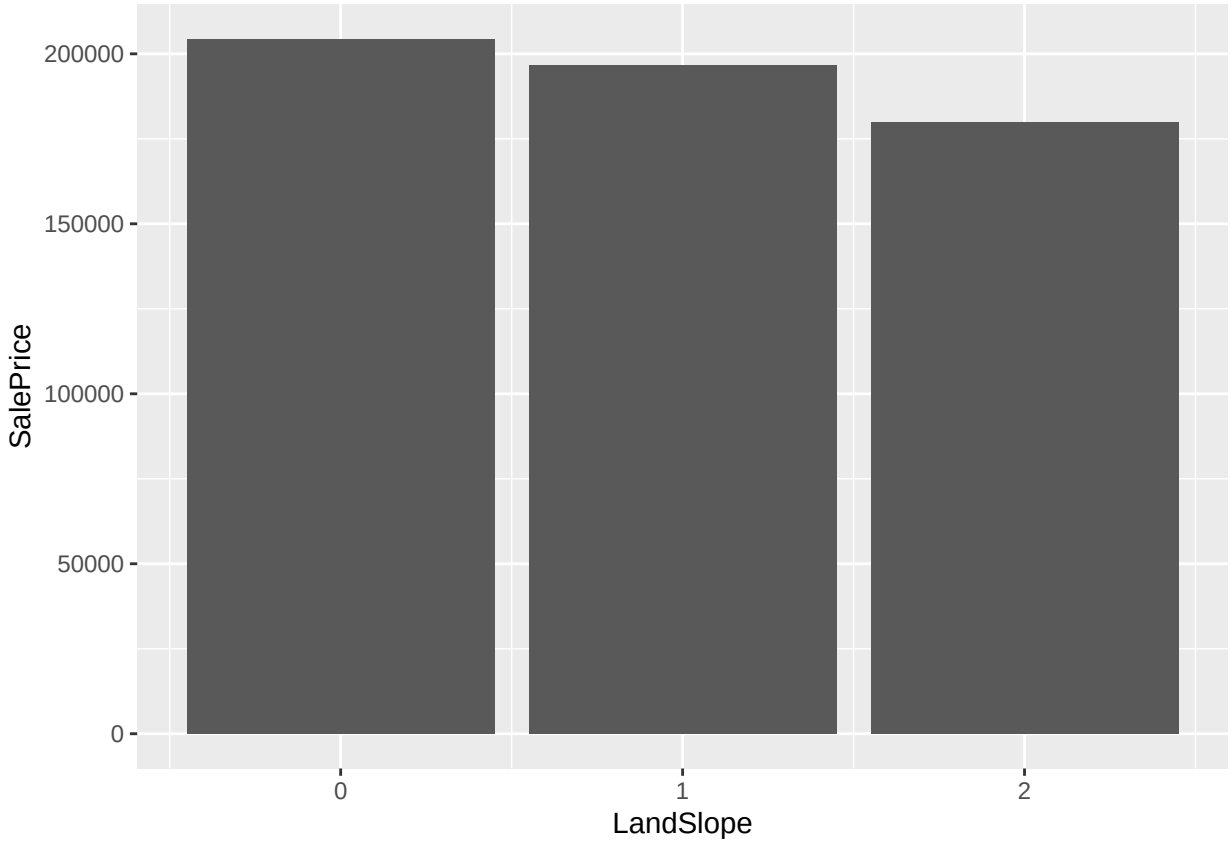
```
##
##    0    1    2
##   13   65 1382
```

```
barplot(table(combined$LandSlope), xlab = "LandSlope", ylab = "Count")
```




```
ggplot(combined, aes(x=LandSlope, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Utilities

```
table(combined$Utilities)
```

```
##
## AllPub NoSeWa
##   1459      1
```

```
# remove utilities as it does not give any valuable information.
combined <- combined[,!names(combined) %in% "Utilities"]
```

Neighborhood

```
table(combined$Neighborhood)
```

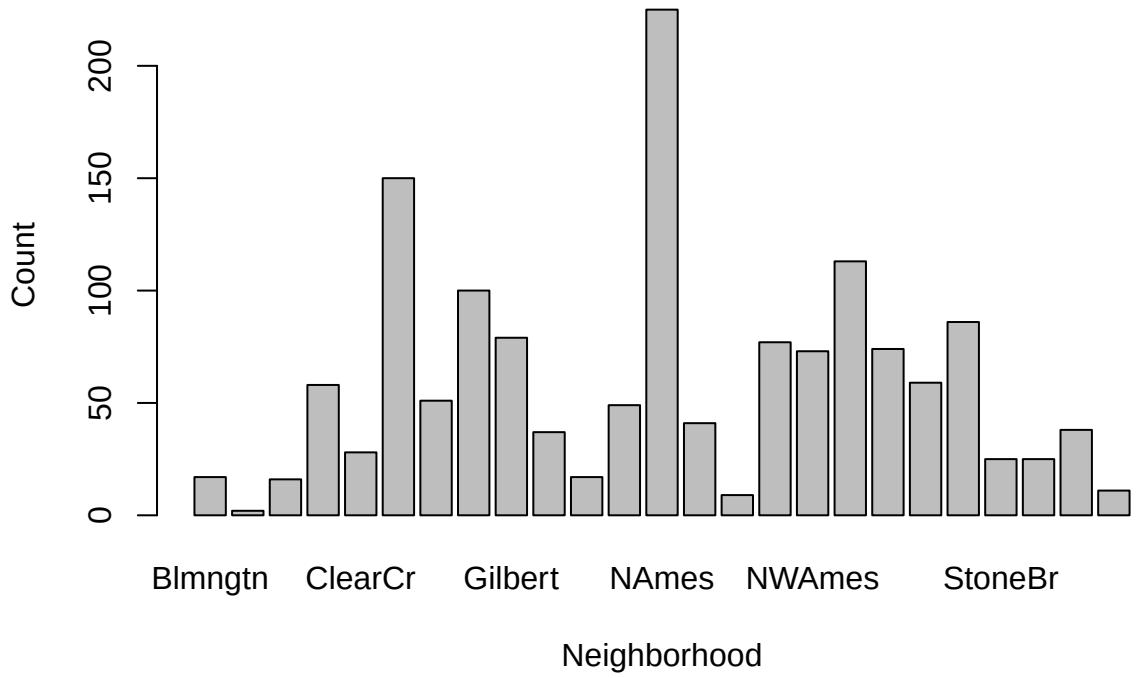
```
##
## Blmngtn Blueste  BrDale BrkSide ClearCr CollgCr Crawfor Edwards Gilbert  IDOTRR
##      17       2      16      58      28     150      51     100      79      37
## MeadowV Mitchel   NAmes NoRidge NPkVill NridgHt  NWAmes OldTown  Sawyer SawyerW
##      17      49     225      41       9      77      73     113      74      59
## Somerst StoneBr   SWISU  Timber Veenker
##      86      25      25      38      11
```

```
combined$Neighborhood <- as.factor(combined$Neighborhood)
table(combined$Neighborhood)
```

```
##
```

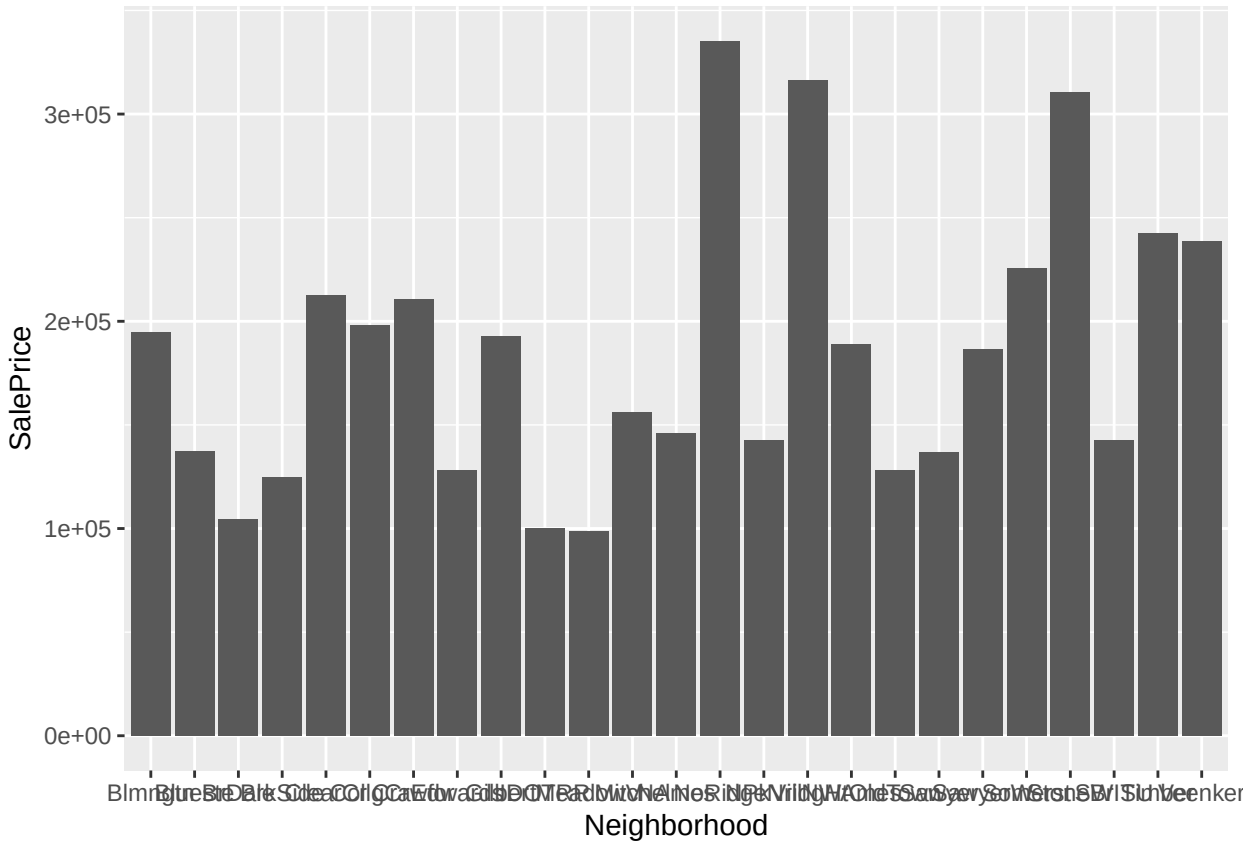
```
## Blmngtn Blueste  BrDale BrkSide ClearCr CollgCr Crawfor Edwards Gilbert  IDOTRR
##       17       2      16       58       28      150       51      100       79       37
## MeadowV Mitchel   NAmes NoRidge NPkVill NridgHt  NWAmes OldTown  Sawyer SawyerW
##       17      49     225       41        9       77       73      113       74       59
## Somerst StoneBr   SWISU  Timber Veenker
##       86       25      25       38       11
```

```
barplot(table(combined$Neighborhood), xlab = "Neighborhood", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=Neighborhood, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Condition1 and Condition2

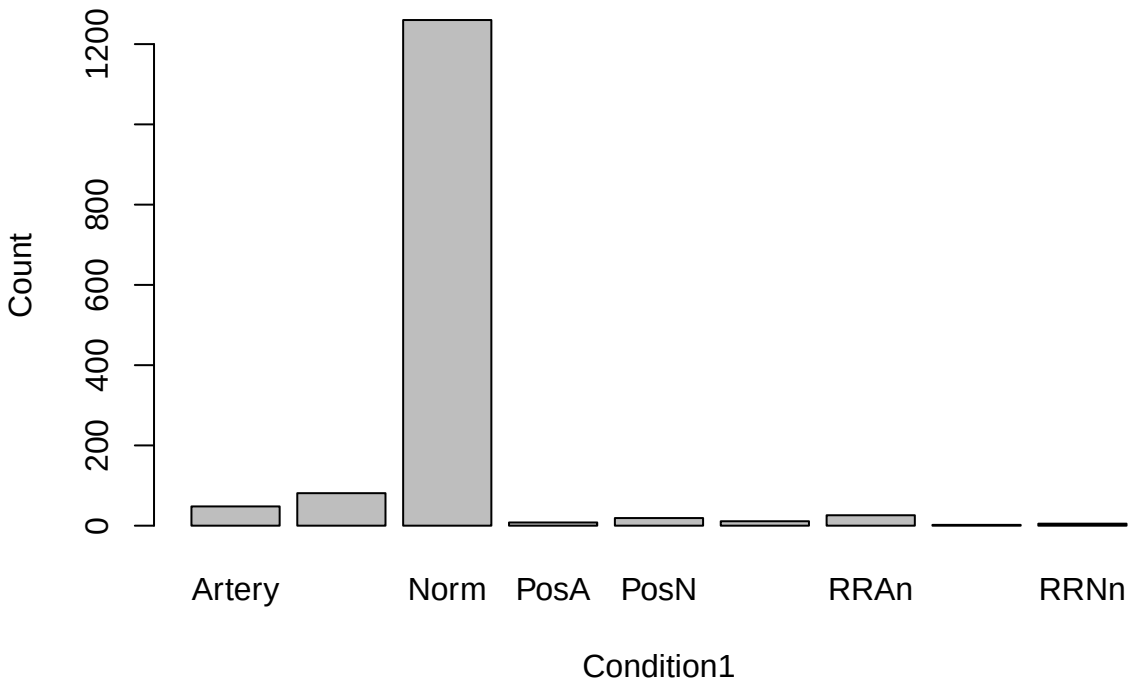
```
table(combined$Condition1)
```

```
##
## Artery  Feedr   Norm   PosA   PosN   RRAe   RRAn   RRNe   RRNn
##     48     81   1260      8     19     11     26      2      5
```

```
combined$Condition1 <- as.factor(combined$Condition1)
table(combined$Condition1)
```

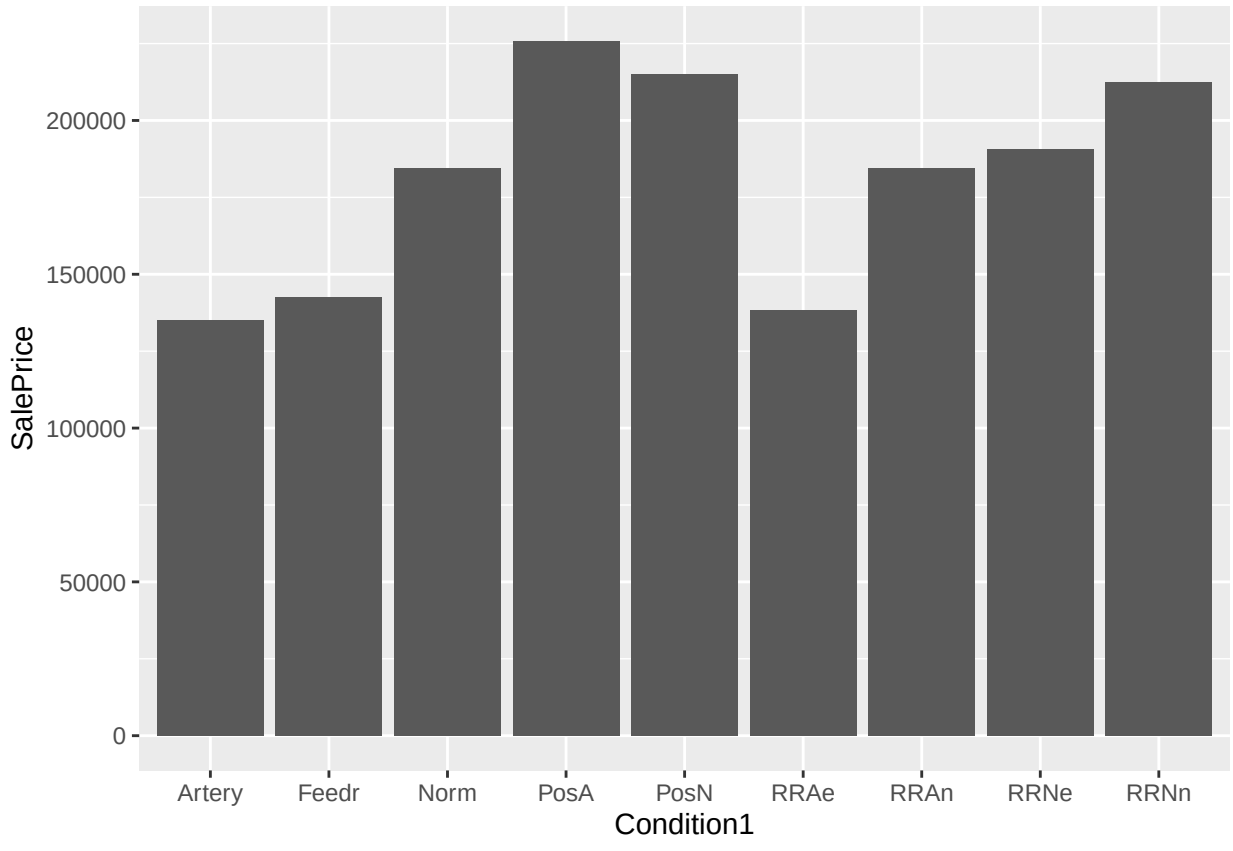
```
##
## Artery  Feedr   Norm   PosA   PosN   RRAe   RRAn   RRNe   RRNn
##     48     81   1260      8     19     11     26      2      5
```

```
barplot(table(combined$Condition1), xlab = "Condition1", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=Condition1, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



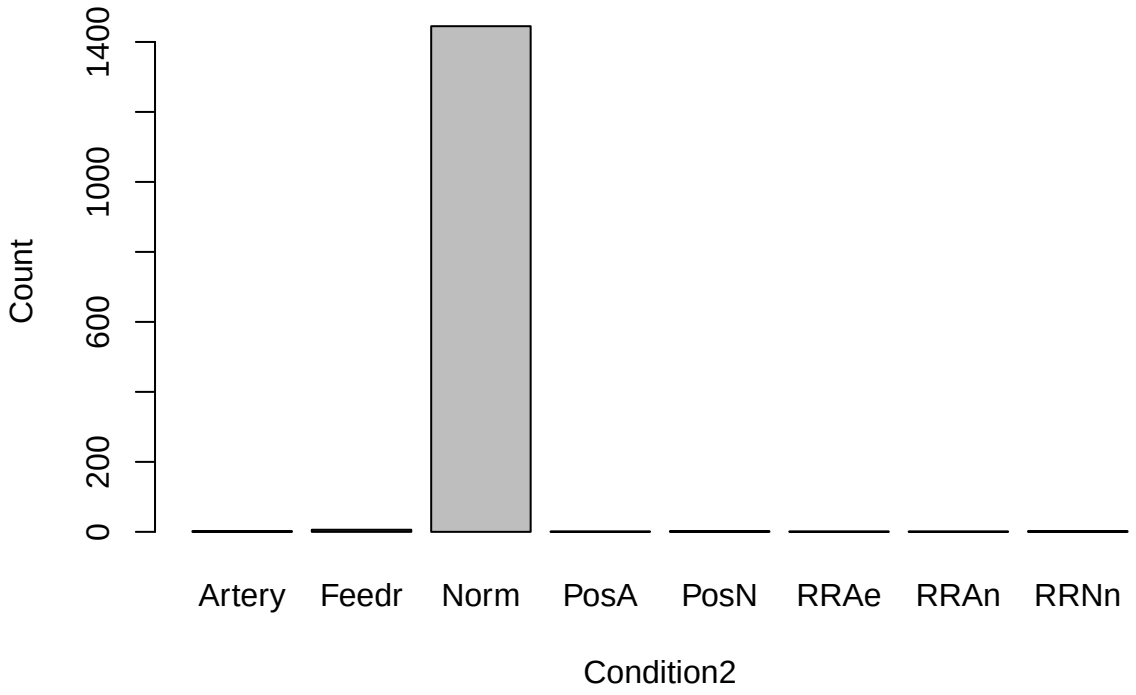
```
table(combined$Condition2)
```

```
##
## Artery  Feedr   Norm   PosA   PosN   RRAe   RRAn   RRNn
##      2      6   1445      1      2      1      1      2
```

```
combined$Condition2 <- as.factor(combined$Condition2)
table(combined$Condition2)
```

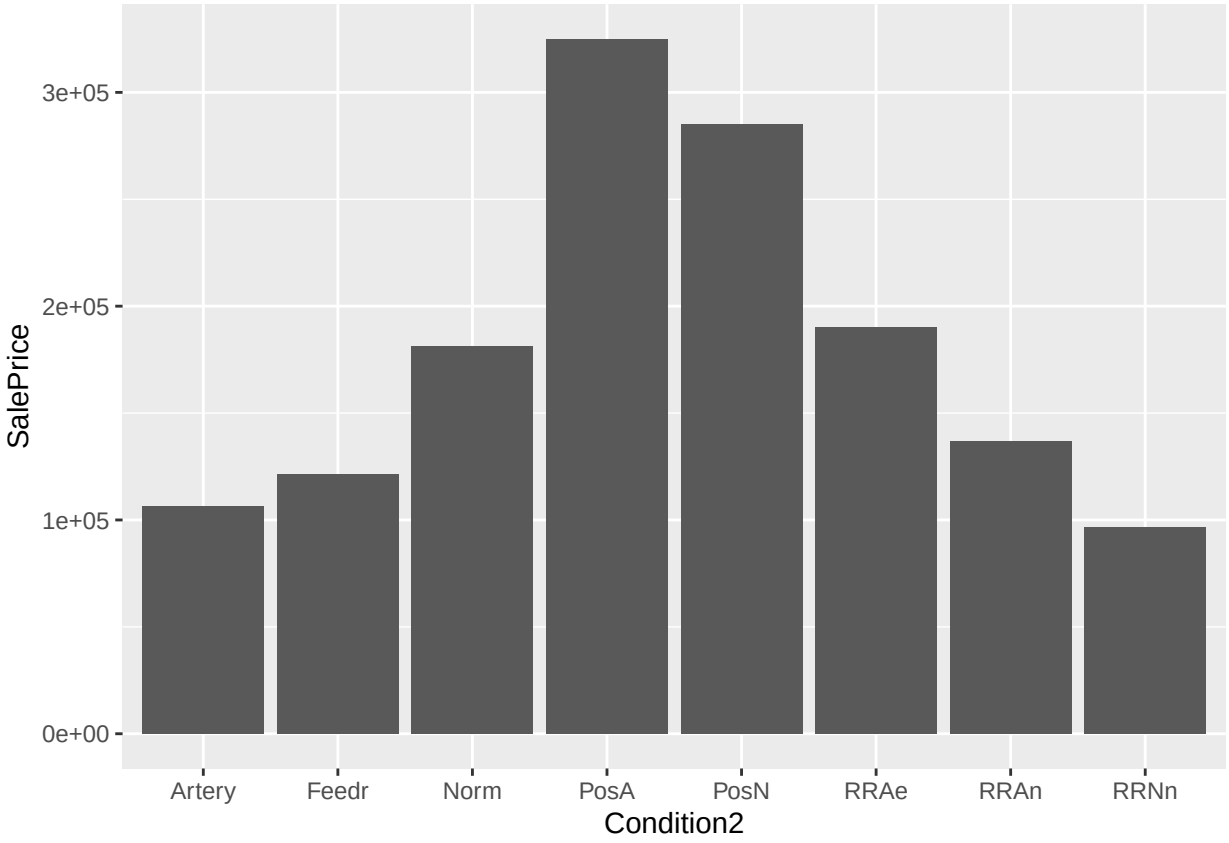
```
##
## Artery  Feedr   Norm   PosA   PosN   RRAe   RRAn   RRNn
##      2      6   1445      1      2      1      1      2
```

```
barplot(table(combined$Condition2), xlab = "Condition2", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=Condition2, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



BldgType

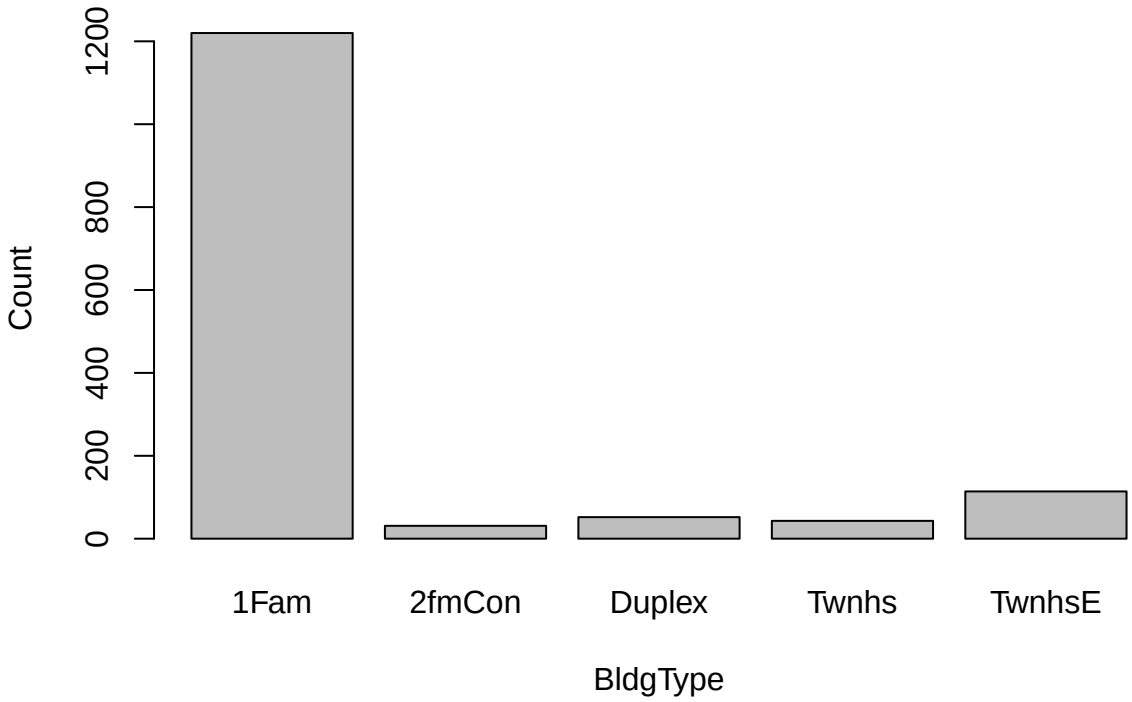
```
table(combined$BldgType)
```

```
##
##   1Fam 2fmCon Duplex  Twnhs TwnhsE
##   1220     31     52     43    114
```

```
combined$BldgType <- as.factor(combined$BldgType)
table(combined$BldgType)
```

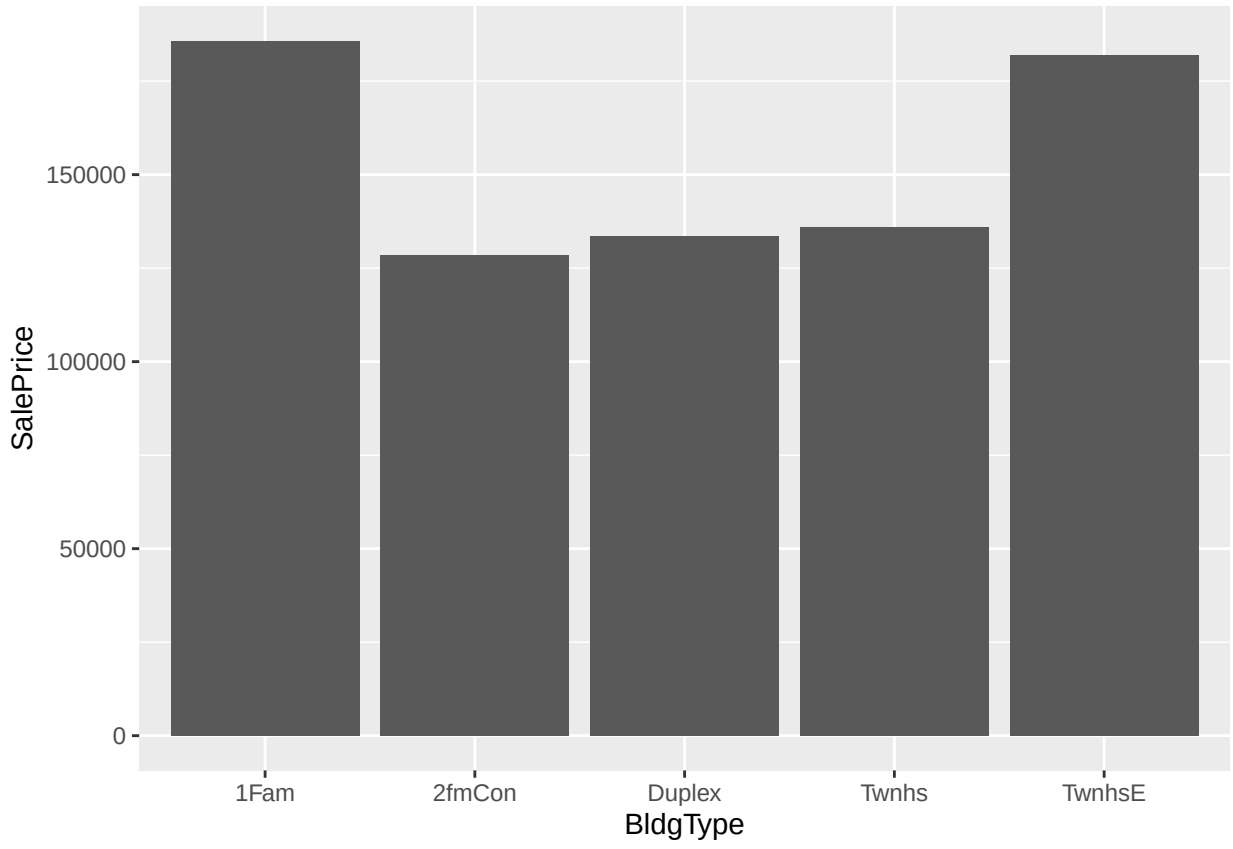
```
##
##   1Fam 2fmCon Duplex  Twnhs TwnhsE
##   1220     31     52     43    114
```

```
barplot(table(combined$BldgType), xlab = "BldgType", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=BldgType, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



HouseStyle

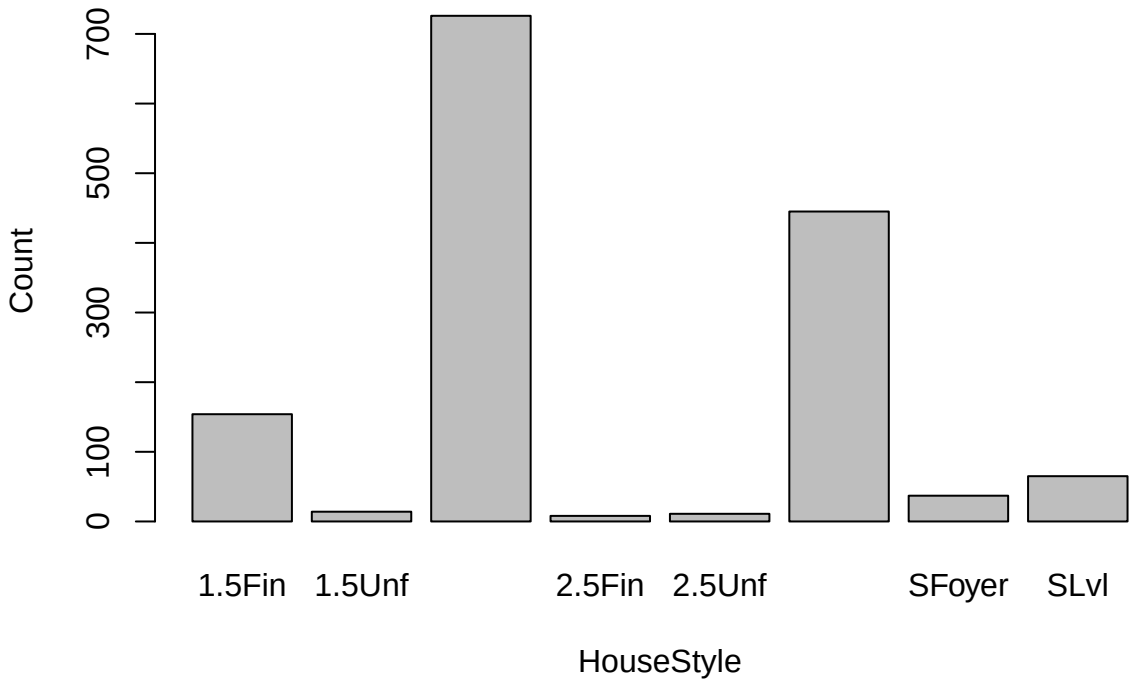
```
table(combined$HouseStyle)
```

```
##
## 1.5Fin 1.5Unf 1Story 2.5Fin 2.5Unf 2Story SFoyer   SLvl
##    154     14    726      8     11    445     37     65
```

```
combined$HouseStyle <- as.factor(combined$HouseStyle)
table(combined$HouseStyle)
```

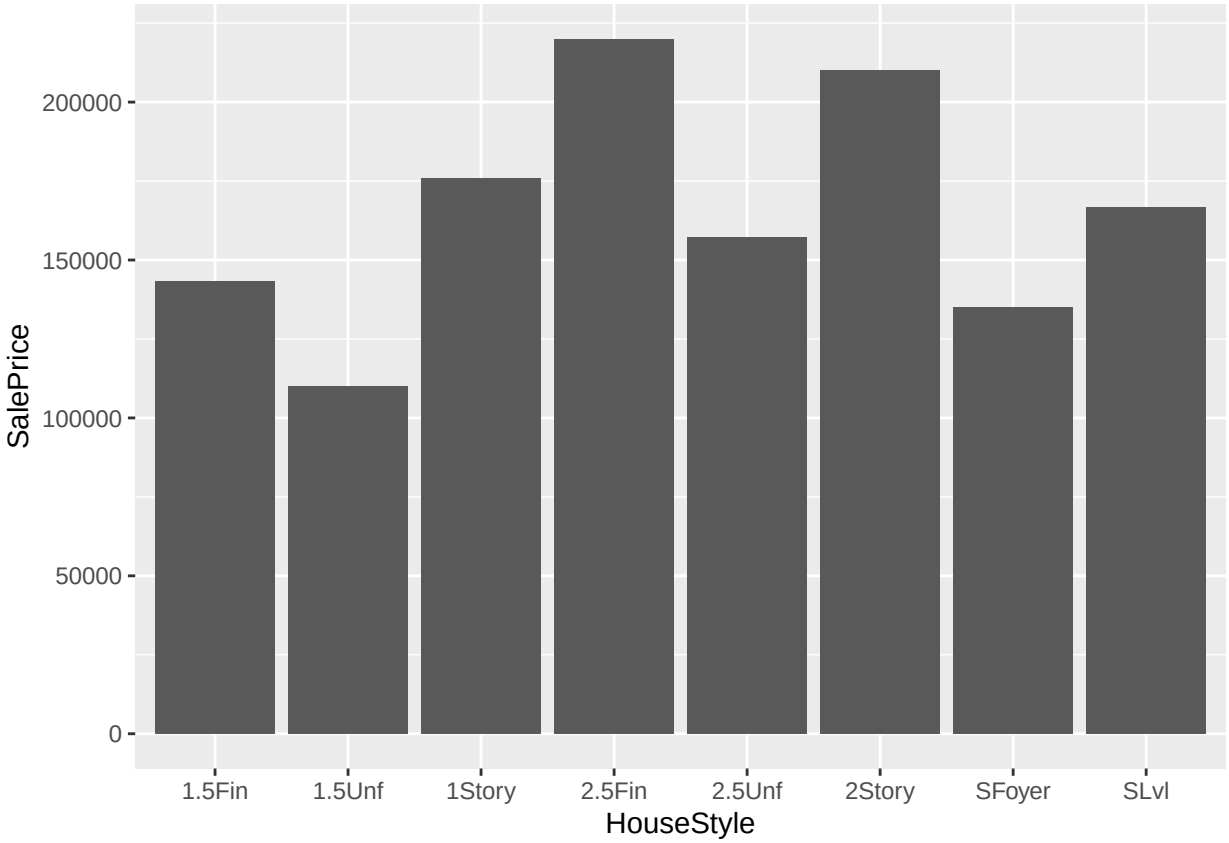
```
##
## 1.5Fin 1.5Unf 1Story 2.5Fin 2.5Unf 2Story SFoyer   SLvl
##    154     14    726      8     11    445     37     65
```

```
barplot(table(combined$HouseStyle), xlab = "HouseStyle", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=HouseStyle, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



RoofStyle

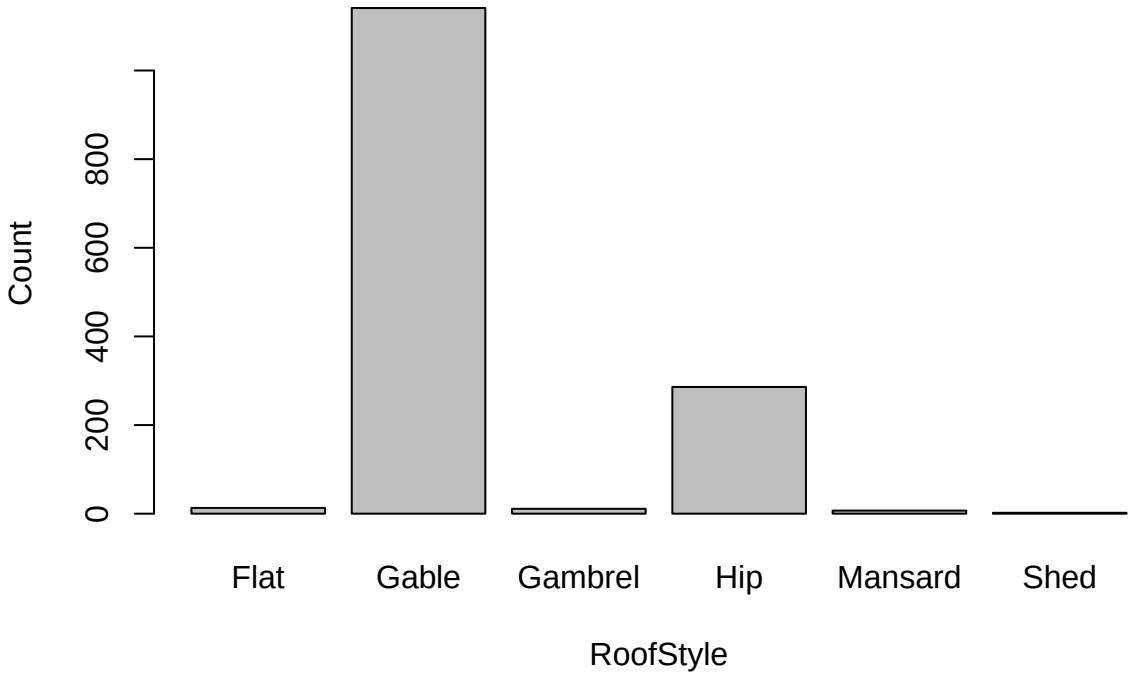
```
table(combined$RoofStyle)
```

```
##
##    Flat   Gable Gambrel     Hip Mansard    Shed
##      13    1141      11     286       7       2
```

```
combined$RoofStyle <- as.factor(combined$RoofStyle)
table(combined$RoofStyle)
```

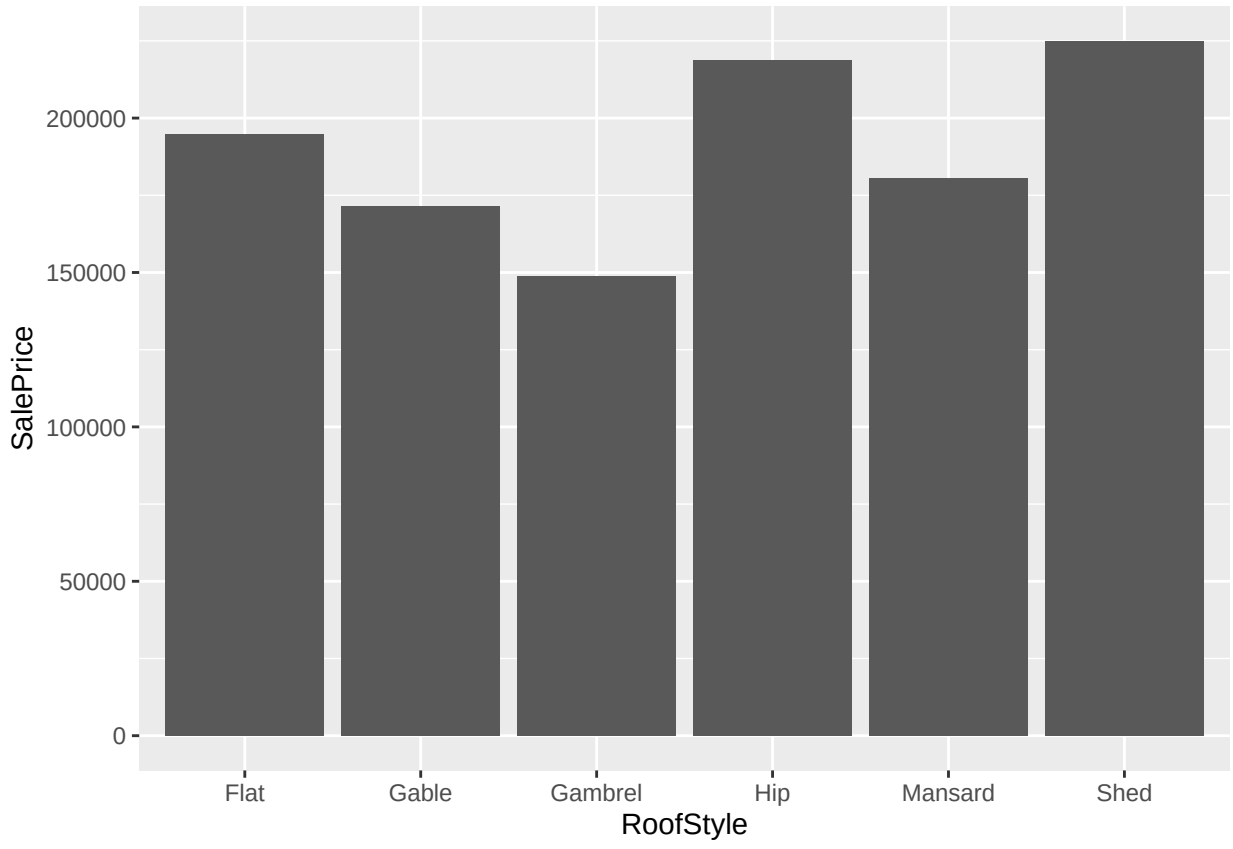
```
##
##    Flat   Gable Gambrel     Hip Mansard    Shed
##      13    1141      11     286       7       2
```

```
barplot(table(combined$RoofStyle), xlab = "RoofStyle", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=RoofStyle, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



RoofMatl

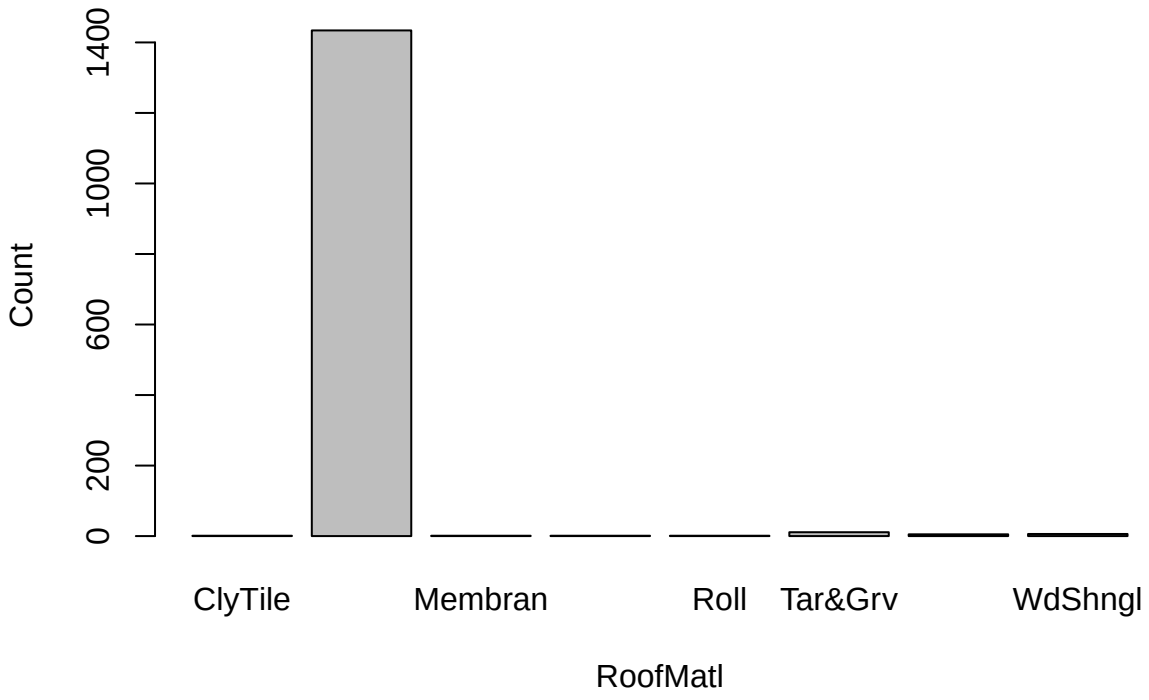
```
table(combined$RoofMatl)
```

```
##
## ClyTile CompShg Membran   Metal    Roll Tar&Grv WdShake WdShngl
##       1    1434       1       1       1      11       5       6
```

```
combined$RoofMatl <- as.factor(combined$RoofMatl)
table(combined$RoofMatl)
```

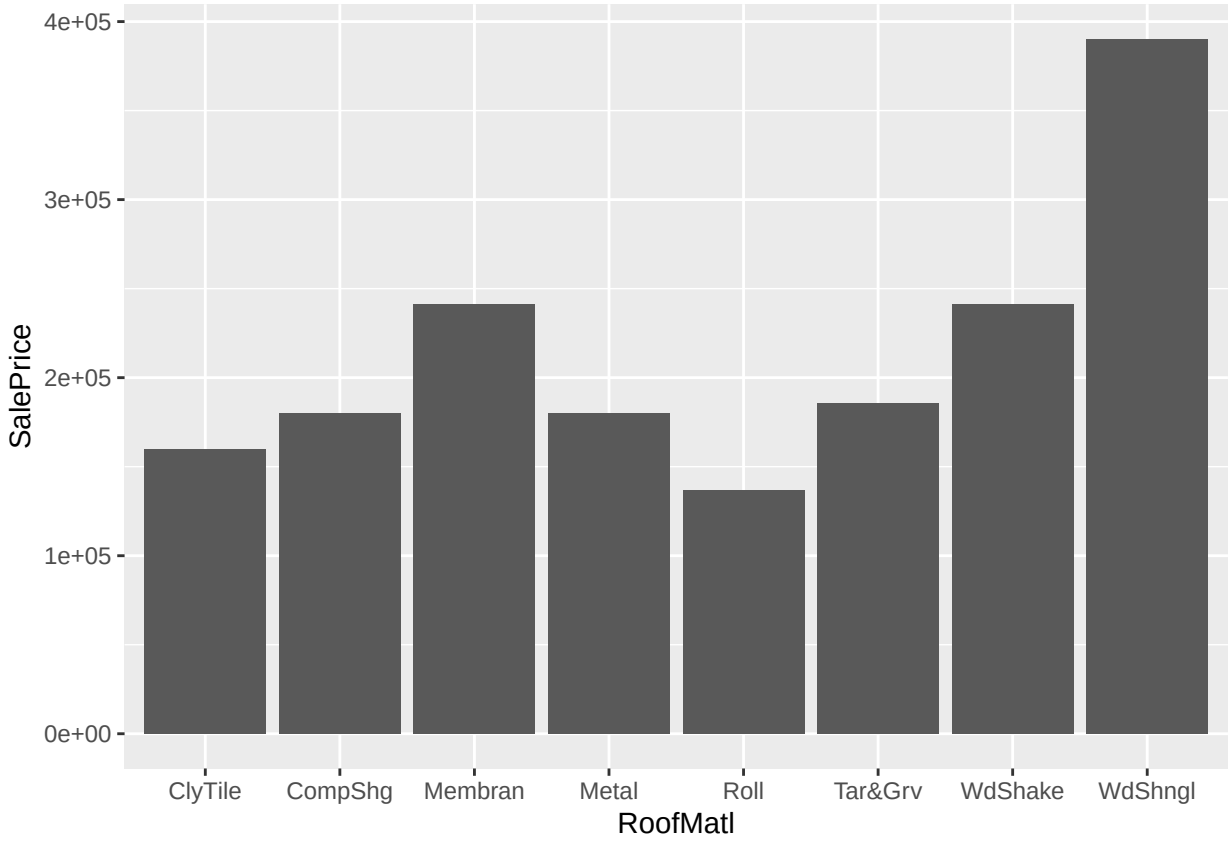
```
##
## ClyTile CompShg Membran   Metal    Roll Tar&Grv WdShake WdShngl
##       1    1434       1       1       1      11       5       6
```

```
barplot(table(combined$RoofMatl), xlab = "RoofMatl", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=RoofMatl, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Exterior variables

"Exterior1st" "Exterior2nd" "ExterQual" "ExterCond"

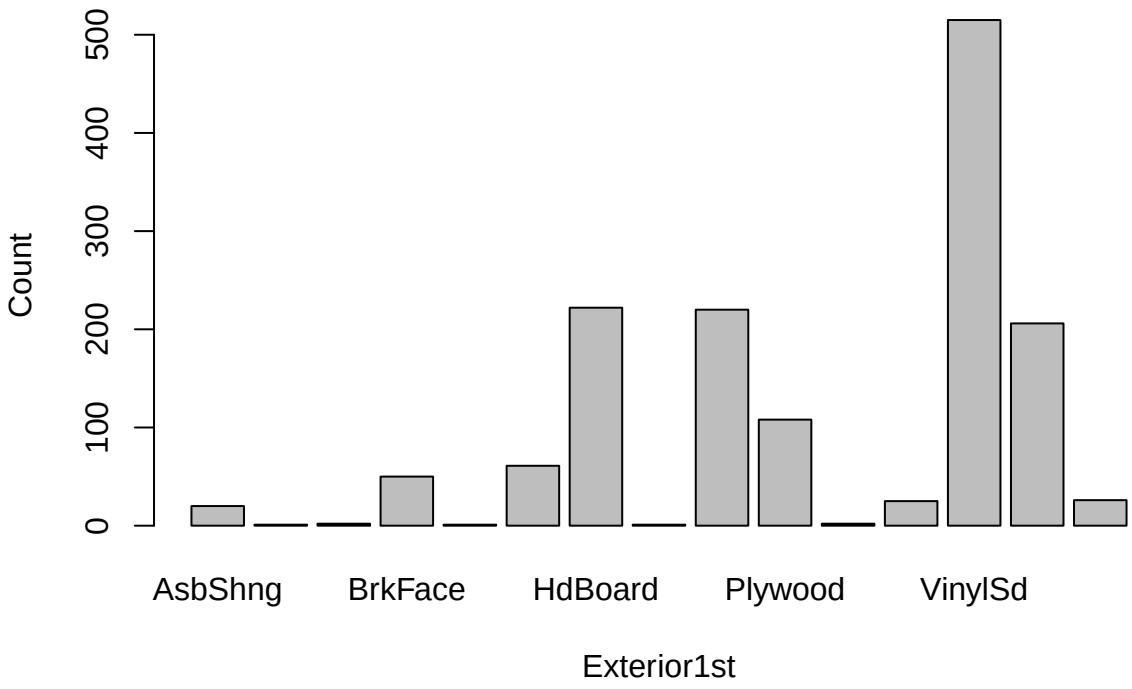
```
table(combined$Exterior1st)
```

```
##
## AsbShng AsphShn BrkComm BrkFace  CBlock CemntBd HdBoard ImStucc MetalSd Plywood
##      20       1       2      50       1      61     222       1     220     108
##   Stone  Stucco VinylSd Wd Sdng WdShing
##       2      25     515     206      26
```

```
combined$Exterior1st <- as.factor(combined$Exterior1st)
table(combined$Exterior1st)
```

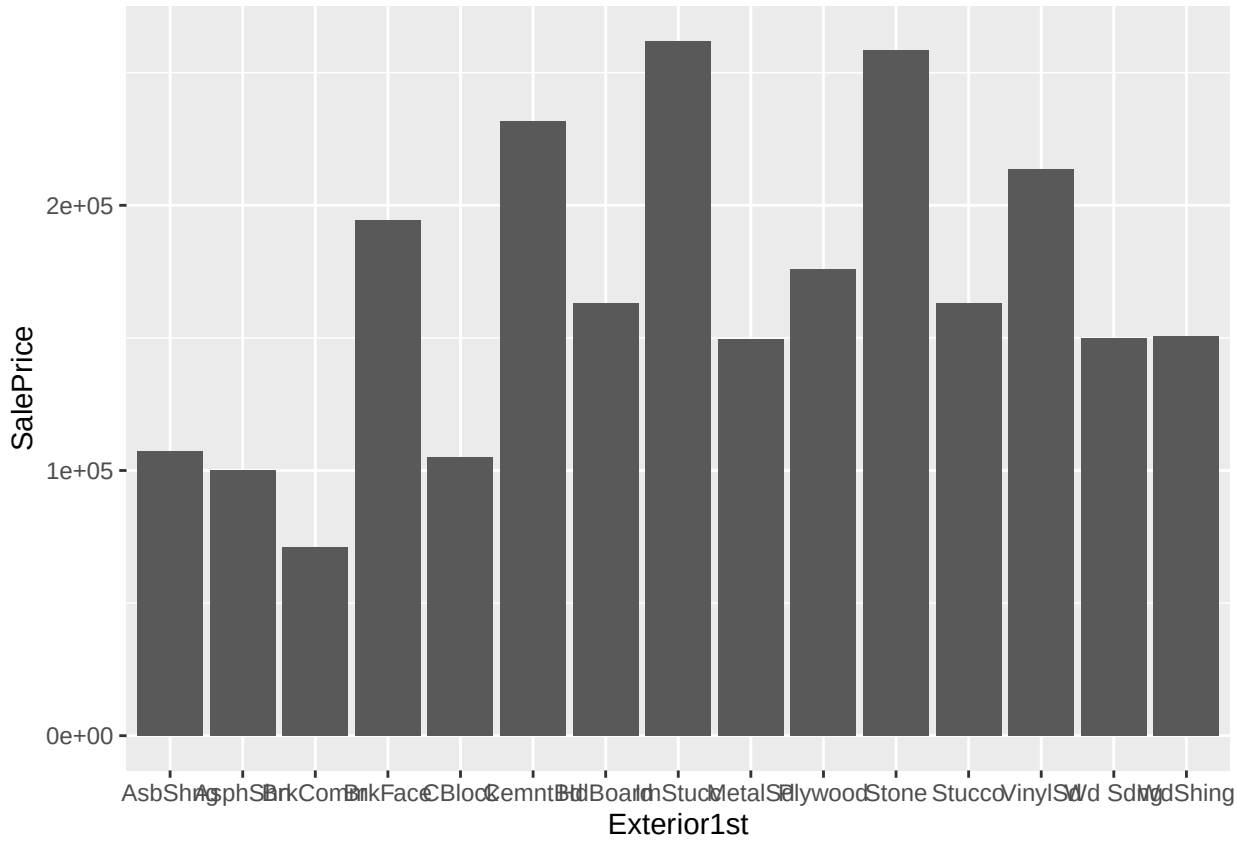
```
##
## AsbShng AsphShn BrkComm BrkFace  CBlock CemntBd HdBoard ImStucc MetalSd Plywood
##      20       1       2      50       1      61     222       1     220     108
##   Stone  Stucco VinylSd Wd Sdng WdShing
##       2      25     515     206      26
```

```
barplot(table(combined$Exterior1st), xlab = "Exterior1st", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=Exterior1st, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



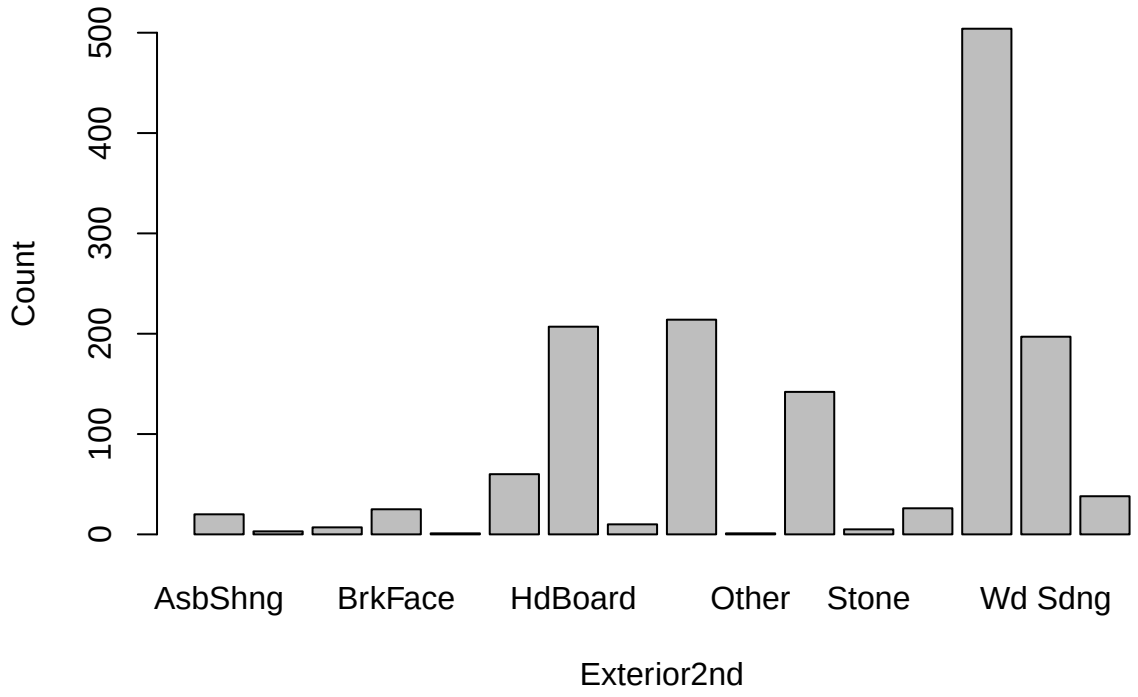
```
table(combined$Exterior2nd)
```

```
##
## AsbShng AsphShn Brk Cmn BrkFace  CBlock CmentBd HdBoard ImStucc MetalSd   Other
##      20       3       7      25       1      60     207      10     214       1
## Plywood   Stone  Stucco VinylSd Wd Sdng Wd Shng
##     142       5      26     504     197      38
```

```
combined$Exterior2nd <- as.factor(combined$Exterior2nd)
table(combined$Exterior2nd)
```

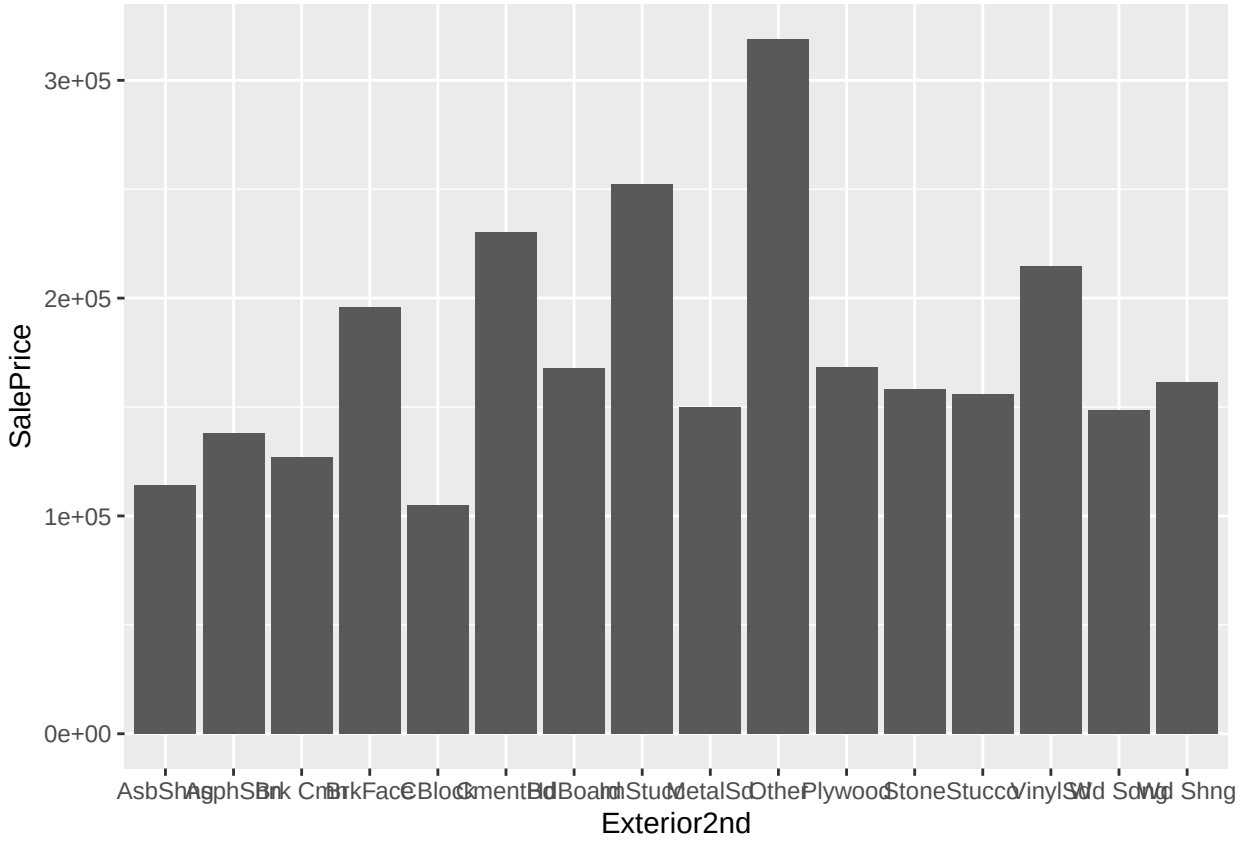
```
##
## AsbShng AsphShn Brk Cmn BrkFace  CBlock CmentBd HdBoard ImStucc MetalSd   Other
##      20       3       7      25       1      60     207      10     214       1
## Plywood   Stone  Stucco VinylSd Wd Sdng Wd Shng
##     142       5      26     504     197      38
```

```
barplot(table(combined$Exterior2nd), xlab = "Exterior2nd", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=Exterior2nd, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```




```
table(combined$ExterQual)
```

```
##
##  Ex  Fa  Gd  TA
##  52  14 488 906
```

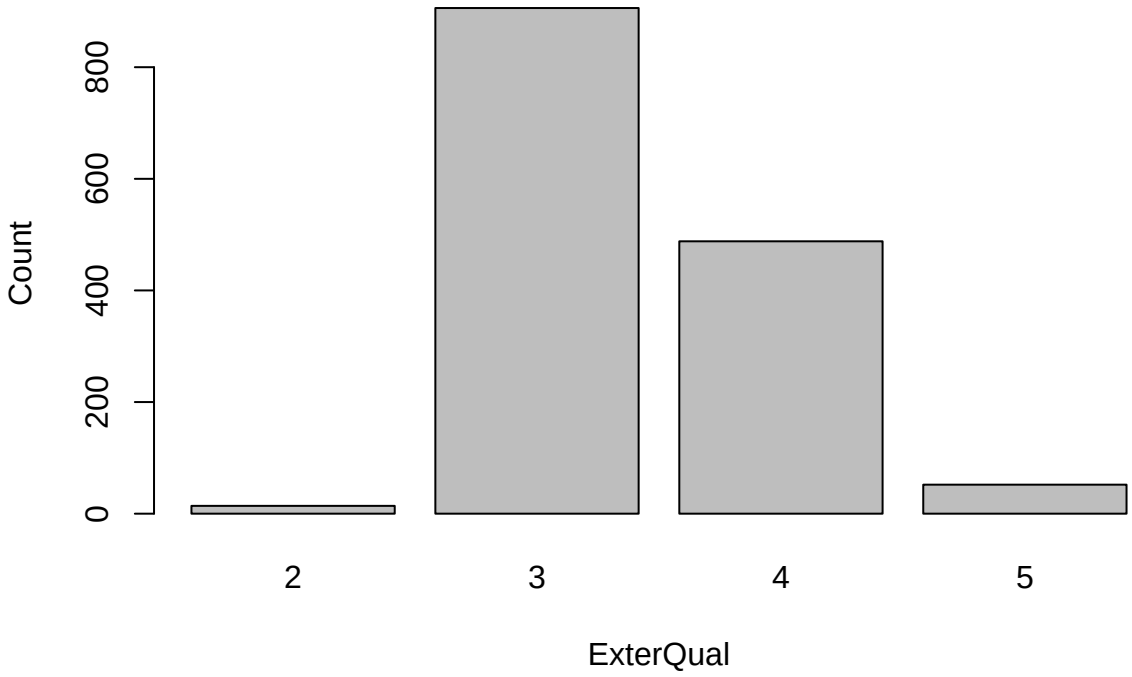
```
combined$ExterQual<-as.integer(revalue(combined$ExterQual, quality))
```

```
## The following `from` values were not present in `x`: None, Po
```

```
table(combined$ExterQual)
```

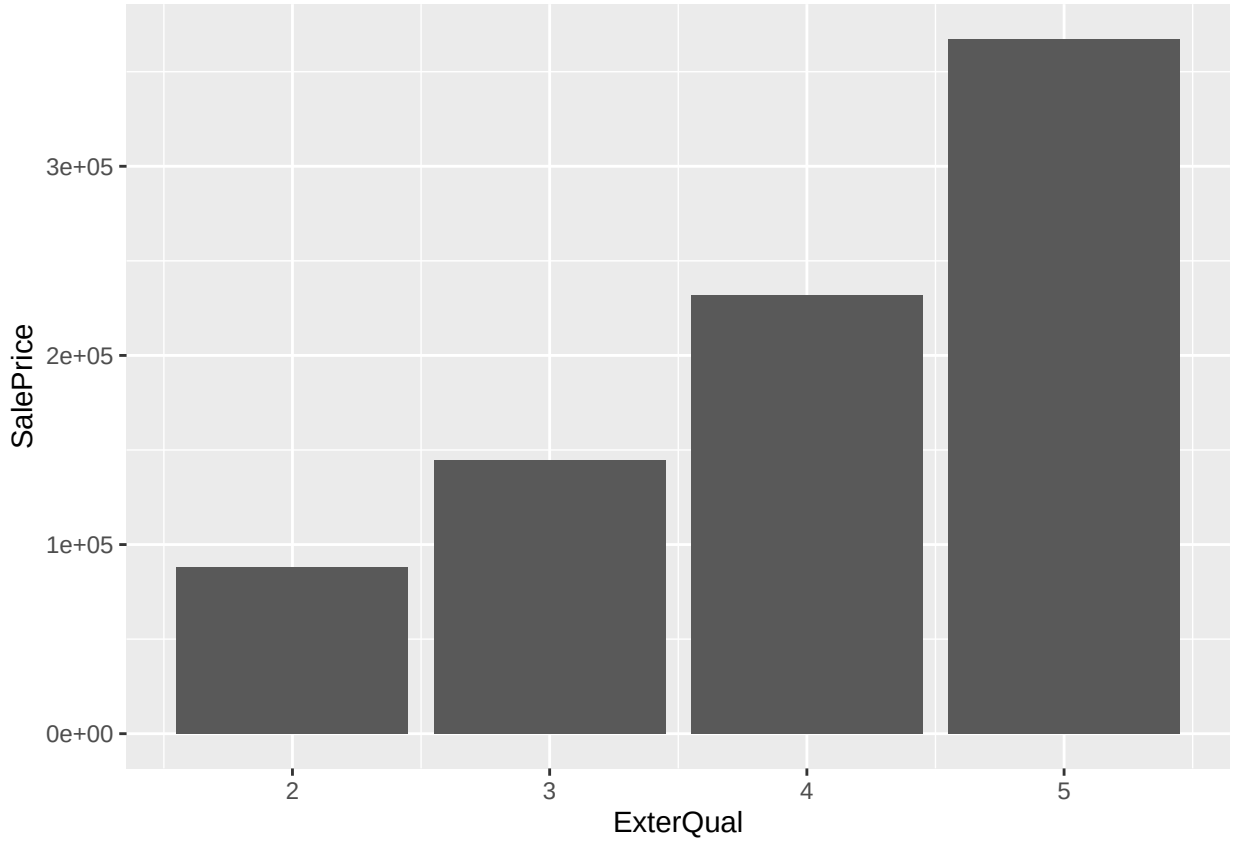
```
##
##   2   3   4   5
##  14 906 488  52
```

```
barplot(table(combined$ExterQual), xlab = "ExterQual", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=ExterQual, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



```
table(combined$ExterCond)
```

```
##
##   Ex   Fa   Gd   Po   TA
##    3   28  146    1 1282
```

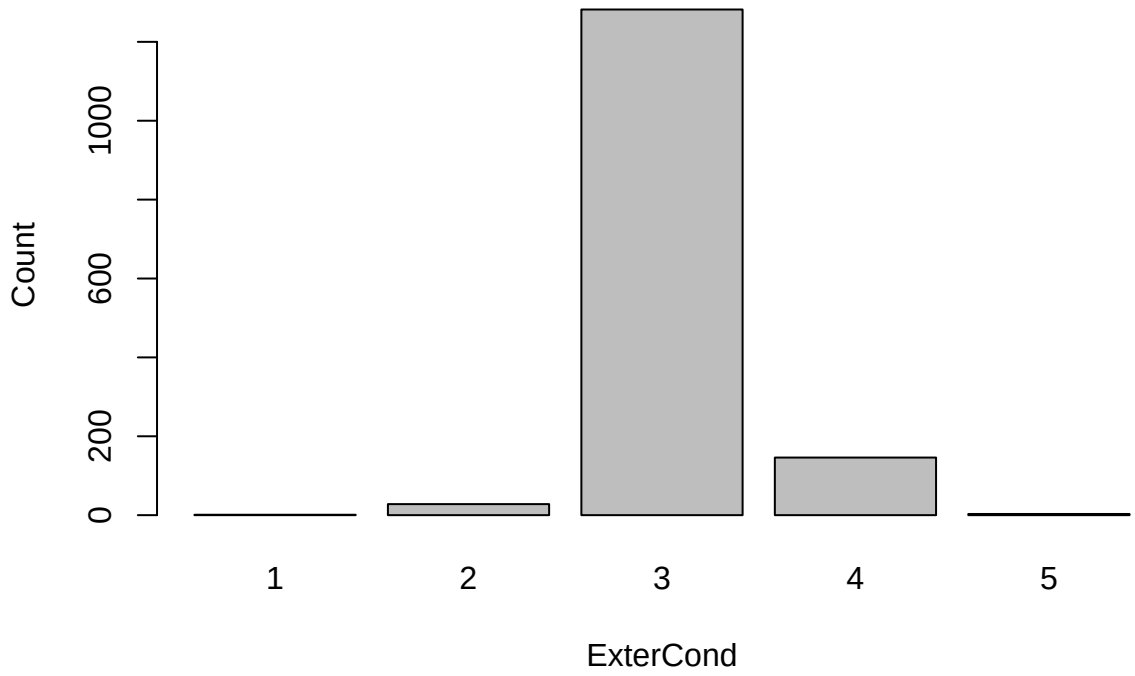
```
combined$ExterCond<-as.integer(revalue(combined$ExterCond, quality))
```

```
## The following `from` values were not present in `x`: None
```

```
table(combined$ExterCond)
```

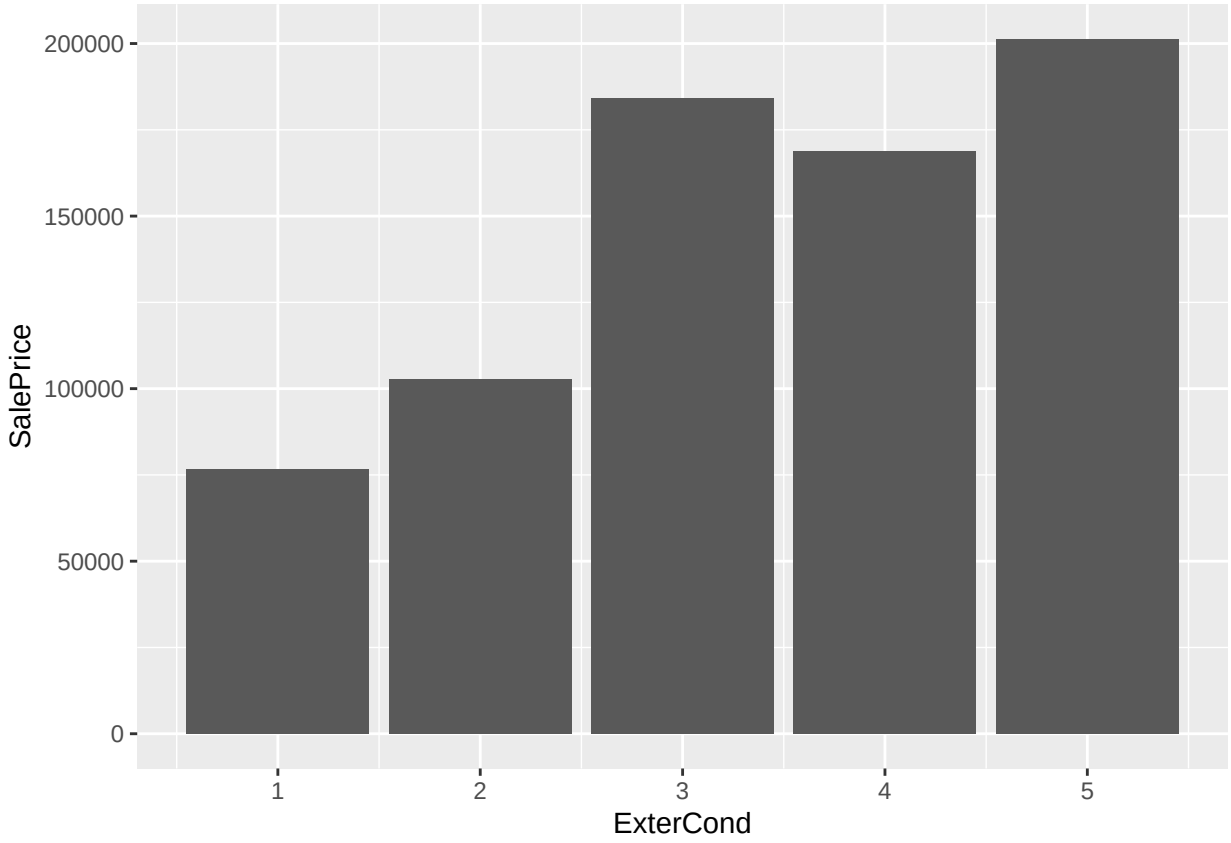
```
##
##    1    2    3    4    5
##    1   28 1282  146    3
```

```
barplot(table(combined$ExterCond), xlab = "ExterCond", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=ExterCond, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Foundation

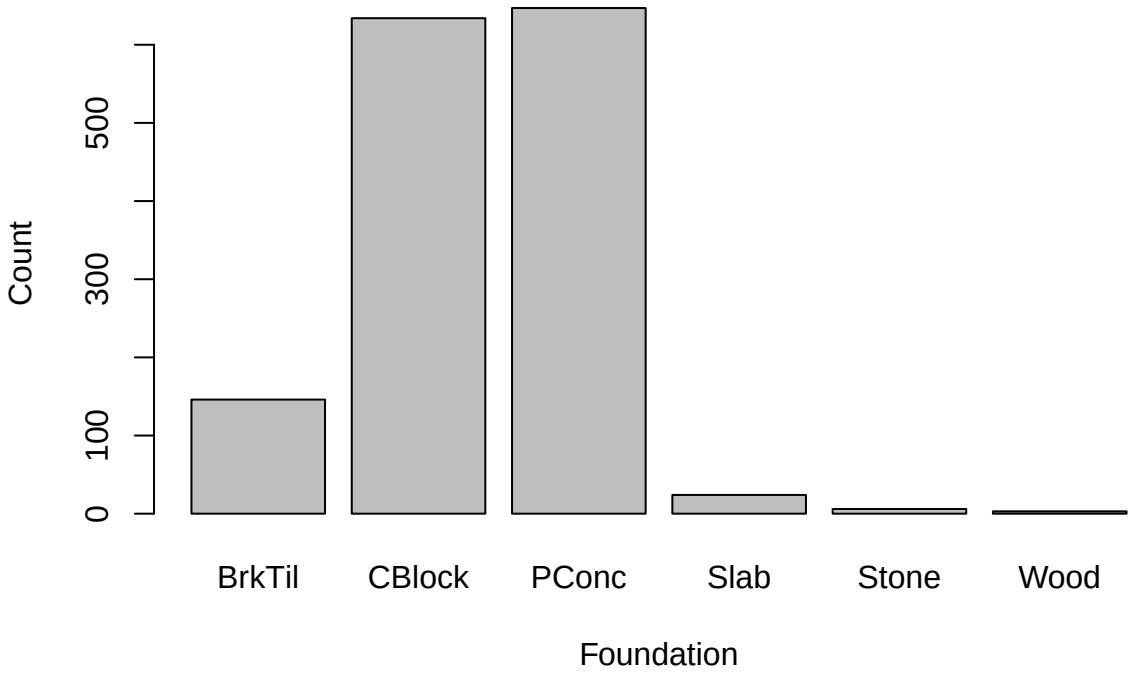
```
table(combined$Foundation)
```

```
##
## BrkTil CBlock  PConc   Slab  Stone   Wood
##    146    634    647     24      6      3
```

```
combined$Foundation <- as.factor(combined$Foundation)
table(combined$Foundation)
```

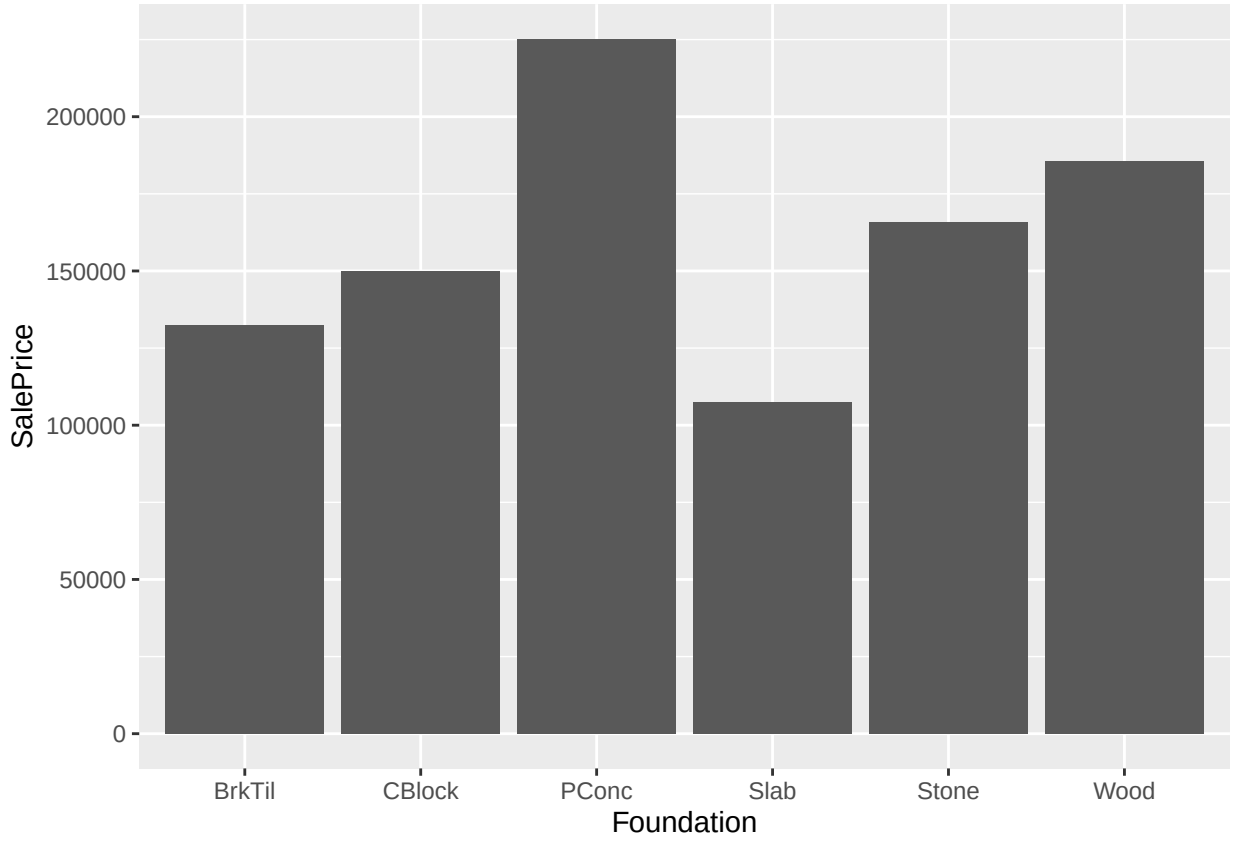
```
##
## BrkTil CBlock  PConc   Slab  Stone   Wood
##    146    634    647     24      6      3
```

```
barplot(table(combined$Foundation), xlab = "Foundation", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=Foundation, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



heating variables

"Heating" "HeatingQC"

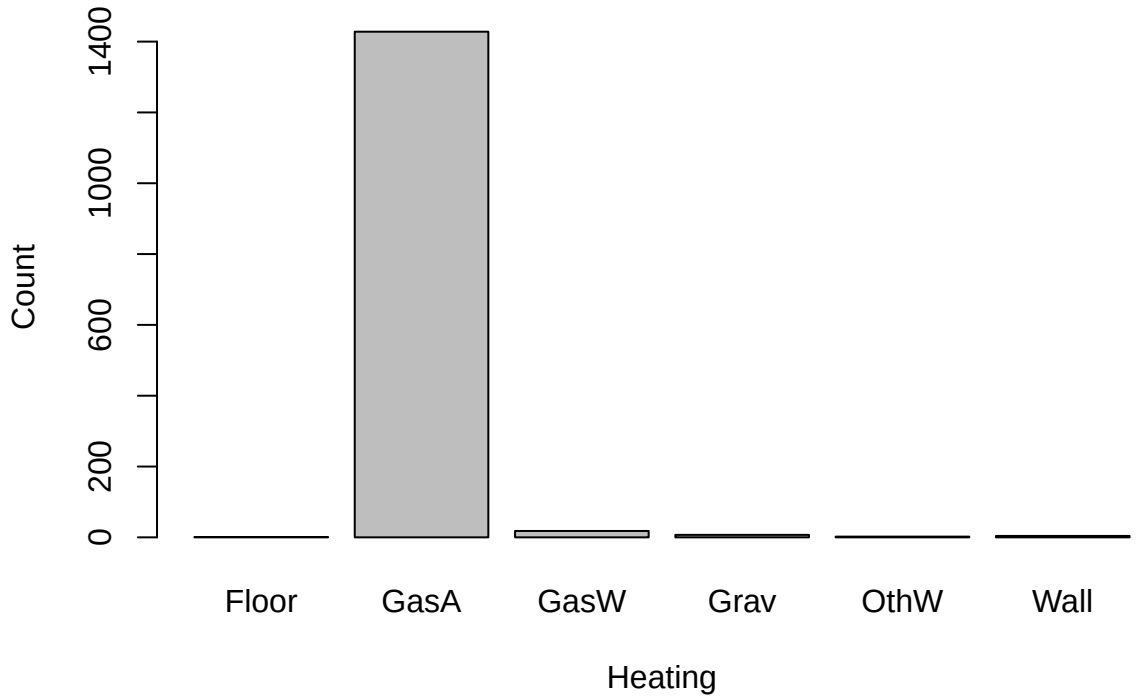
```
table(combined$Heating)
```

```
##
## Floor  GasA  GasW  Grav  OthW  Wall
##     1  1428    18     7     2     4
```

```
combined$Heating <- as.factor(combined$Heating)
table(combined$Heating)
```

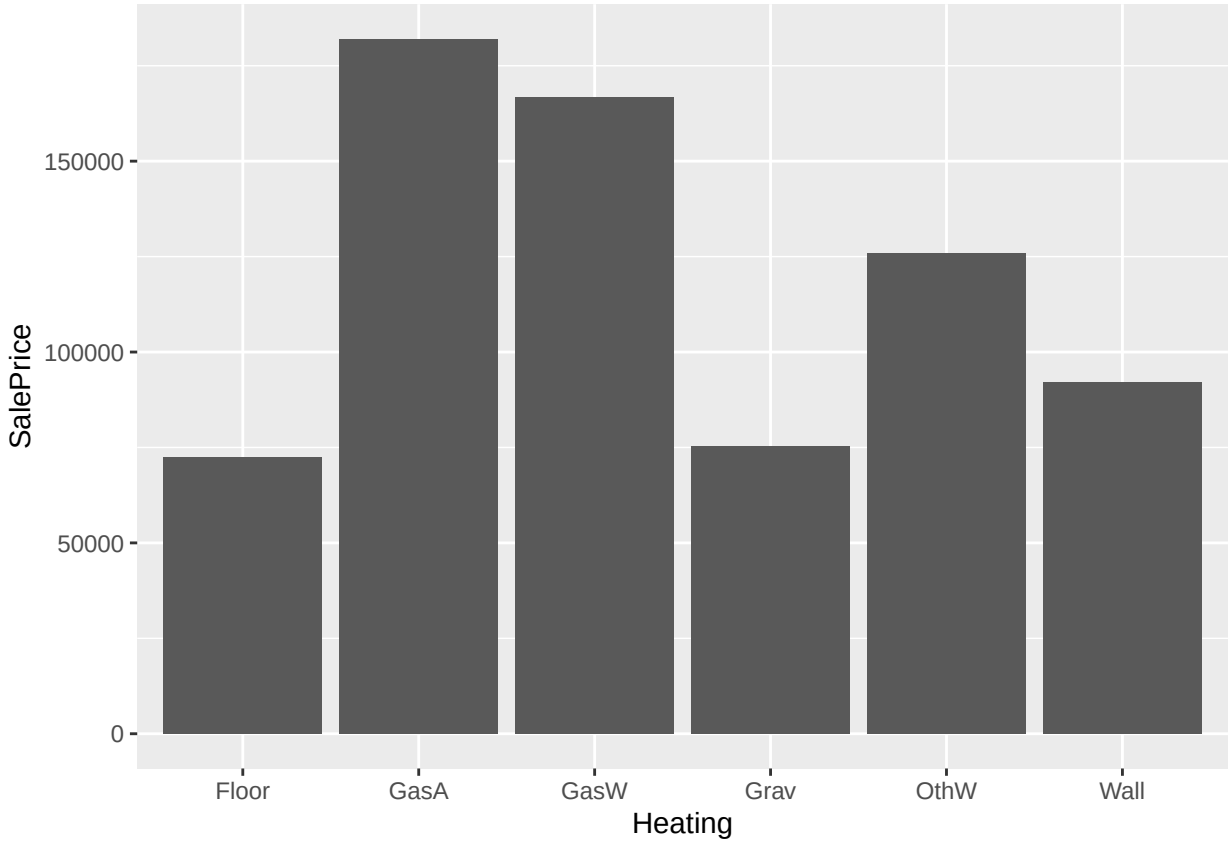
```
##
## Floor  GasA  GasW  Grav  OthW  Wall
##     1  1428    18     7     2     4
```

```
barplot(table(combined$Heating), xlab = "Heating", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=Heating, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```




```
table(combined$HeatingQC)
```

```
##
##  Ex  Fa  Gd  Po  TA
## 741  49 241   1 428
```

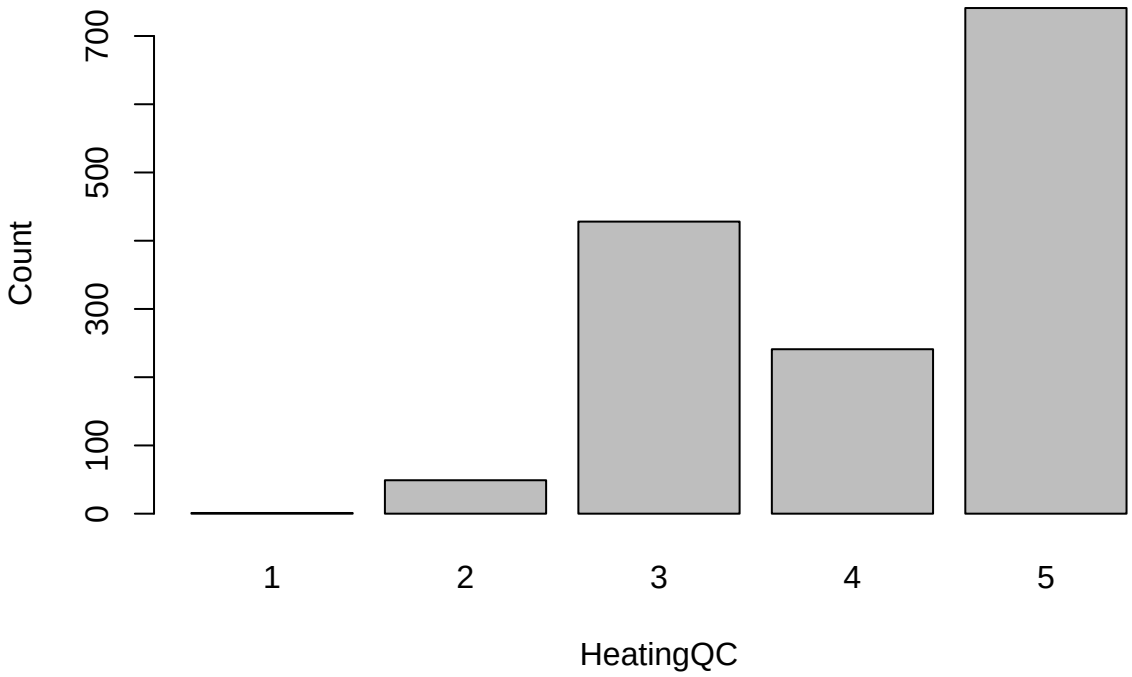
```
combined$HeatingQC<-as.integer(revalue(combined$HeatingQC, quality))
```

```
## The following `from` values were not present in `x`: None
```

```
table(combined$HeatingQC)
```

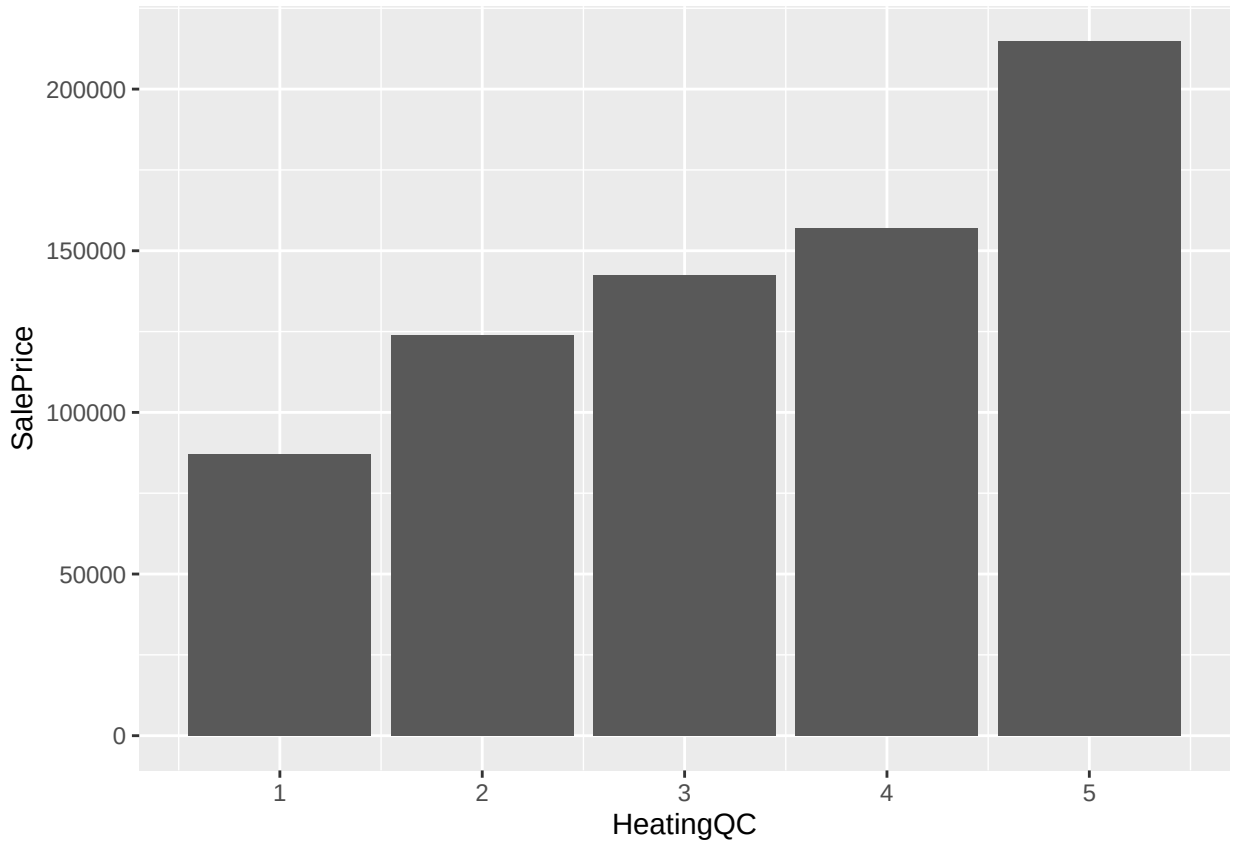
```
##
##   1   2   3   4   5
##   1  49 428 241 741
```

```
barplot(table(combined$HeatingQC), xlab = "HeatingQC", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=HeatingQC, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



CentralAir

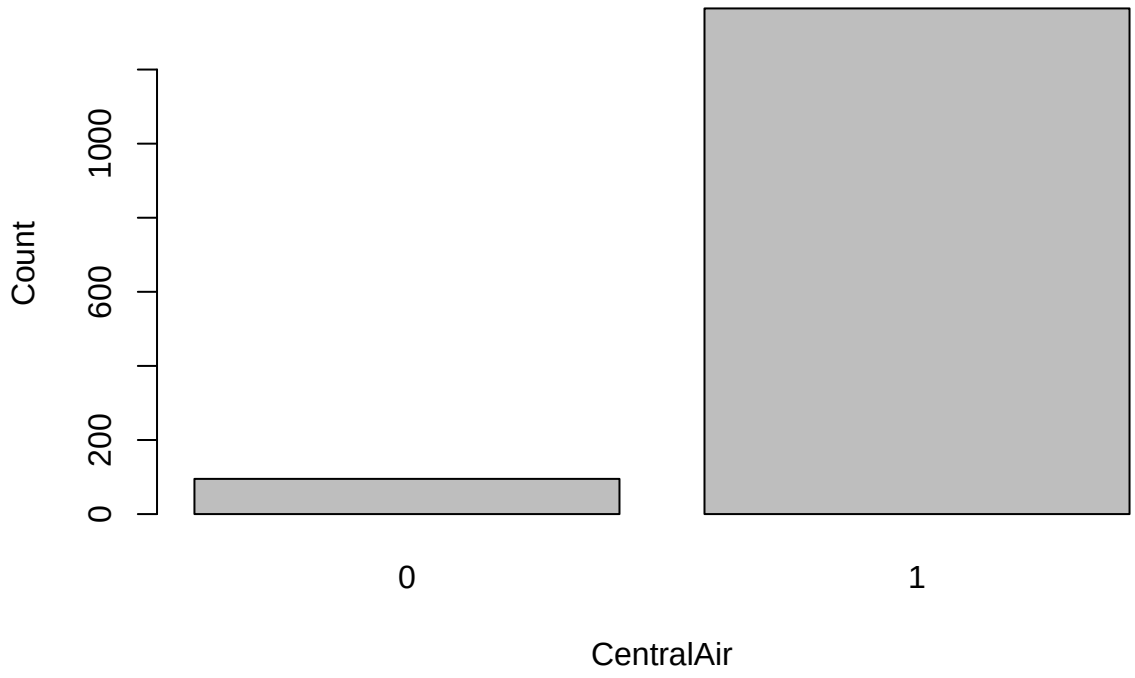
```
table(combined$CentralAir)
```

```
##
##    N    Y
##   95 1365
```

```
combined$CentralAir<-as.integer(revalue(combined$CentralAir, c('N'=0, 'Y'=1)))
table(combined$CentralAir)
```

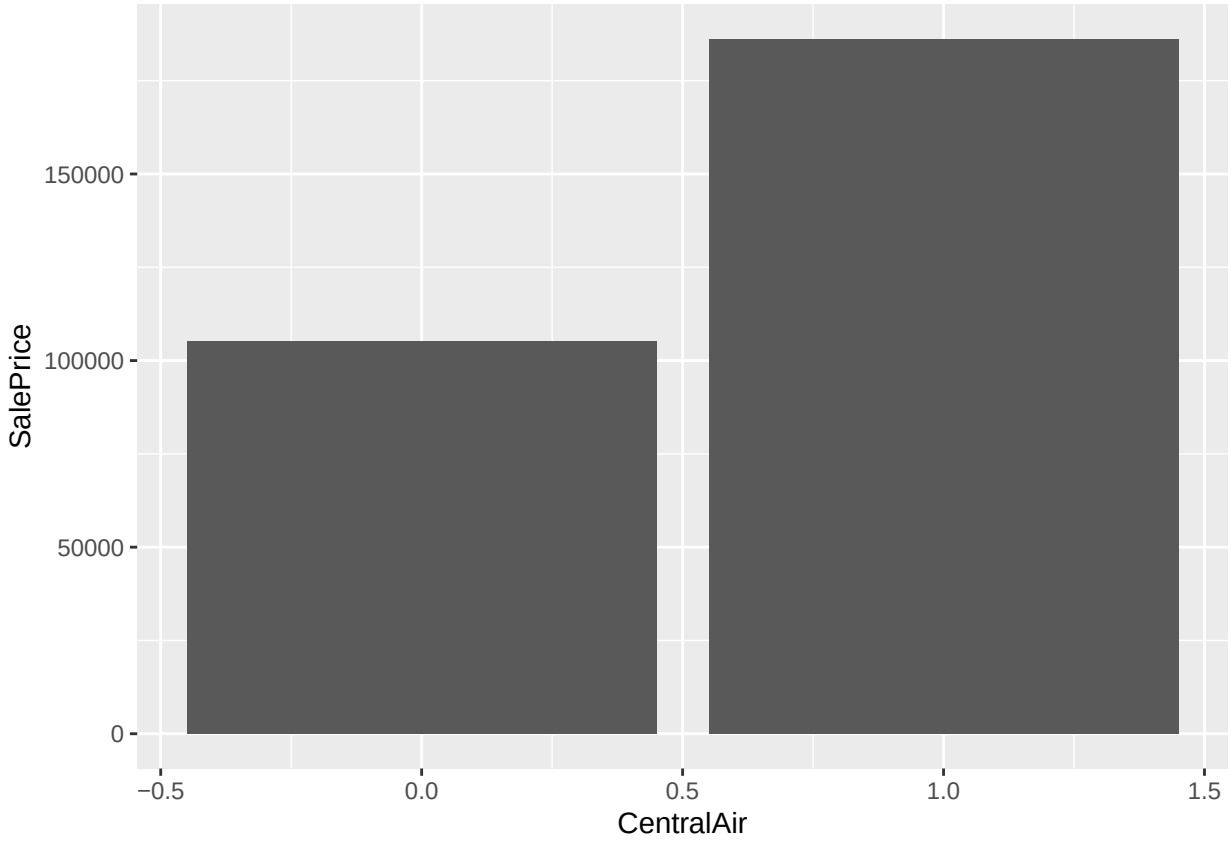
```
##
##    0    1
##   95 1365
```

```
barplot(table(combined$CentralAir), xlab = "CentralAir", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=CentralAir, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



KitchenQual

```
table(combined$KitchenQual)
```

```
##
##  Ex  Fa  Gd  TA
## 100  39 586 735
```

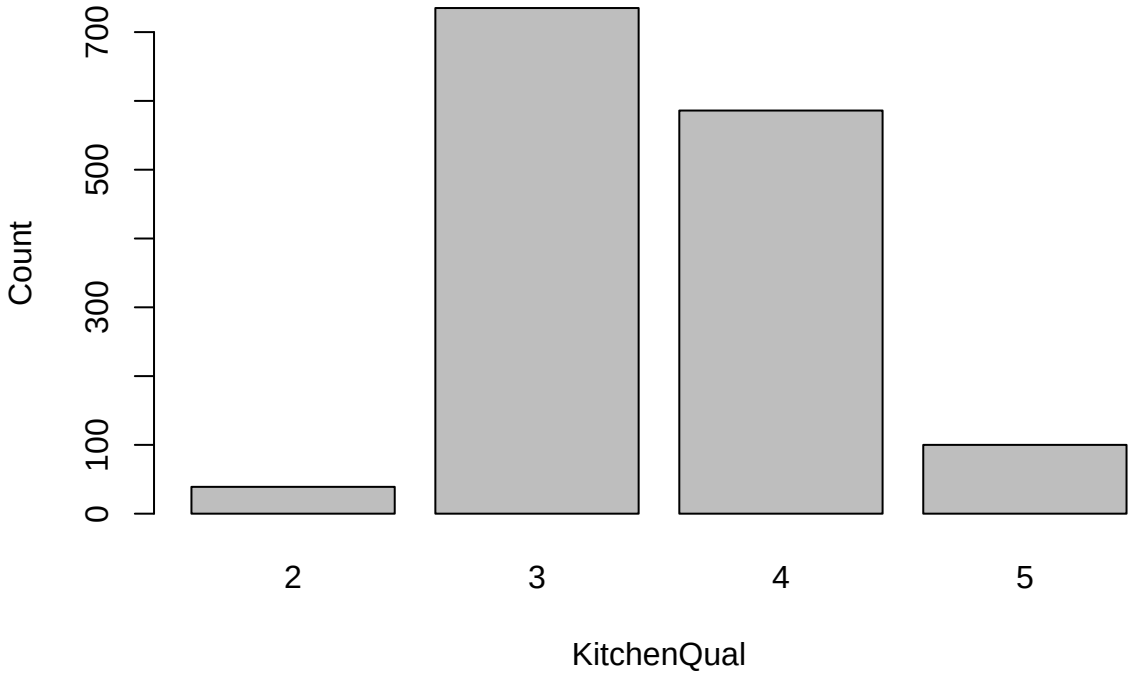
```
combined$KitchenQual<-as.integer(revalue(combined$KitchenQual, quality))
```

```
## The following 'from' values were not present in 'x': None, Po
```

```
table(combined$KitchenQual)
```

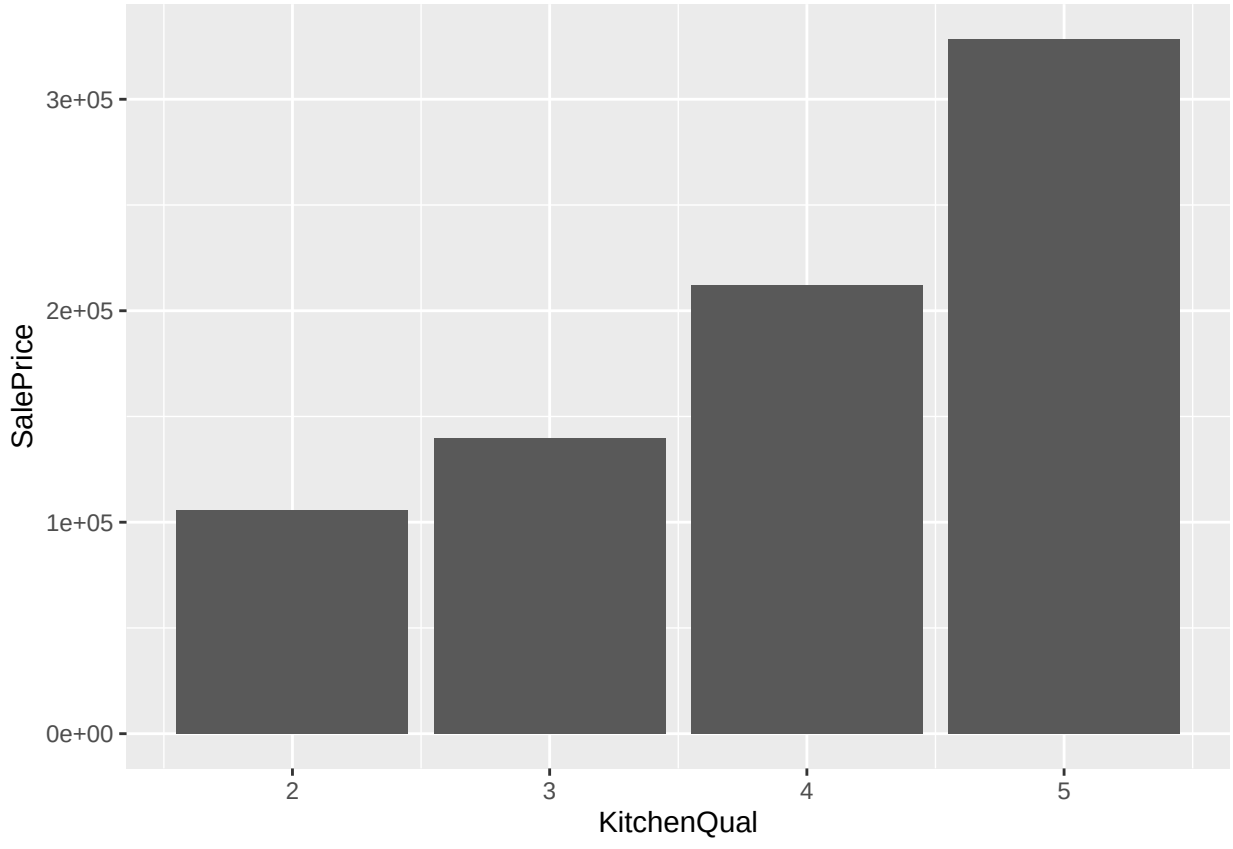
```
##
##   2   3   4   5
##  39 735 586 100
```

```
barplot(table(combined$KitchenQual), xlab = "KitchenQual", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=KitchenQual, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Functional

```
table(combined$Functional)
```

```
##
## Maj1 Maj2 Min1 Min2  Mod  Sev  Typ
##   14    5   31   34   15    1 1360
```

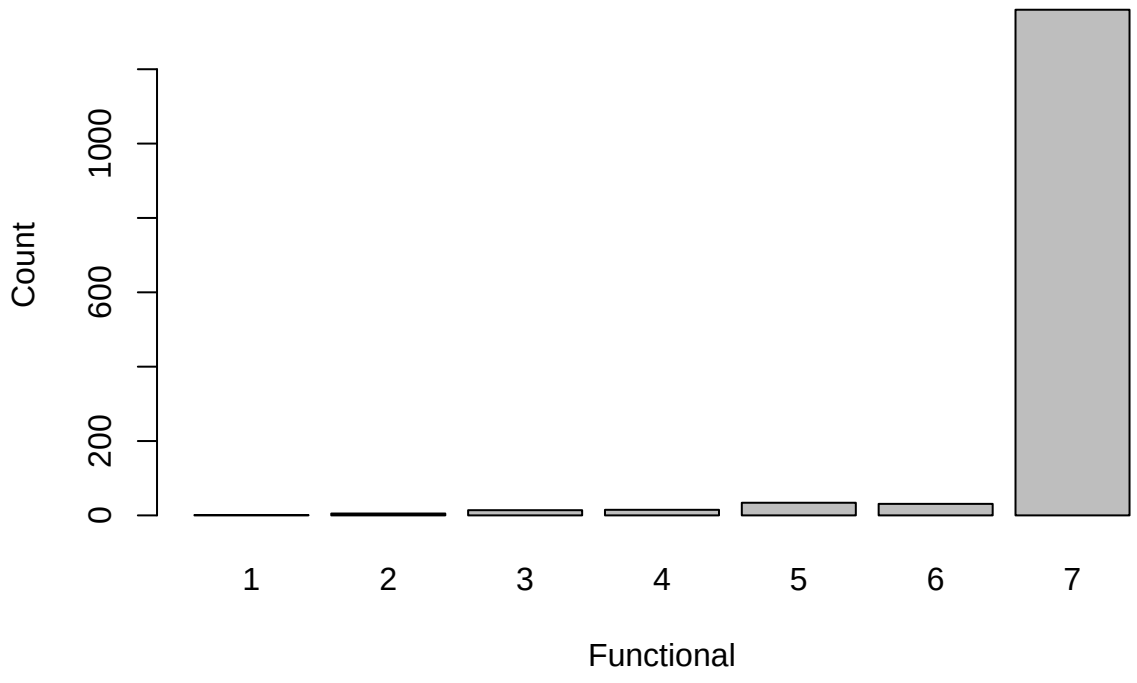
```
combined$Functional<-as.integer(revalue(combined$Functional, c('Sal'=0, 'Sev'=1, 'Maj2'=2, 'Maj1'=3, 'Mod'=4, 'M
```

```
## The following 'from' values were not present in 'x': Sal
```

```
table(combined$Functional)
```

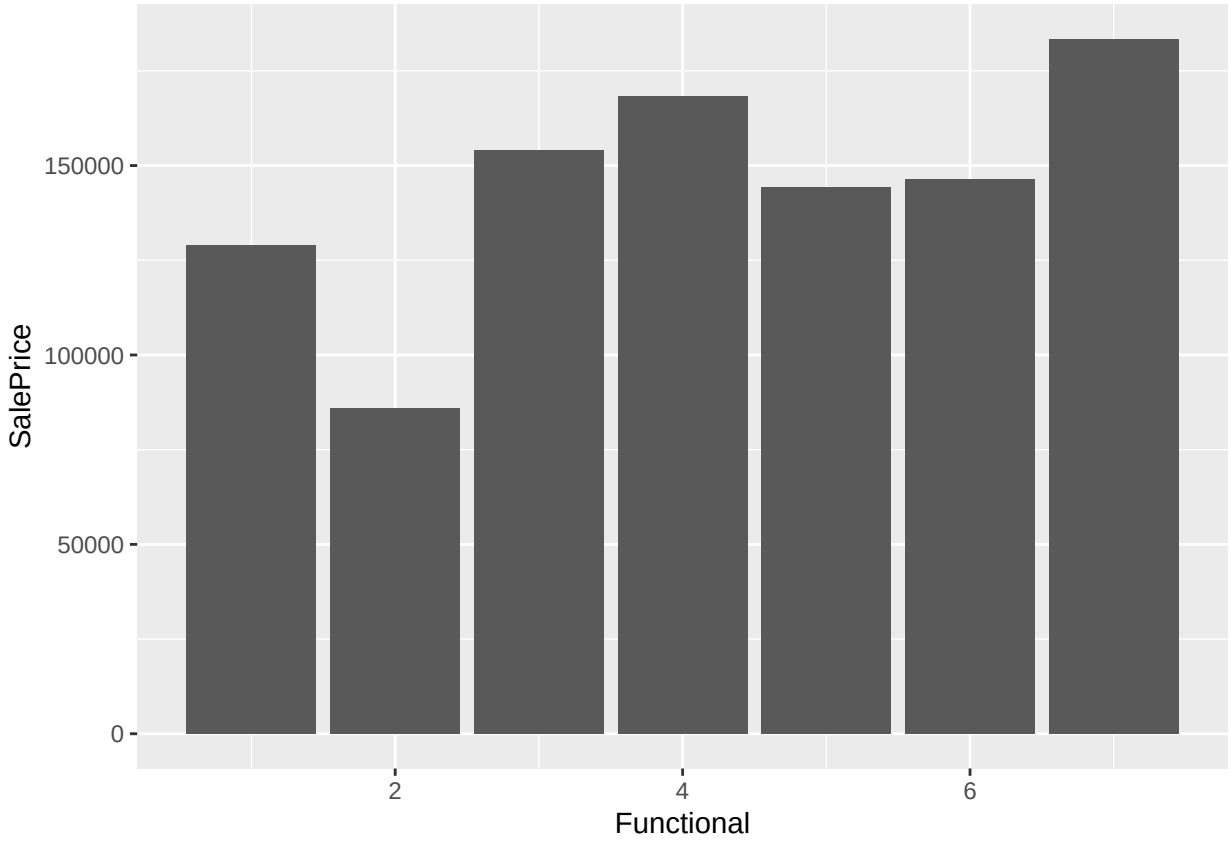
```
##
##    1    2    3    4    5    6    7
##    1    5   14   15   34   31 1360
```

```
barplot(table(combined$Functional), xlab = "Functional", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=Functional, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to 'mean_se()'
```



PavedDrive

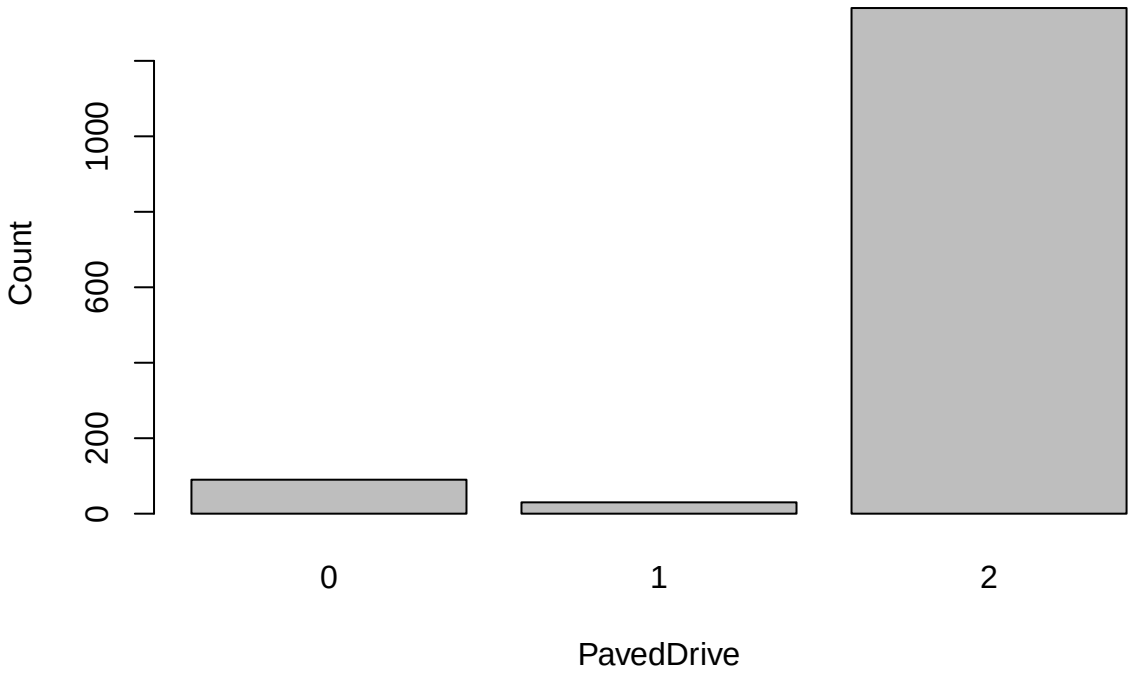
```
table(combined$PavedDrive)
```

```
##
##    N    P    Y
##   90   30 1340
```

```
combined$PavedDrive<-as.integer(revalue(combined$PavedDrive, c('N'=0, 'P'=1, 'Y'=2)))
table(combined$PavedDrive)
```

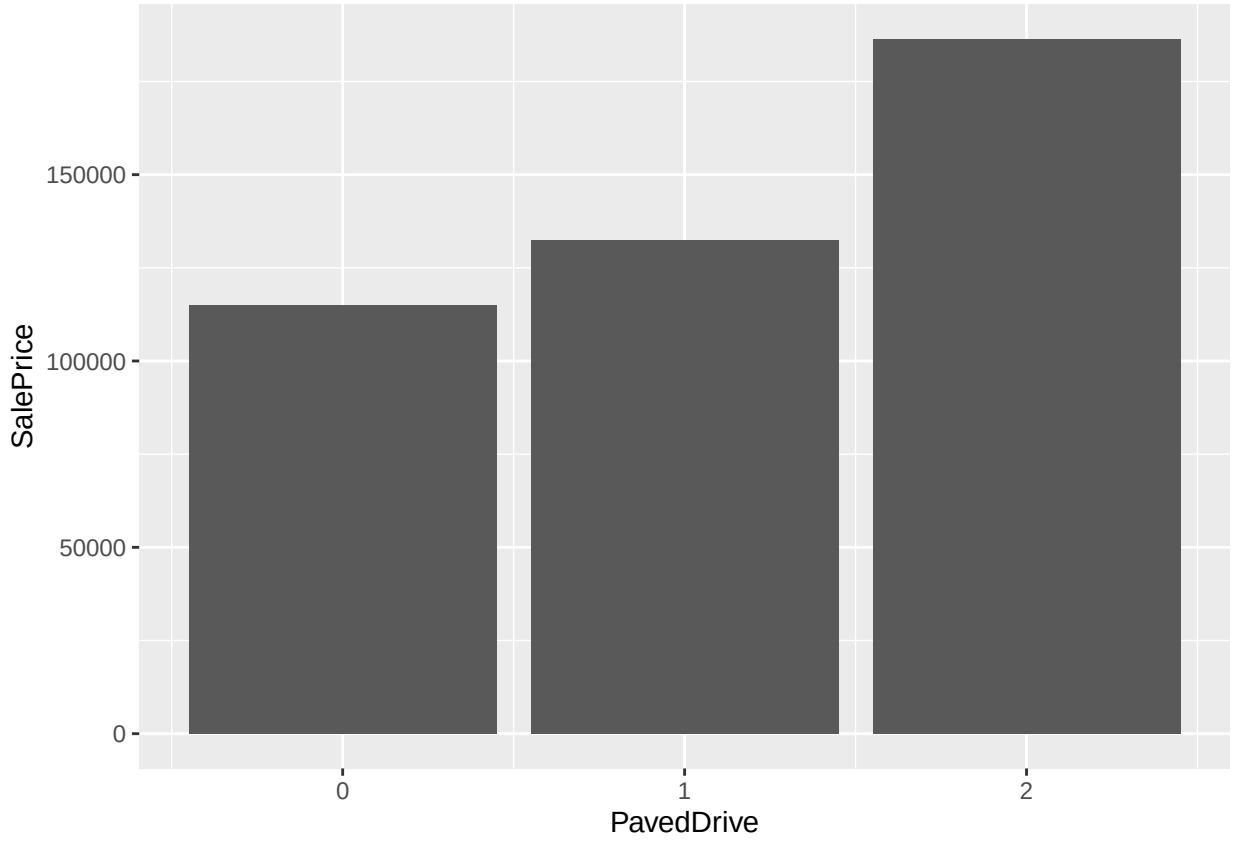
```
##
##    0    1    2
##   90   30 1340
```

```
barplot(table(combined$PavedDrive), xlab = "PavedDrive", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=PavedDrive, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Sales variables

"SaleType" "SaleCondition"

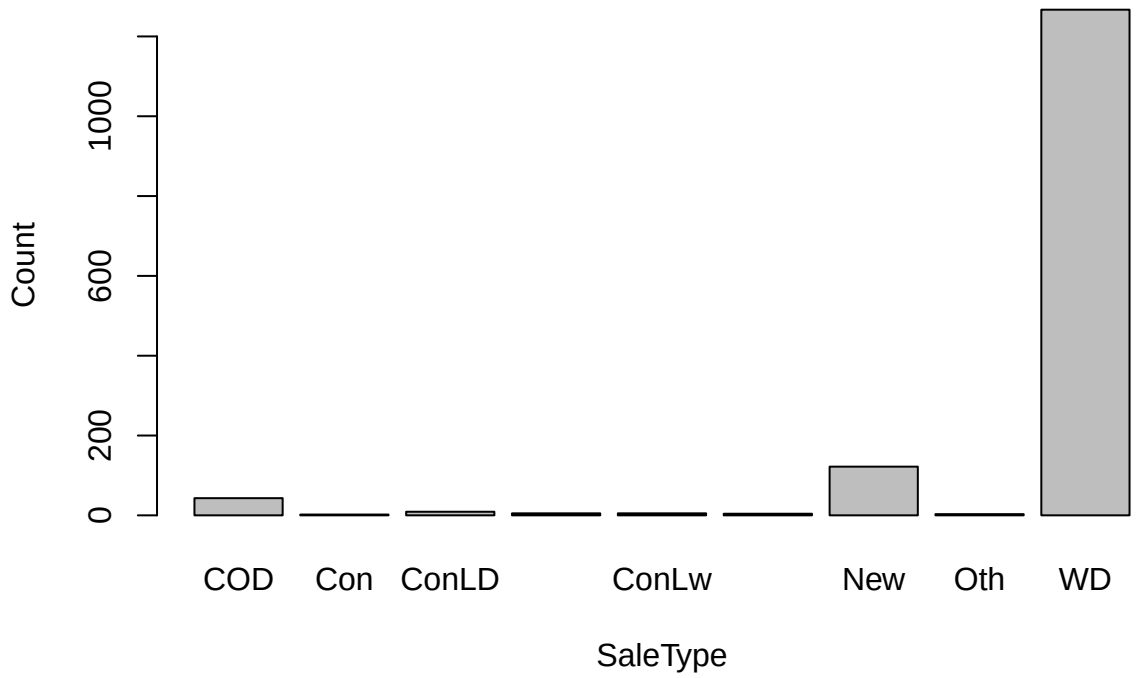
```
table(combined$SaleType)
```

```
##
##   COD   Con ConLD ConLI ConLw   CWD   New   Oth    WD
##    43     2     9     5     5     4   122     3  1267
```

```
combined$SaleType <- as.factor(combined$SaleType)
table(combined$SaleType)
```

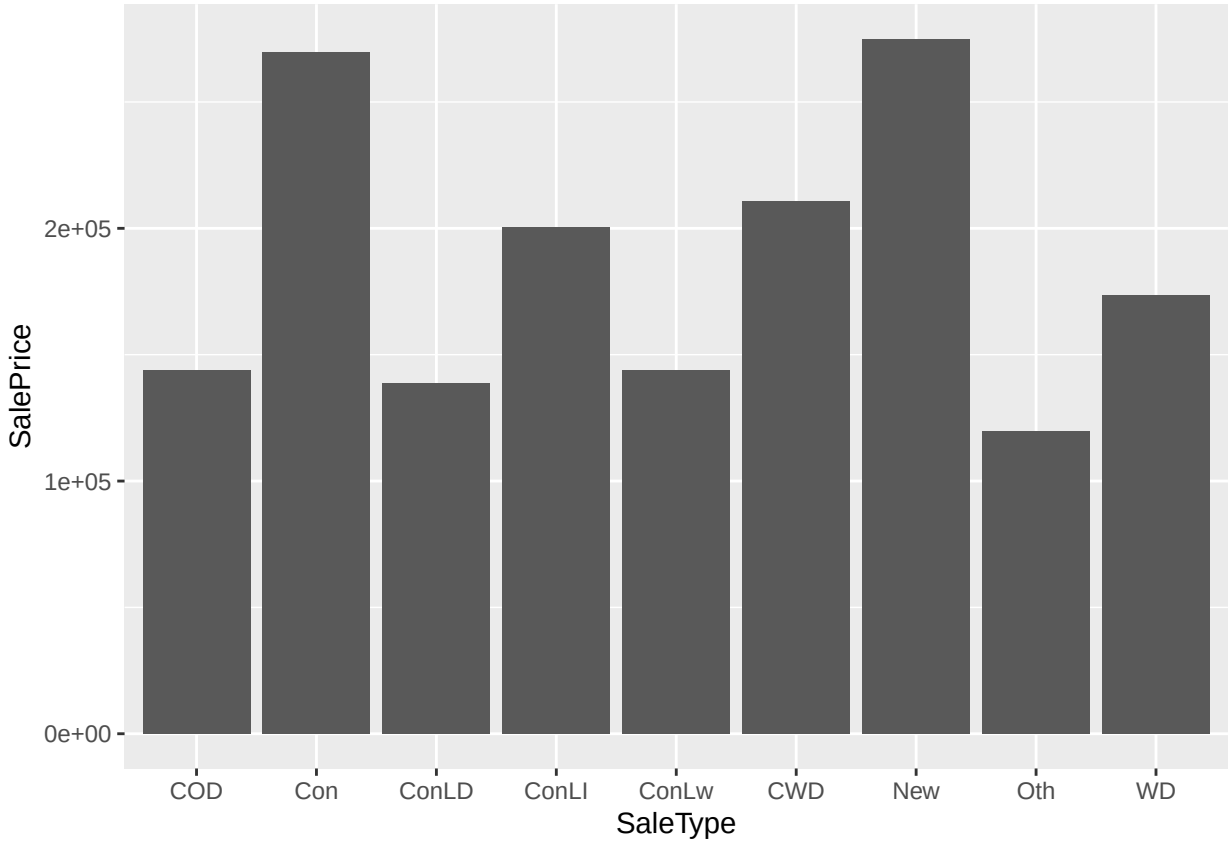
```
##
##   COD   Con ConLD ConLI ConLw   CWD   New   Oth    WD
##    43     2     9     5     5     4   122     3  1267
```

```
barplot(table(combined$SaleType), xlab = "SaleType", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=SaleType, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



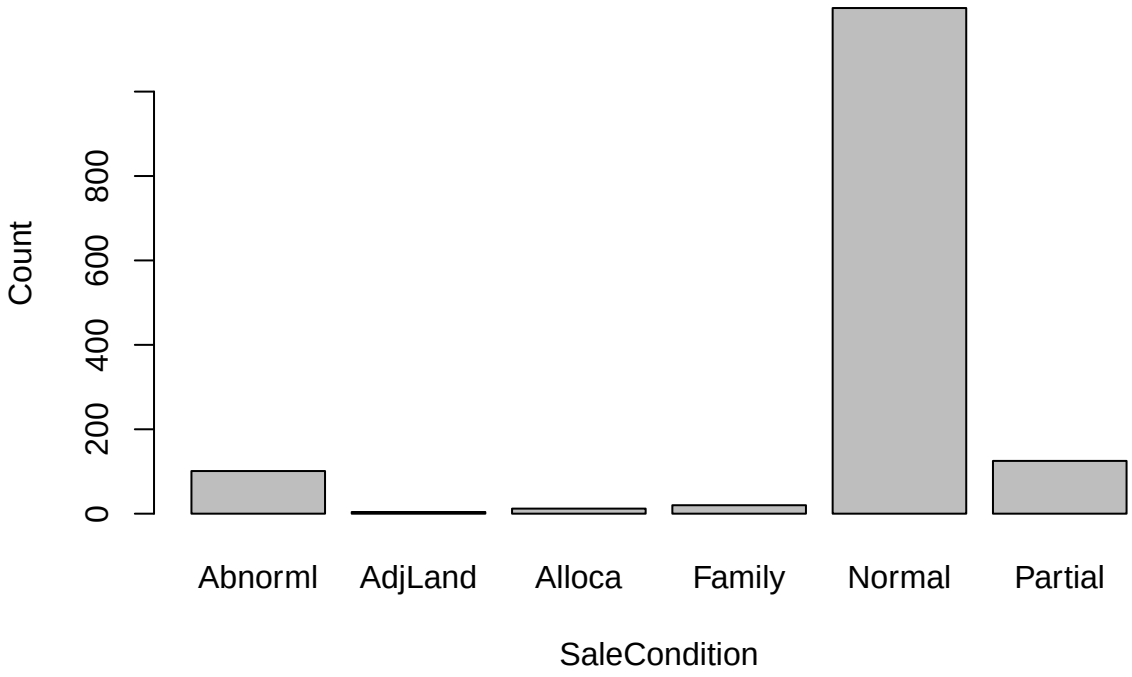

```
table(combined$SaleCondition)
```

```
##
## Abnorml AdjLand  Alloca  Family  Normal Partial
##     101       4      12      20    1198     125
```

```
combined$SaleCondition <- as.factor(combined$SaleCondition)
table(combined$SaleCondition)
```

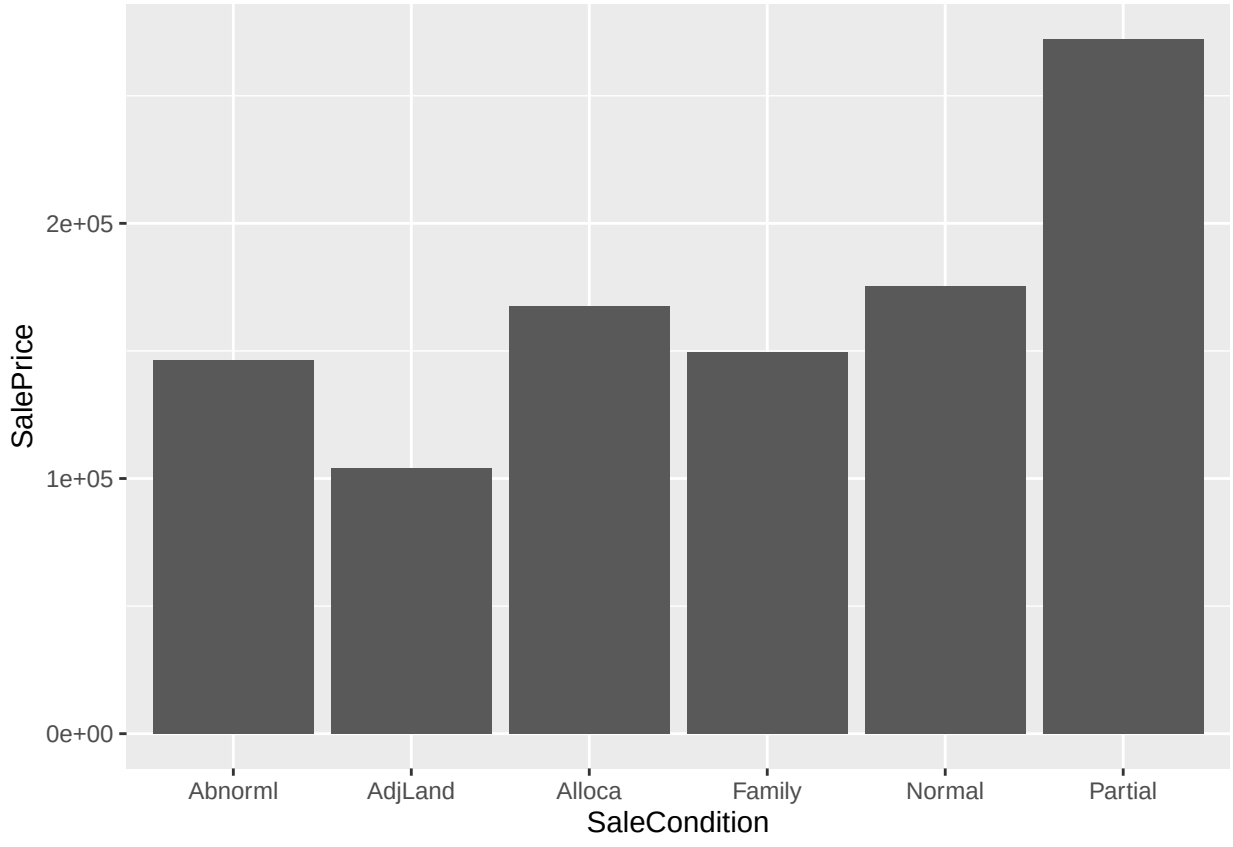
```
##
## Abnorml AdjLand  Alloca  Family  Normal Partial
##     101       4      12      20    1198     125
```

```
barplot(table(combined$SaleCondition), xlab = "SaleCondition", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=SaleCondition, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Remaining character variables

```
Charcol <- names(combined[,sapply(combined, is.character)])
Charcol
```

```
## character(0)
```

MSSubClass

20 1-STORY 1946 & NEWER ALL STYLES
30 1-STORY 1945 & OLDER
40 1-STORY W/FINISHED ATTIC ALL AGES
45 1-1/2 STORY - UNFINISHED ALL AGES
50 1-1/2 STORY FINISHED ALL AGES
60 2-STORY 1946 & NEWER
70 2-STORY 1945 & OLDER
75 2-1/2 STORY ALL AGES
80 SPLIT OR MULTI-LEVEL
85 SPLIT FOYER
90 DUPLEX - ALL STYLES AND AGES

120 1-STORY PUD (Planned Unit Development) - 1946 & NEWER 150 1-1/2 STORY PUD - ALL AGES 160 2-STORY PUD - 1946 & NEWER 180 PUD - MULTILEVEL - INCL SPLIT LEV/FOYER 190 2 FAMILY CONVERSION - ALL STYLES AND AGES

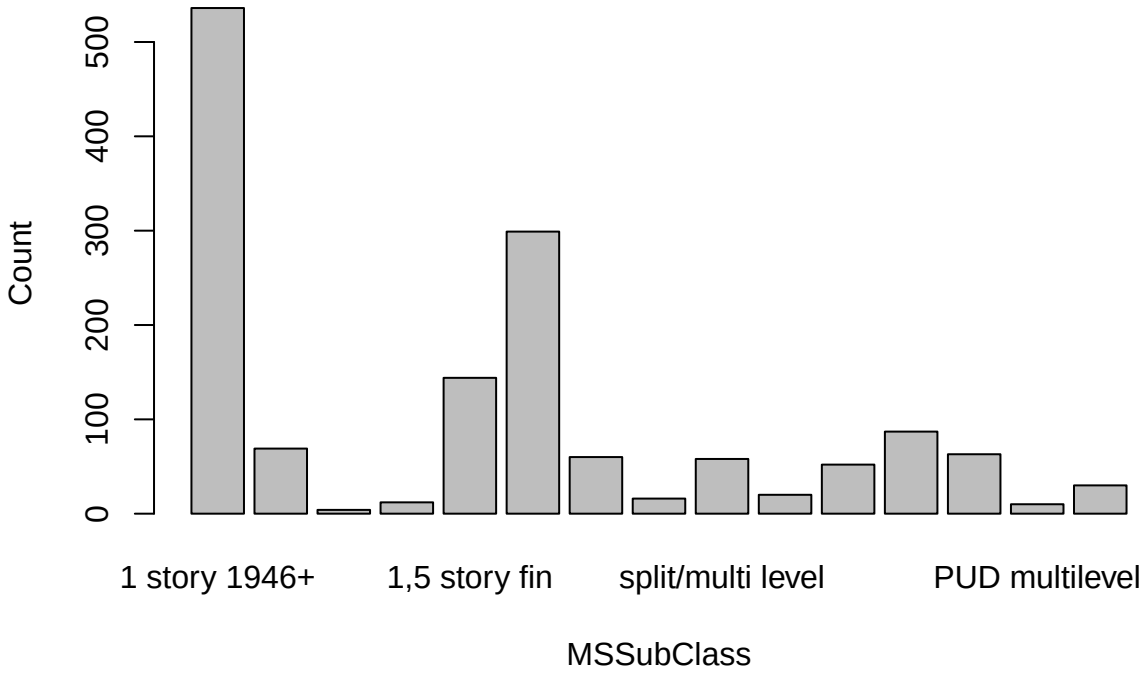
```
table(combined$MSSubClass)
```

```
##
##  20  30  40  45  50  60  70  75  80  85  90 120 160 180 190
## 536  69   4  12 144 299  60  16  58  20  52  87  63  10  30
```

```
combined$MSSubClass <- as.factor(combined$MSSubClass)

#revalue for better readability
combined$MSSubClass<-revalue(combined$MSSubClass, c('20'='1 story 1946+', '30'='1 story 1945-', '40'='1 story ur
```

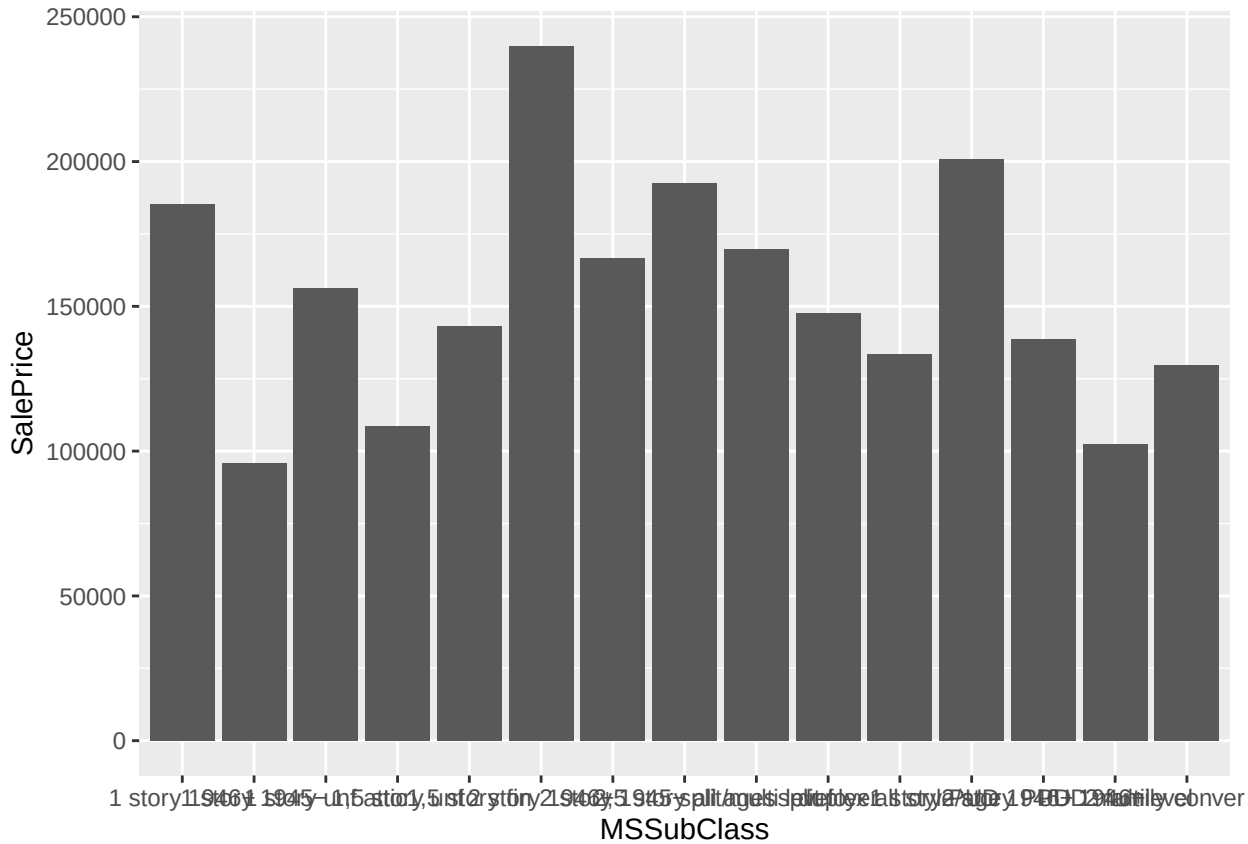
```
## The following `from` values were not present in `x`: 150
```

```
barplot(table(combined$MSSubClass), xlab = "MSSubClass", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=MSSubClass, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



MoSold

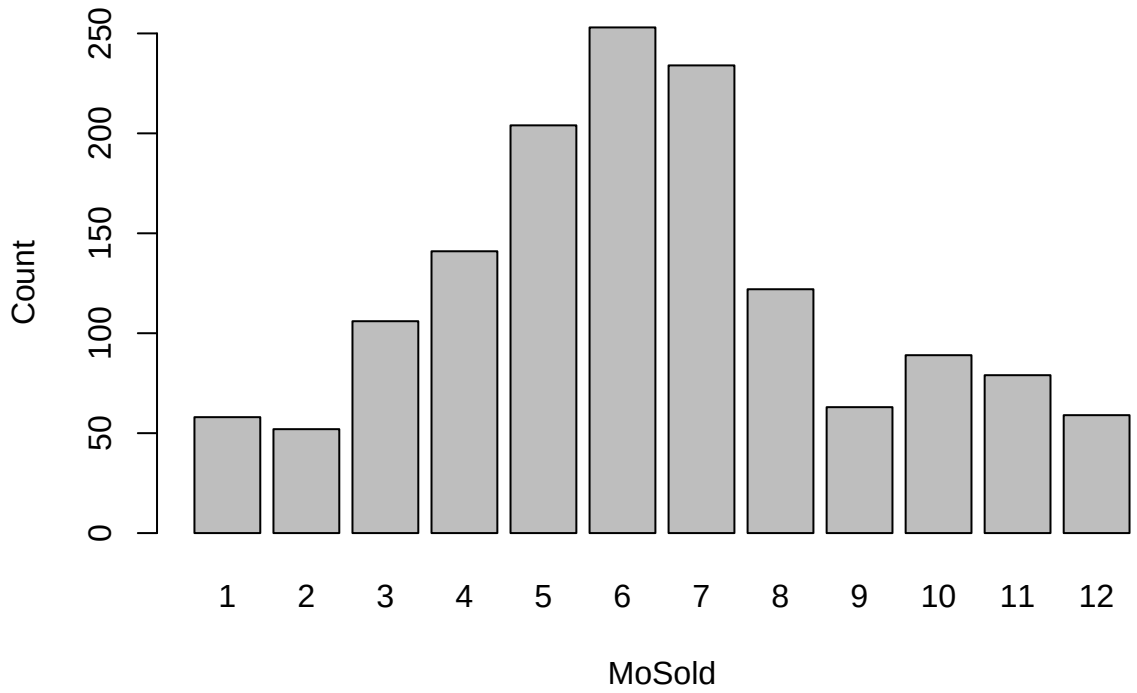
```
table(combined$MoSold)
```

```
##
##   1   2   3   4   5   6   7   8   9  10  11  12
##  58  52 106 141 204 253 234 122  63  89  79  59
```

```
combined$MoSold <- as.factor(combined$MoSold)
table(combined$MoSold)
```

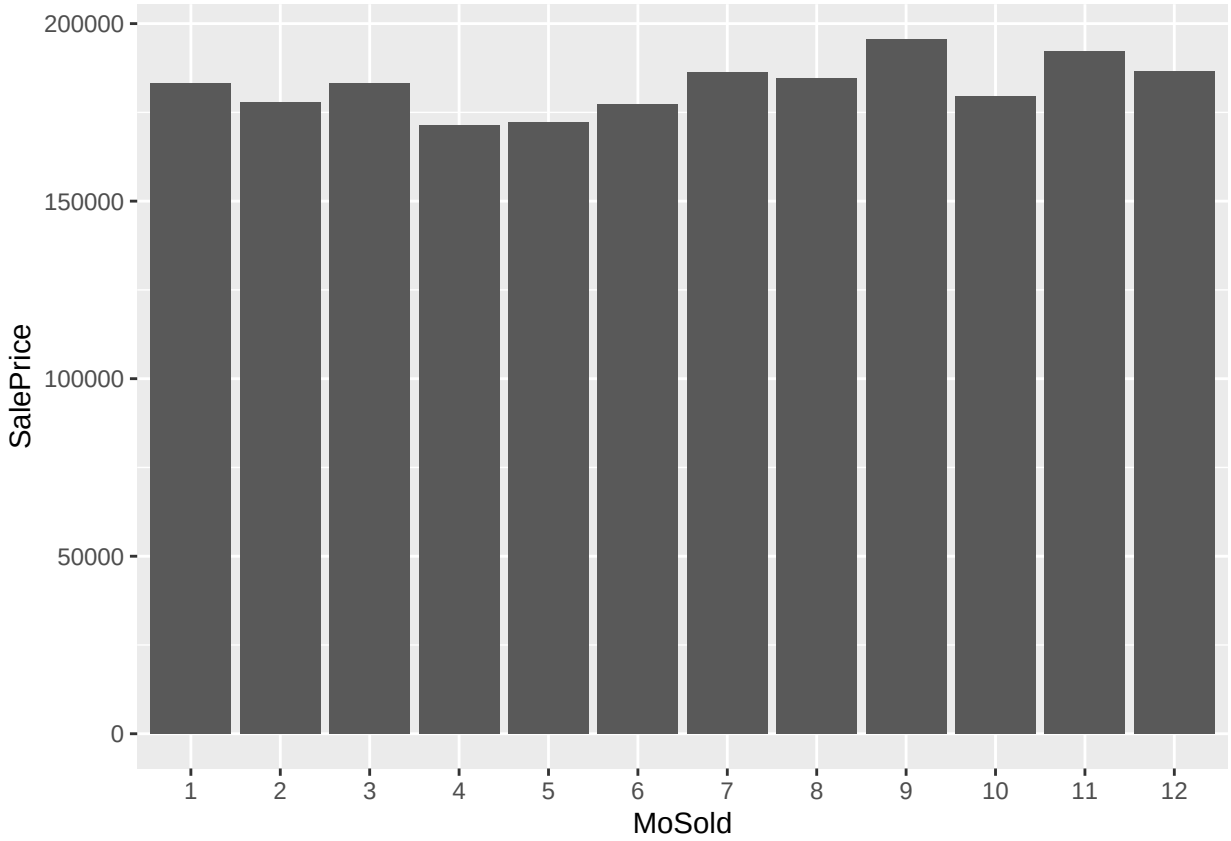
```
##
##   1   2   3   4   5   6   7   8   9  10  11  12
##  58  52 106 141 204 253 234 122  63  89  79  59
```

```
barplot(table(combined$MoSold), xlab = "MoSold", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=MoSold, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



YrSold

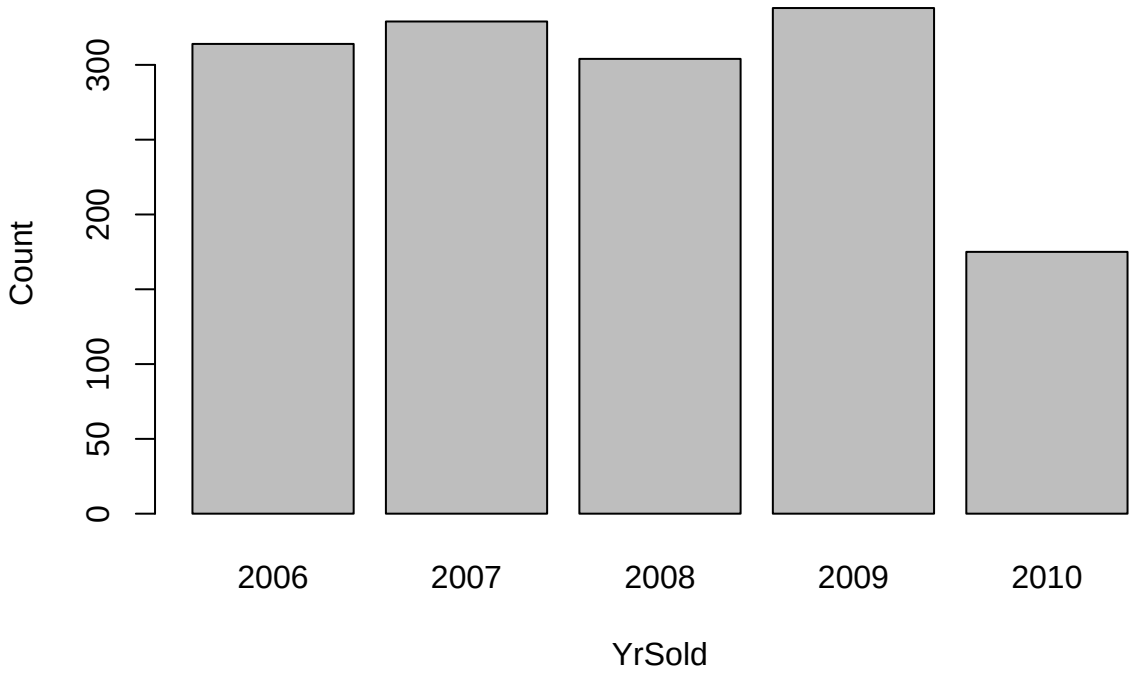
```
table(combined$YrSold)
```

```
##
## 2006 2007 2008 2009 2010
##  314  329  304  338  175
```

```
combined$YrSold <- as.factor(combined$YrSold)
table(combined$YrSold)
```

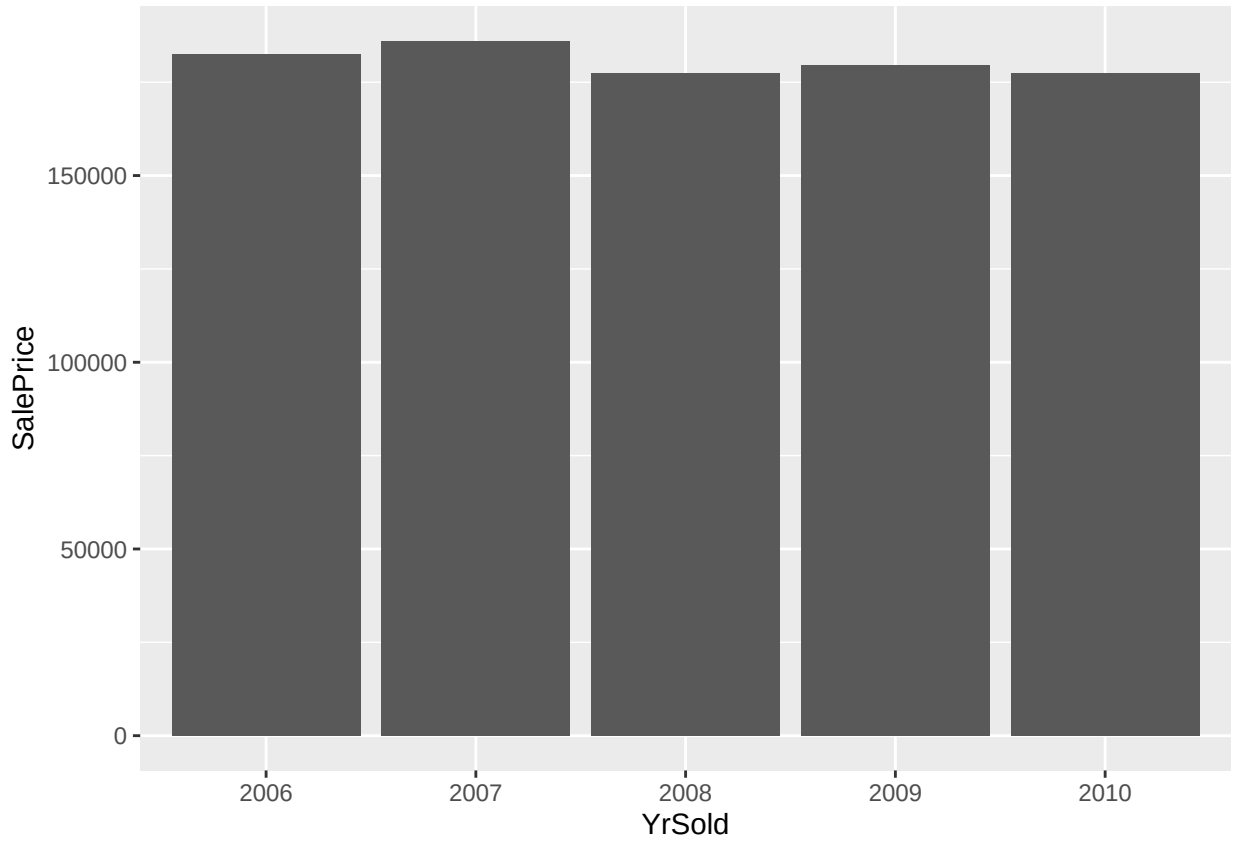
```
##
## 2006 2007 2008 2009 2010
##  314  329  304  338  175
```

```
barplot(table(combined$YrSold), xlab = "YrSold", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=YrSold, y = SalePrice)) + geom_bar(stat = 'summary')
```

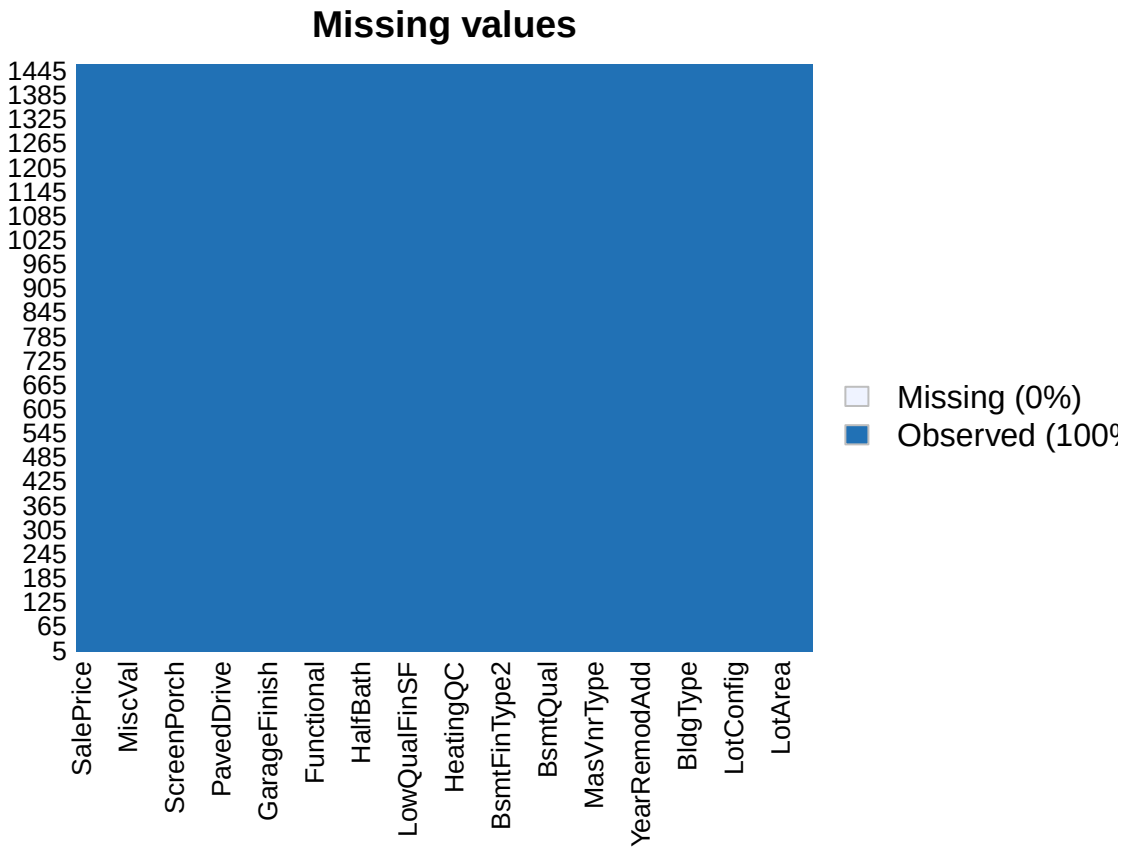
```
## No summary function supplied, defaulting to `mean_se()`
```



```
sort(colSums(sapply(combined, is.na)), decreasing = T)
```

```
##    MSSubClass      MSZoning   LotFrontage       LotArea        Street
##             0             0             0             0             0
##         Alley      LotShape   LandContour     LotConfig     LandSlope
##             0             0             0             0             0
##  Neighborhood    Condition1    Condition2      BldgType    HouseStyle
##             0             0             0             0             0
##   OverallQual   OverallCond     YearBuilt  YearRemodAdd     RoofStyle
##             0             0             0             0             0
##      RoofMatl   Exterior1st   Exterior2nd    MasVnrType    MasVnrArea
##             0             0             0             0             0
##     ExterQual     ExterCond    Foundation      BsmtQual      BsmtCond
##             0             0             0             0             0
##  BsmtExposure  BsmtFinType1    BsmtFinSF1  BsmtFinType2    BsmtFinSF2
##             0             0             0             0             0
##     BsmtUnfSF   TotalBsmtSF       Heating     HeatingQC    CentralAir
##             0             0             0             0             0
##    Electrical     X1stFlrSF     X2ndFlrSF  LowQualFinSF     GrLivArea
##             0             0             0             0             0
##  BsmtFullBath  BsmtHalfBath      FullBath      HalfBath  BedroomAbvGr
##             0             0             0             0             0
##  KitchenAbvGr   KitchenQual  TotRmsAbvGrd    Functional    Fireplaces
##             0             0             0             0             0
##   FireplaceQu    GarageType   GarageYrBlt  GarageFinish    GarageCars
##             0             0             0             0             0
##    GarageArea    GarageQual    GarageCond    PavedDrive    WoodDeckSF
##             0             0             0             0             0
##   OpenPorchSF EnclosedPorch    X3SsnPorch   ScreenPorch      PoolArea
##             0             0             0             0             0
##        PoolQC         Fence   MiscFeature       MiscVal        MoSold
##             0             0             0             0             0
##        YrSold      SaleType SaleCondition     SalePrice
##             0             0             0             0
```

```
misscounts <- sapply(combined,function(x) sum(is.na(x)))
missmap(combined, main = "Missing values")
```




```
anyNA(combined)
```

```
## [1] FALSE
```

As we can see there are no missing values.

```
num_vars <- names(Filter(is.numeric,combined)) #index vector numeric variables
factor_vars <- names(Filter(is.factor,combined))
cat('numeric variables: ', length(num_vars),' and categorical variables: ',length(factor_vars),'\n')
```

```
## numeric variables:  54  and categorical variables:  25
```

```
write.csv(combined, "../data/processed/clean_data.csv")
```

EDA

Summarize Datasets

```
# primary dataset
str(combined)
```

```
## 'data.frame':    1460 obs. of  79 variables:
##  $ MSSubClass   : Factor w/ 15 levels "1 story 1946+",..: 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 75 51 50 ...
##  $ LotArea      : int  8450 9600 11250 9550 14260 14115 10084 10382 6120 7420 ...
##  $ Street       : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ Alley        : Factor w/ 3 levels "Grvl","None",..: 2 2 2 2 2 2 2 2 2 2 ...
```

```
##  $ LotShape     : int  3 3 2 2 2 2 3 2 3 3 ...
##  $ LandContour  : Factor w/ 4 levels "Bnk","HLS","Low",..: 4 4 4 4 4 4 4 4 4 4 ...
##  $ LotConfig    : Factor w/ 5 levels "Corner","CulDSac",..: 5 3 5 1 3 5 5 1 5 1 ...
##  $ LandSlope    : int  2 2 2 2 2 2 2 2 2 2 ...
##  $ Neighborhood : Factor w/ 25 levels "Blmngtn","Blueste",..: 6 25 6 7 14 12 21 17 18 4 ...
##  $ Condition1   : Factor w/ 9 levels "Artery","Feedr",..: 3 2 3 3 3 3 3 5 1 1 ...
##  $ Condition2   : Factor w/ 8 levels "Artery","Feedr",..: 3 3 3 3 3 3 3 3 3 1 ...
##  $ 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  : 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    : 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 ...
##  $ Exterior2nd  : Factor w/ 16 levels "AsbShng","AsphShn",..: 14 9 14 16 14 14 14 7 16 9 ...
##  $ MasVnrType   : Factor w/ 4 levels "BrkCmn","BrkFace",..: 2 3 2 3 2 3 4 4 3 3 ...
##  $ MasVnrArea   : num  196 0 162 0 350 0 186 240 0 0 ...
##  $ ExterQual    : int  4 3 4 3 4 3 4 3 3 3 ...
##  $ ExterCond    : int  3 3 3 3 3 3 3 3 3 3 ...
##  $ Foundation   : Factor w/ 6 levels "BrkTil","CBlock",..: 3 2 3 1 3 6 3 2 1 1 ...
##  $ BsmtQual     : int  4 4 4 3 4 4 5 4 3 3 ...
##  $ BsmtCond     : int  3 3 3 4 3 3 3 3 3 3 ...
##  $ BsmtExposure : int  1 4 2 1 3 1 3 2 1 1 ...
##  $ BsmtFinType1 : int  6 5 6 5 6 6 6 5 1 6 ...
##  $ BsmtFinSF1   : int  706 978 486 216 655 732 1369 859 0 851 ...
##  $ BsmtFinType2 : int  1 1 1 1 1 1 1 4 1 1 ...
##  $ 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      : Factor w/ 6 levels "Floor","GasA",..: 2 2 2 2 2 2 2 2 2 2 ...
##  $ HeatingQC    : int  5 5 5 4 5 5 5 5 4 5 ...
##  $ CentralAir   : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ Electrical   : Factor w/ 5 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 : num  1 0 1 1 1 1 1 1 0 1 ...
##  $ BsmtHalfBath : num  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  : int  4 3 4 4 4 3 4 3 3 3 ...
##  $ TotRmsAbvGrd : int  8 6 6 7 9 5 7 7 8 5 ...
##  $ Functional   : int  7 7 7 7 7 7 7 7 6 7 ...
##  $ Fireplaces   : int  0 1 1 1 1 0 1 2 2 2 ...
##  $ FireplaceQu  : int  0 3 3 4 3 0 4 3 3 3 ...
##  $ GarageType   : Factor w/ 7 levels "2Types","Attchd",..: 2 2 2 6 2 2 2 2 6 2 ...
##  $ GarageYrBlt  : int  2003 1976 2001 1998 2000 1993 2004 1973 1931 1939 ...
##  $ GarageFinish : int  2 2 2 1 2 1 2 2 1 2 ...
##  $ 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   : int  3 3 3 3 3 3 3 3 2 4 ...
##  $ GarageCond   : int  3 3 3 3 3 3 3 3 3 3 ...
##  $ PavedDrive   : int  2 2 2 2 2 2 2 2 2 2 ...
##  $ 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       : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ 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       : Factor w/ 12 levels "1","2","3","4",..: 2 5 9 2 12 10 8 11 4 1 ...
##  $ YrSold       : Factor w/ 5 levels "2006","2007",..: 3 2 3 1 3 4 2 4 3 3 ...
##  $ SaleType     : Factor w/ 9 levels "COD","Con","ConLD",..: 9 9 9 9 9 9 9 9 9 9 ...
##  $ SaleCondition: Factor w/ 6 levels "Abnorml","AdjLand",..: 5 5 5 1 5 5 5 5 1 5 ...
##  $ SalePrice    : int  208500 181500 223500 140000 250000 143000 307000 200000 129900 118000 ...
```

Numerical variables

SalePrice variable

```
library(ggplot2)
layout(mat = matrix(c(1,2),2,1, byrow=TRUE), height = c(1,8))
par(mar=c(0, 3.1, 1.1, 2.1))
boxplot(combined$SalePrice , horizontal=TRUE , xaxt="n", frame=F, main=sprintf('Histogram of SalePrice'))
par(mar=c(4, 3.1, 1.1, 2.1))
hist(combined$SalePrice,main='', xlab = "SalePrice", ylab = "count")
```

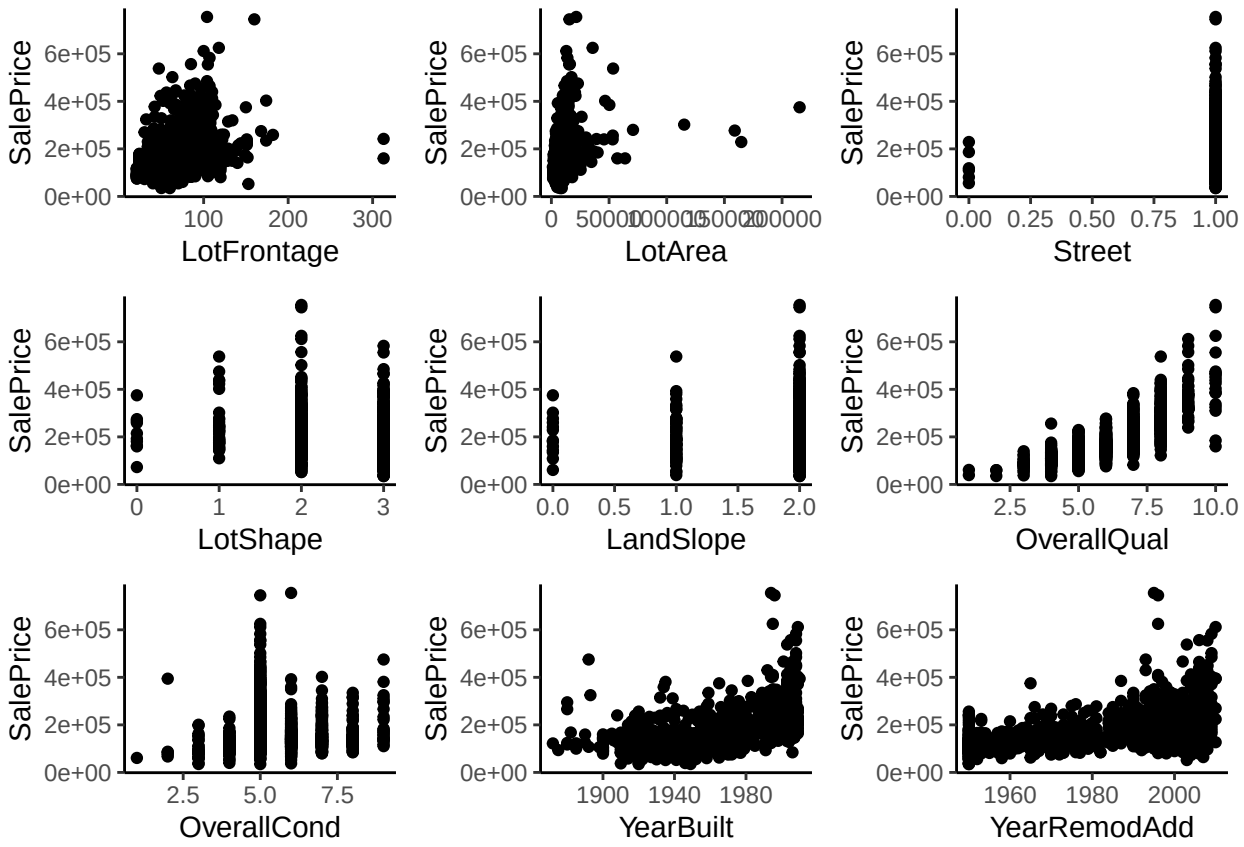
SalePrice vs all other numerical variable scatterplots

```
plot = function(variable){
  print(variable)
  ggplot(combined,aes(x = combined[,variable], y = SalePrice)) + geom_point() + theme_classic() + labs(x=variabl
library(gridExtra)
```

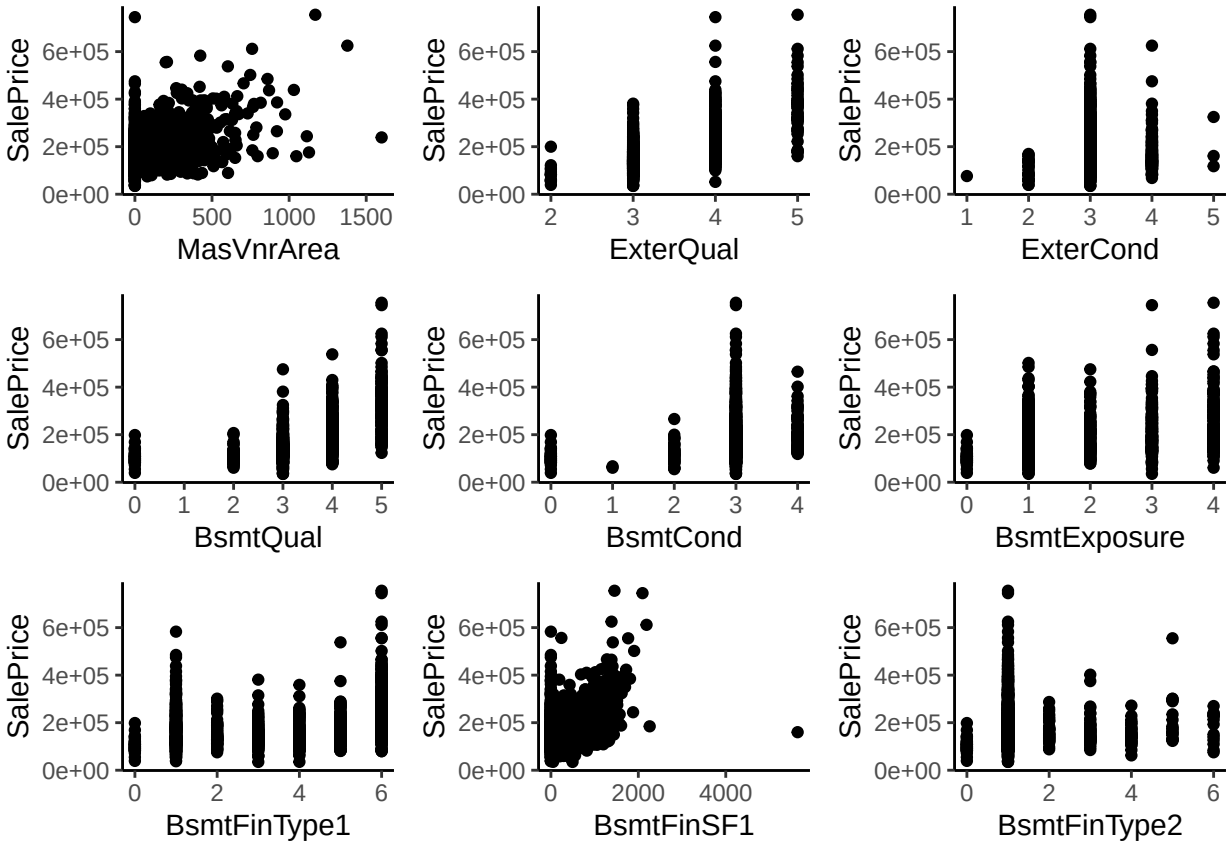
```
## Warning: package 'gridExtra' was built under R version 4.0.3
```

```
p = list()
p <- NULL
val <- 0
d <- combined[,num_vars]
for(j in 1:6){
  for(i in 1:9){
    name = names(d[i+val])
    p[[i]] = plot(as.character(name))}
  val = i+val
  do.call(grid.arrange,p)
  p <- NULL}
```

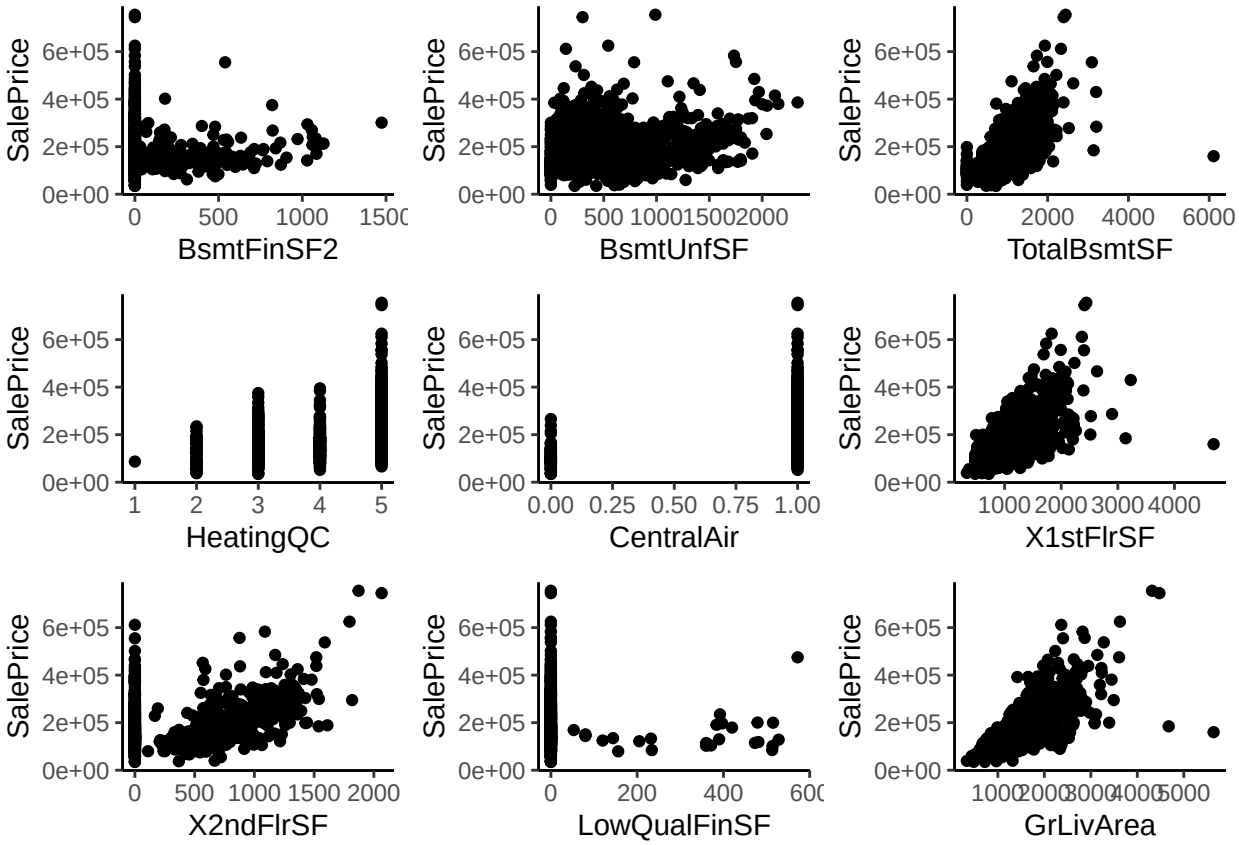
```
## [1] "LotFrontage"
## [1] "LotArea"
## [1] "Street"
## [1] "LotShape"
## [1] "LandSlope"
## [1] "OverallQual"
## [1] "OverallCond"
## [1] "YearBuilt"
## [1] "YearRemodAdd"
```



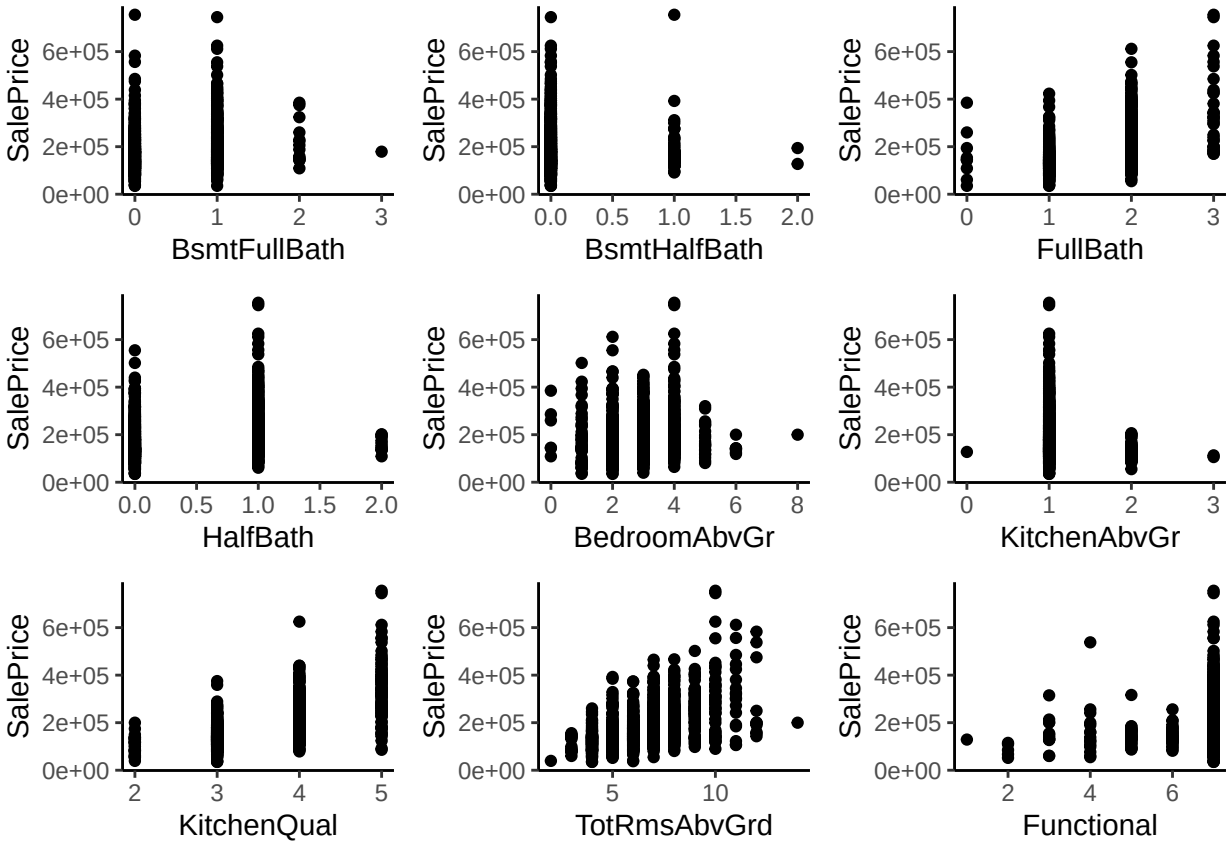

```
## [1] "MasVnrArea"
## [1] "ExterQual"
## [1] "ExterCond"
## [1] "BsmtQual"
## [1] "BsmtCond"
## [1] "BsmtExposure"
## [1] "BsmtFinType1"
## [1] "BsmtFinSF1"
## [1] "BsmtFinType2"
```



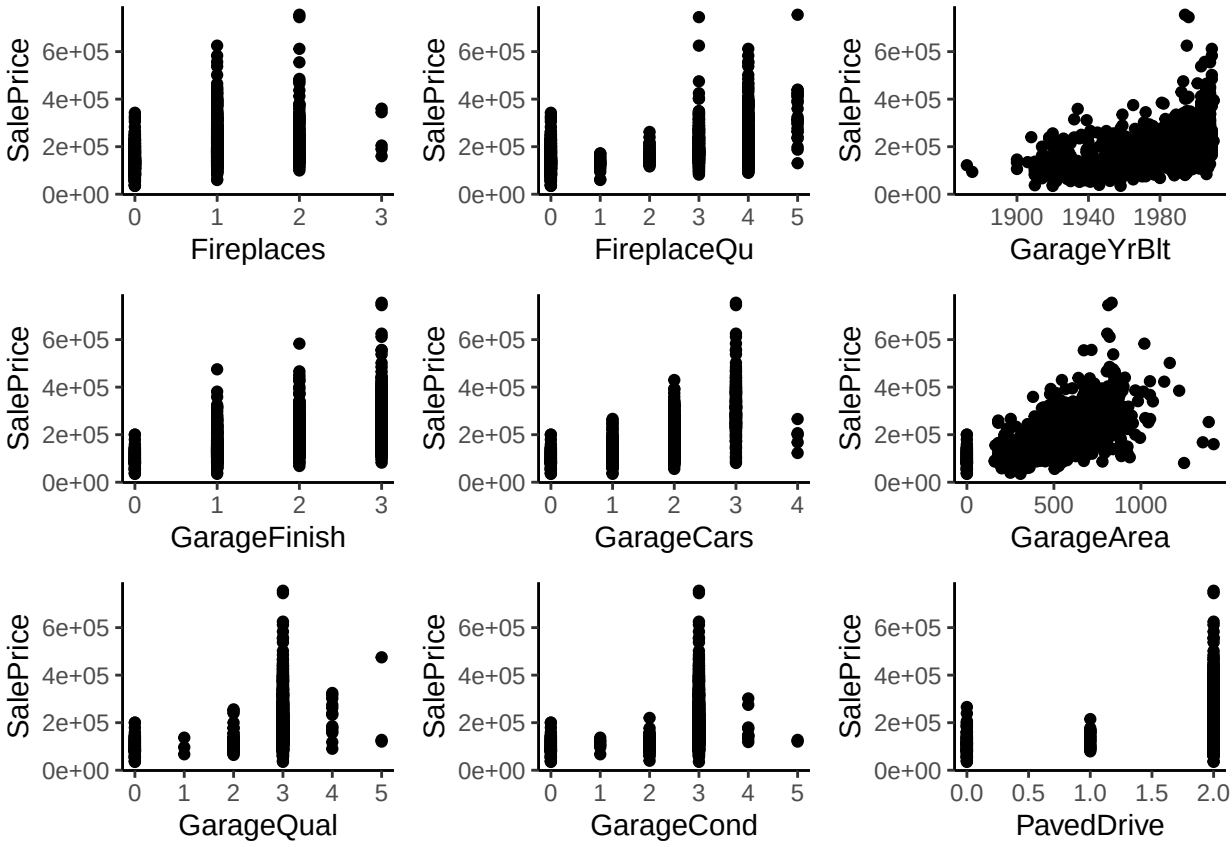

```
## [1] "BsmtFinSF2"
## [1] "BsmtUnfSF"
## [1] "TotalBsmtSF"
## [1] "HeatingQC"
## [1] "CentralAir"
## [1] "X1stFlrSF"
## [1] "X2ndFlrSF"
## [1] "LowQualFinSF"
## [1] "GrLivArea"
```



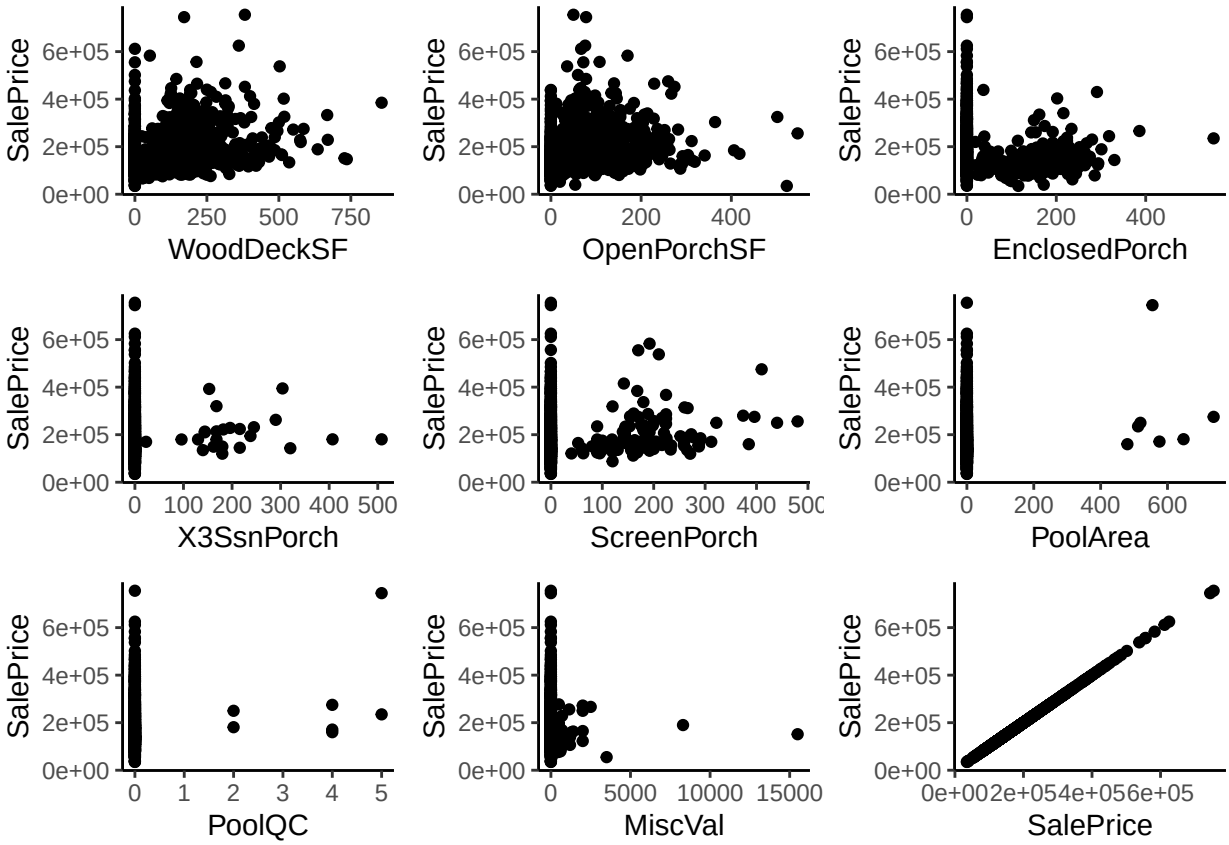

```
## [1] "BsmtFullBath"
## [1] "BsmtHalfBath"
## [1] "FullBath"
## [1] "HalfBath"
## [1] "BedroomAbvGr"
## [1] "KitchenAbvGr"
## [1] "KitchenQual"
## [1] "TotRmsAbvGrd"
## [1] "Functional"
```




```
## [1] "Fireplaces"
## [1] "FireplaceQu"
## [1] "GarageYrBlt"
## [1] "GarageFinish"
## [1] "GarageCars"
## [1] "GarageArea"
## [1] "GarageQual"
## [1] "GarageCond"
## [1] "PavedDrive"
```




```
## [1] "WoodDeckSF"
## [1] "OpenPorchSF"
## [1] "EnclosedPorch"
## [1] "X3SsnPorch"
## [1] "ScreenPorch"
## [1] "PoolArea"
## [1] "PoolQC"
## [1] "MiscVal"
## [1] "SalePrice"
```



all numerical variables density plots

```
library(purrr)
```

```
## Warning: package 'purrr' was built under R version 4.0.3
```

```
##
## Attaching package: 'purrr'
```

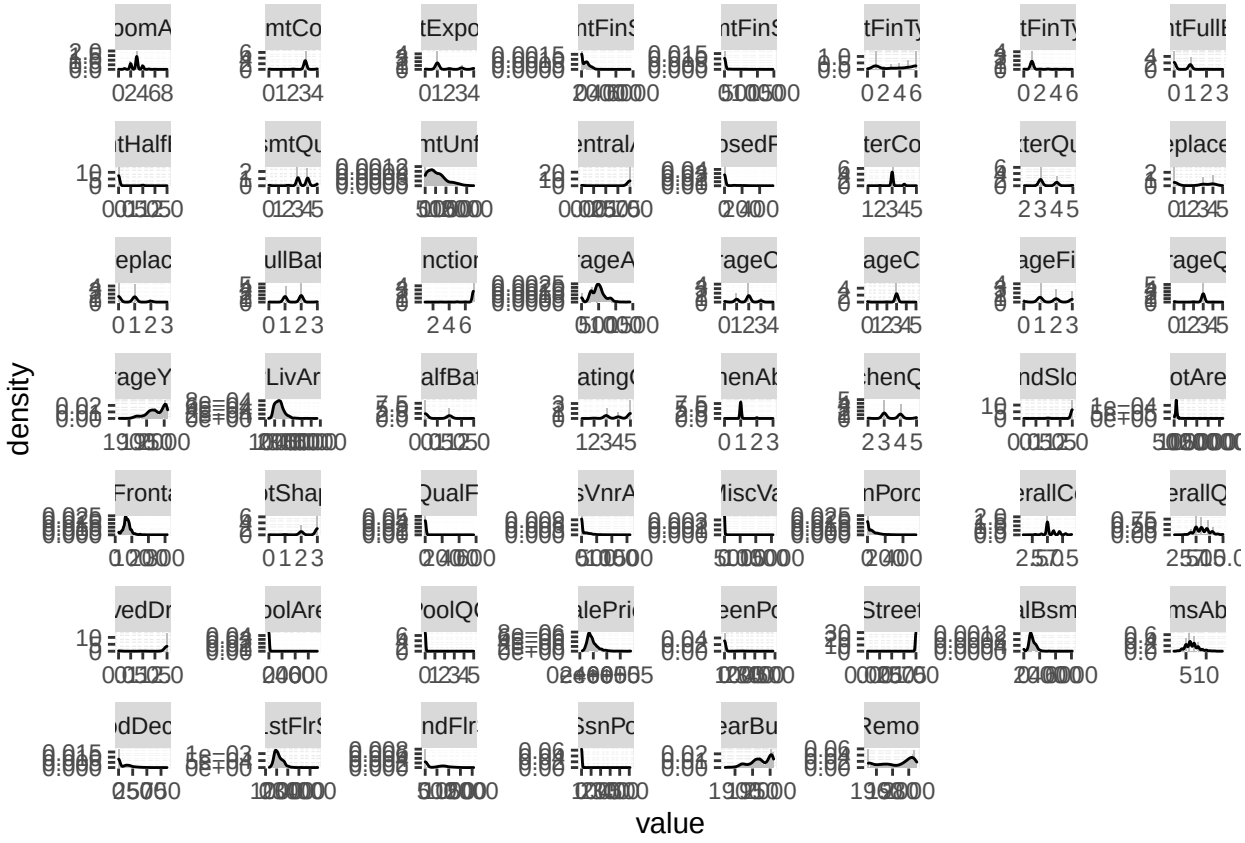
```
## The following object is masked from 'package:plyr':
##
##     compact
```

```
library(tidyr)
```

```
## Warning: package 'tidyr' was built under R version 4.0.3
```

```
library(ggplot2)
combined %>%
  keep(is.numeric) %>%
  gather() %>%
  ggplot(aes(value)) +
      facet_wrap(~ key, scales = "free") +
      geom_histogram(aes(y=..density..), fill = "grey") +
      geom_density()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```




```
ggsave("../Plots/density_numerical_variables.jpg", plot = last_plot(), width = 10, height = 7)
```

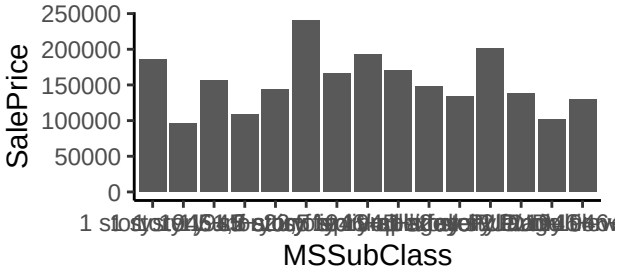
```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

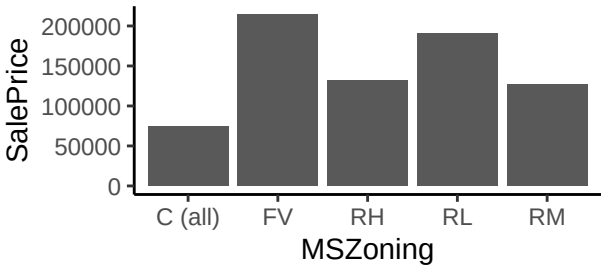
Categorical variables

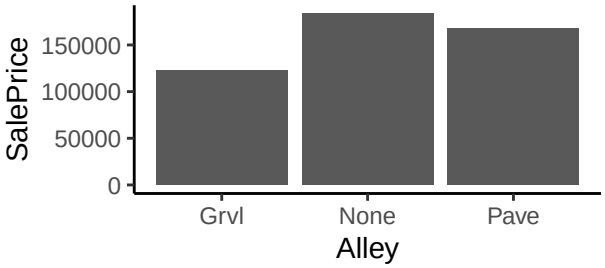
Histograms for Categorical Variables

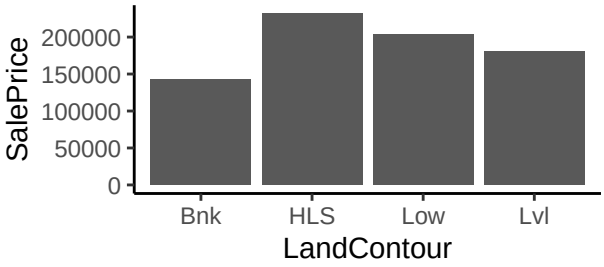
```
plot_factor = function(variable){
  ggplot(combined,aes(x = combined[,variable], y = SalePrice)) +geom_bar(stat = 'summary') + theme_classic() + l

library(gridExtra)
p = list()
p <- NULL
val <- 0
d <- combined[,factor_vars]
for(j in 1:5){
  for(i in 1:5){
    name = names(d[i+val])
    p[[i]] = plot_factor((name))}
  val = i+val
  do.call(grid.arrange,p)
  p <- NULL}
```

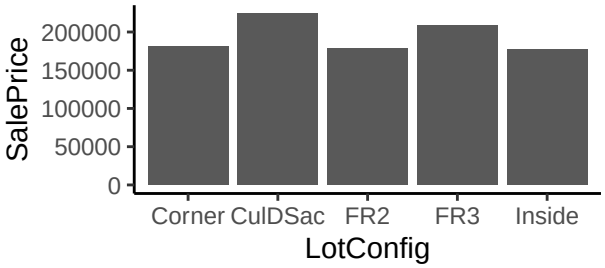
```
## No summary function supplied, defaulting to `mean_se()`
## No summary function supplied, defaulting to `mean_se()`
## No summary function supplied, defaulting to `mean_se()`
## No summary function supplied, defaulting to `mean_se()`
## No summary function supplied, defaulting to `mean_se()`
```












```
## No summary function supplied, defaulting to ‘mean_se()‘
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```

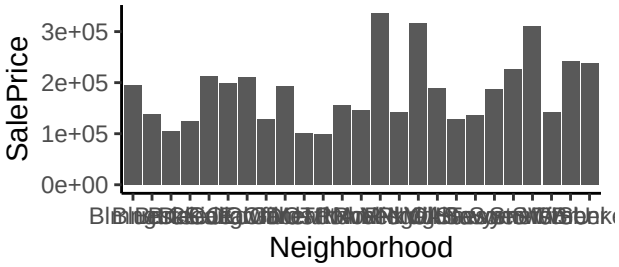

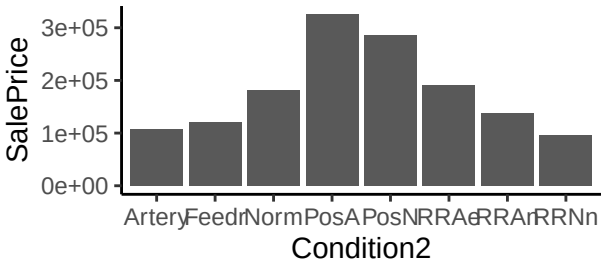

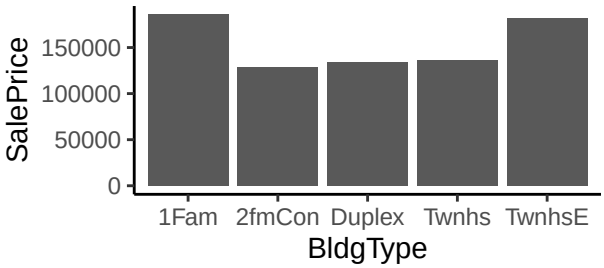

```
## No summary function supplied, defaulting to ‘mean_se()‘
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```

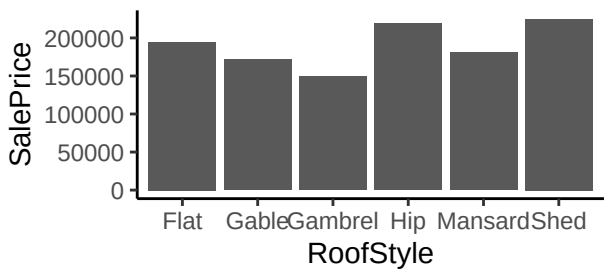

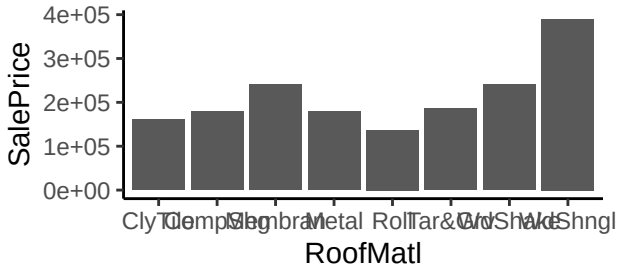

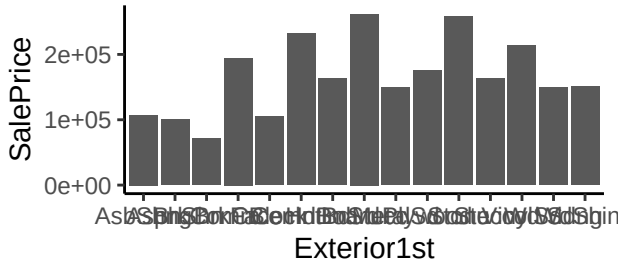

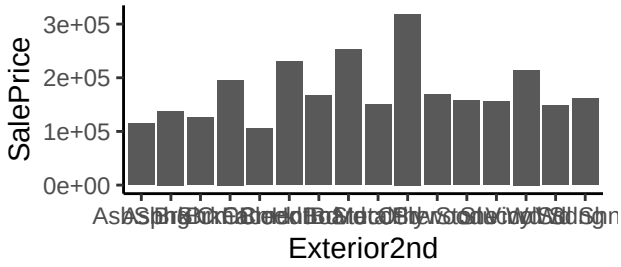

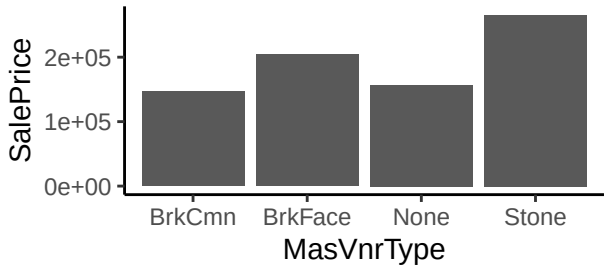


```
## No summary function supplied, defaulting to ‘mean_se()‘
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## No summary function supplied, defaulting to ‘mean_se()‘
## No summary function supplied, defaulting to ‘mean_se()‘
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```

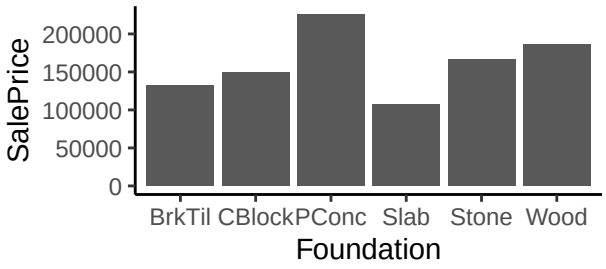

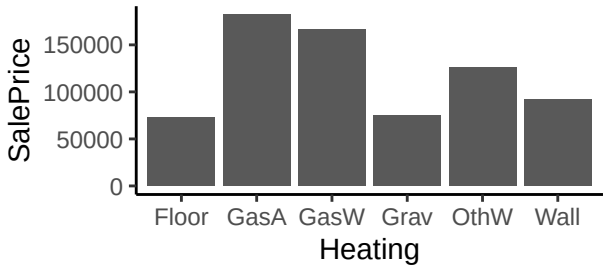

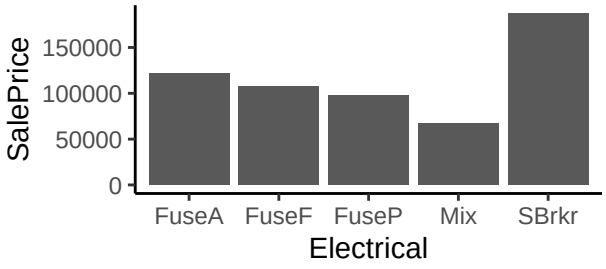

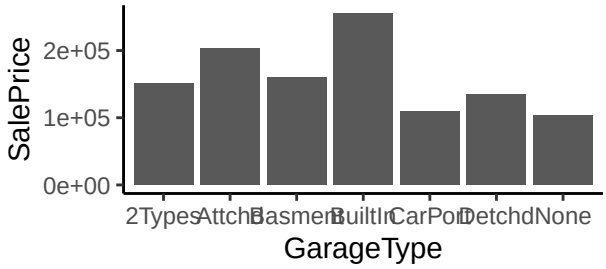

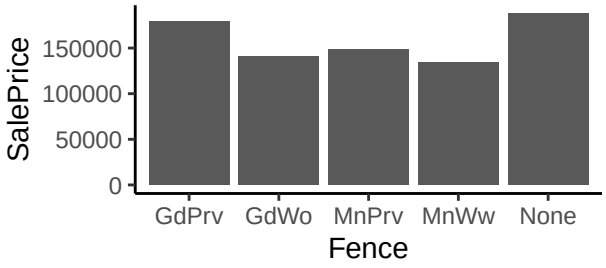


```
## No summary function supplied, defaulting to ‘mean_se()‘
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## No summary function supplied, defaulting to ‘mean_se()‘
## No summary function supplied, defaulting to ‘mean_se()‘
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```
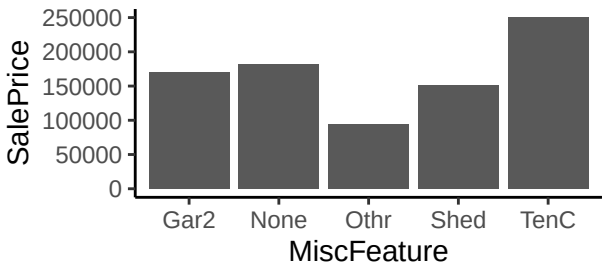
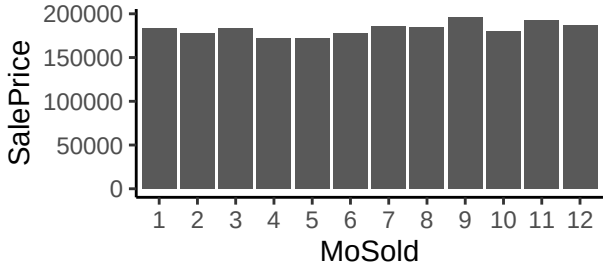
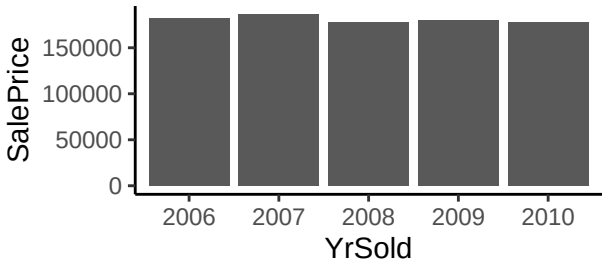
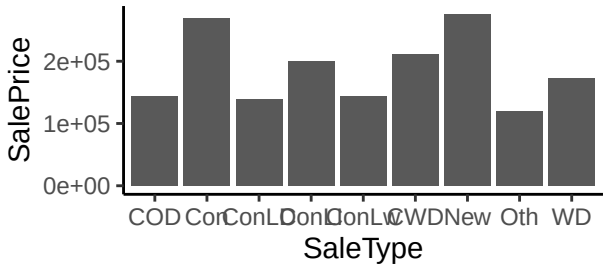









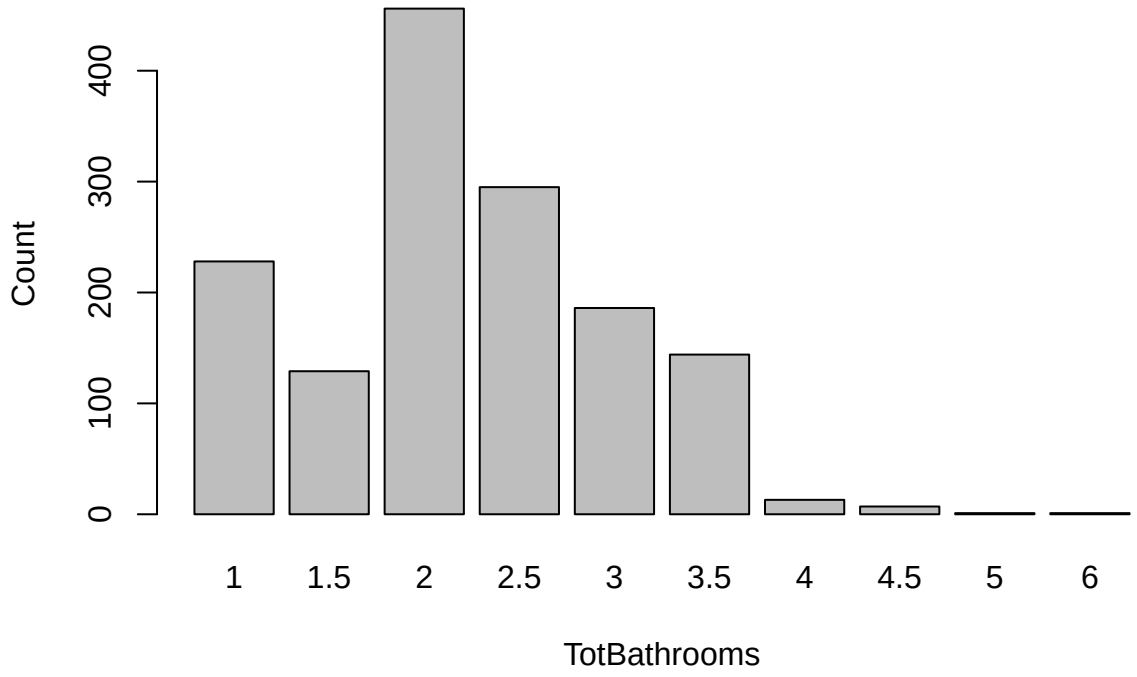
Feature engineering

Total bathrooms

```
combined$TotBathrooms <- combined$FullBath + (combined$HalfBath*0.5) + combined$BsmtFullBath + (combined$BsmtHal
table(combined$TotBathrooms)
```

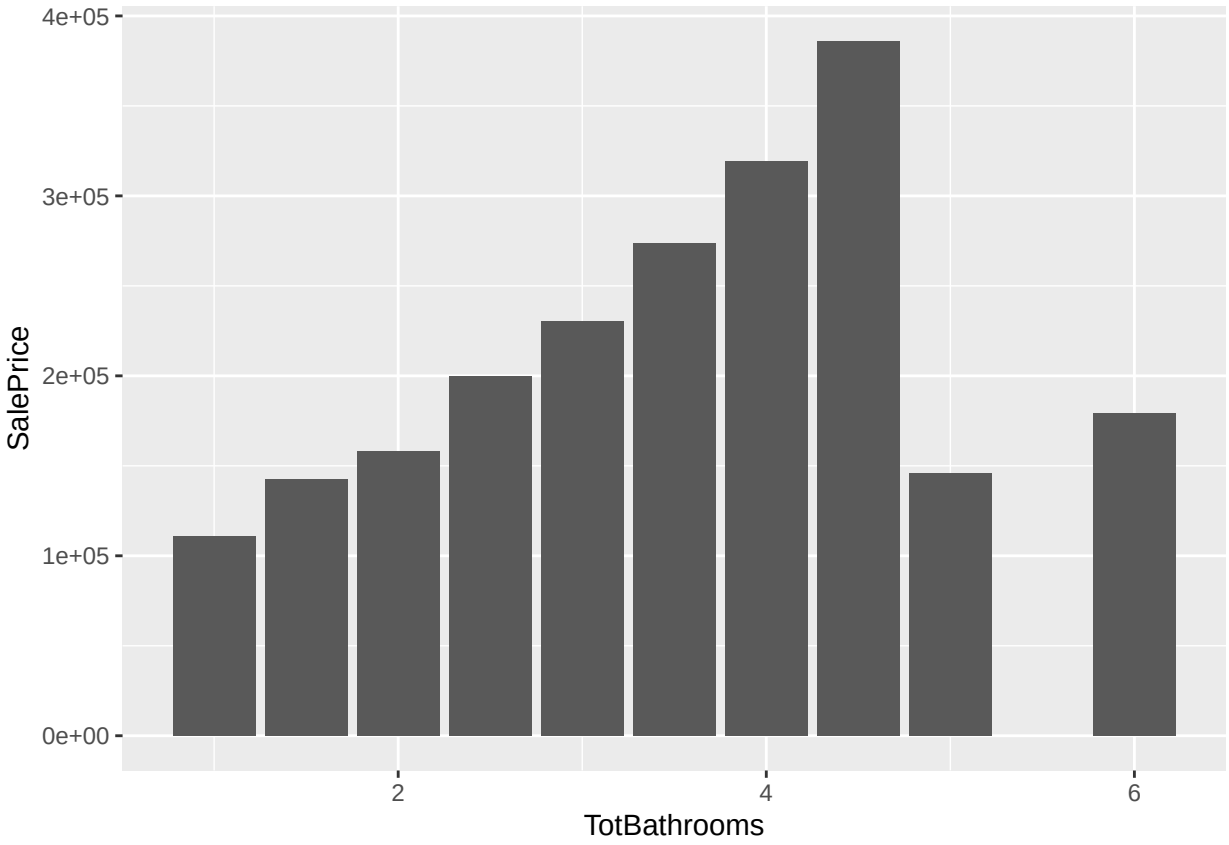
```
##
##   1 1.5   2 2.5   3 3.5   4 4.5   5   6
## 228 129 456 295 186 144  13   7   1   1
```

```
barplot(table(combined$TotBathrooms), xlab = "TotBathrooms", ylab = "Count")
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=TotBathrooms, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```

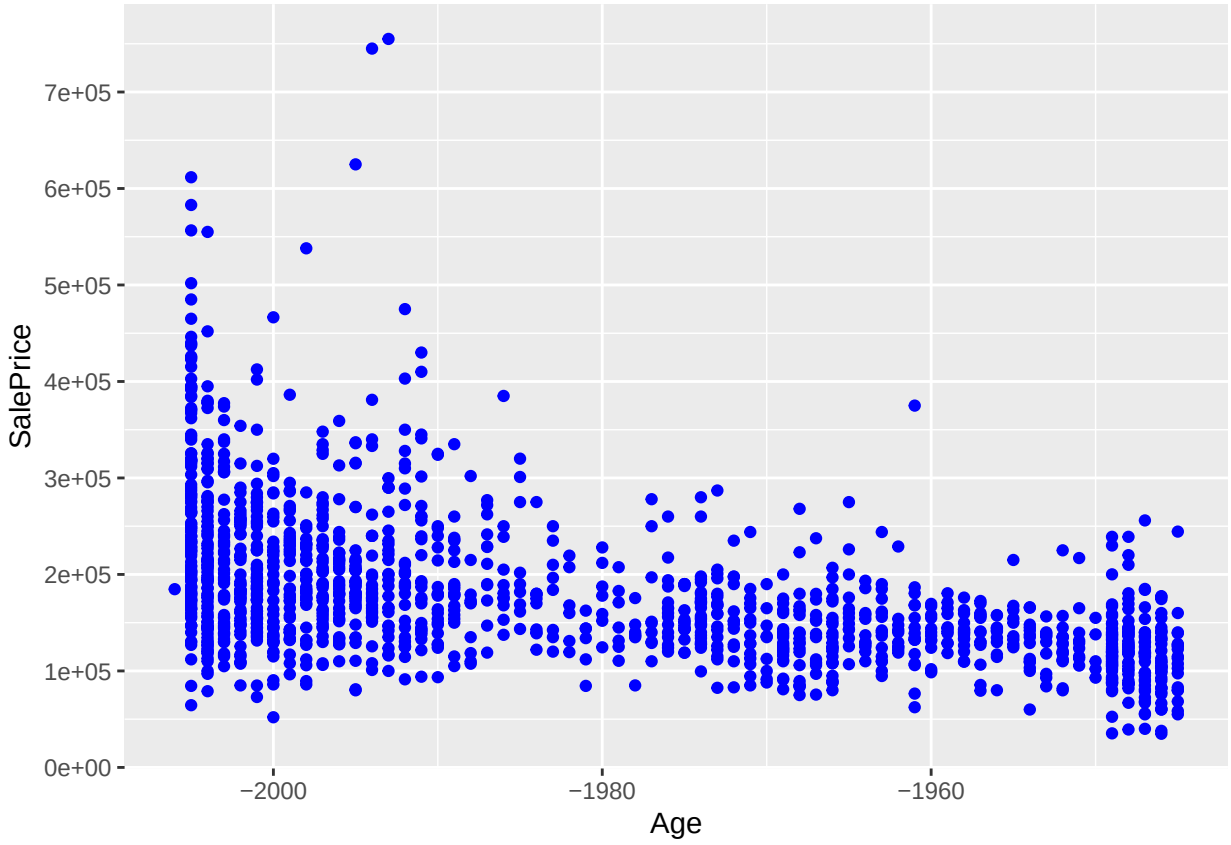


House age and remodelled houses

After looking at the density plots and EDA, we found that there is no house age but ther e is remodeled year and year built variables so adding the age of the house to the data set and whether or not its been remodeled was important as Sale price does depend on how old the house is and whether or not its a remodeled house.

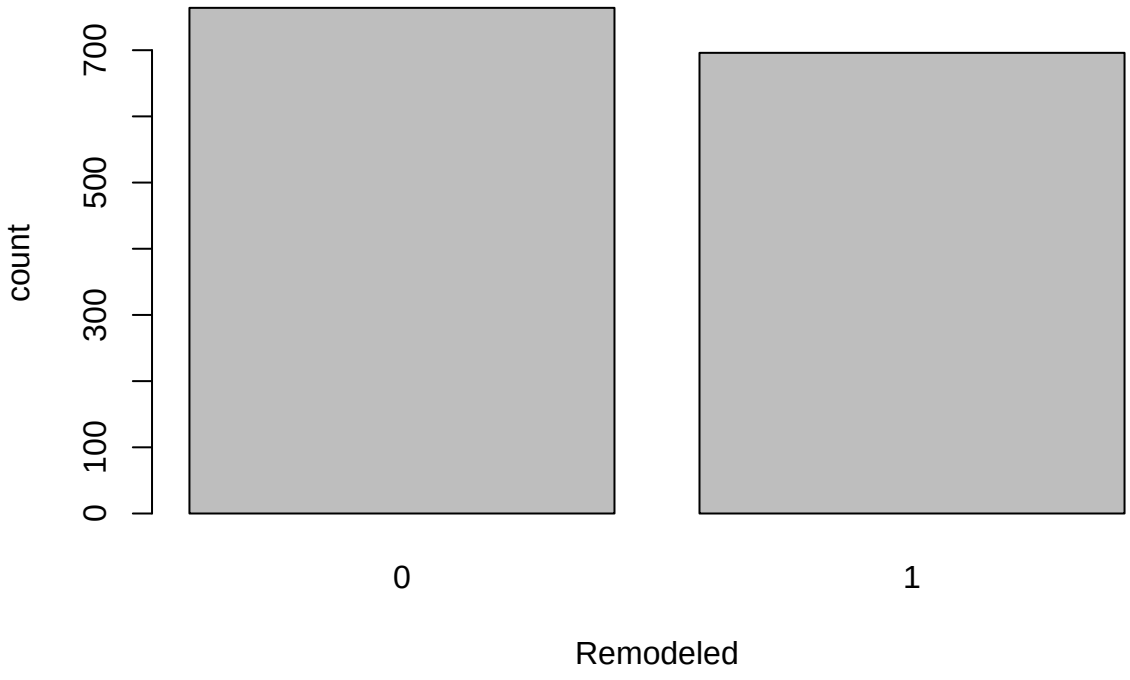
house age plot

```
combined$Remod <- ifelse(combined$YearBuilt==combined$YearRemodAdd, 0, 1) #0=No Remodeling, 1=Remodeling
combined$Age <- as.numeric(combined$YrSold)-combined$YearRemodAdd
ggplot(data=combined[!is.na(combined$SalePrice),], aes(x=Age, y=SalePrice))+
        geom_point(col='blue')+
        scale_y_continuous(breaks= seq(0, 800000, by=100000))
```



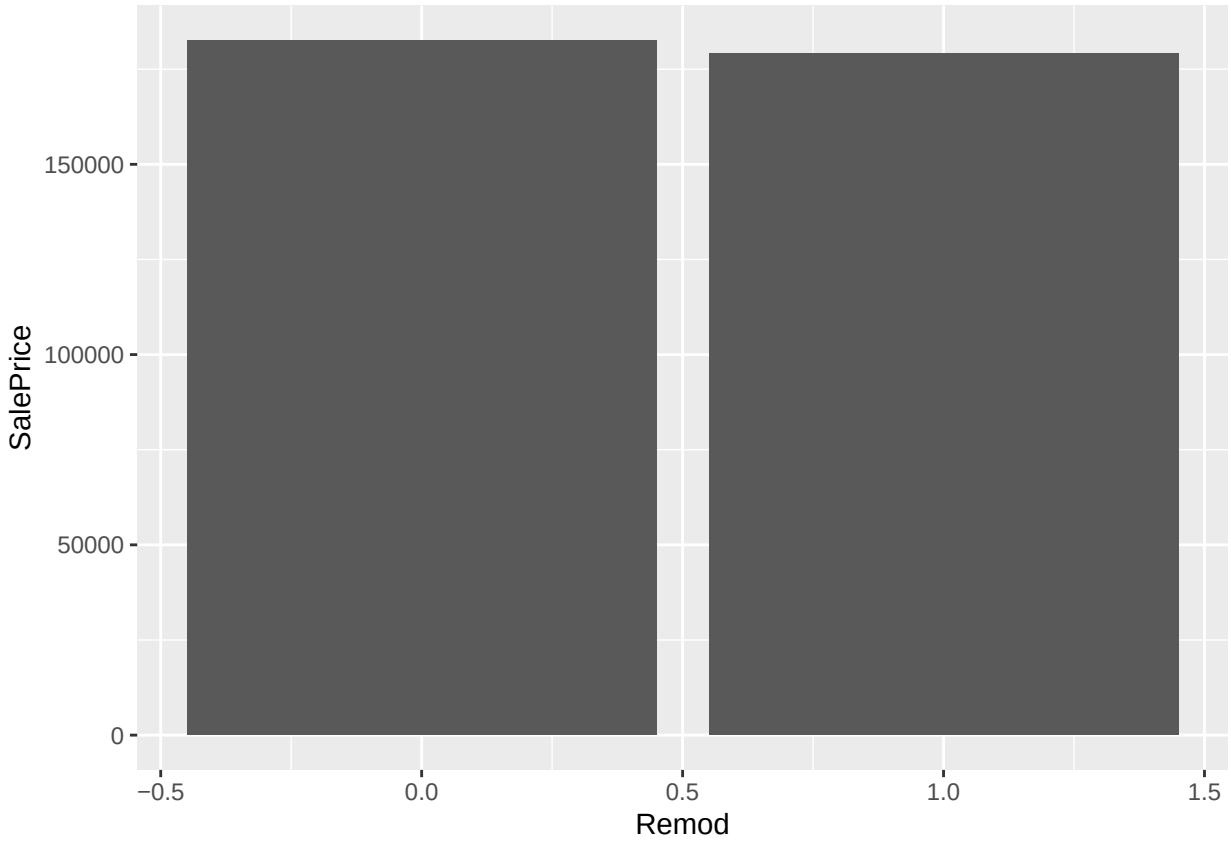
histogram of remodeled house variable

```
barplot(table(combined$Remod), xlab = "Remodeled", ylab = "count")
```



```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=Remod, y = SalePrice)) + geom_bar(stat = 'summary')
```

```
## No summary function supplied, defaulting to `mean_se()`
```



Correlations

correlation matrix

```
num_vars <- names(Filter(is.numeric,combined)) #index vector numeric variables
factor_vars <- names(Filter(is.factor,combined))

corr_matrix <- cor(combined[num_vars],method = "pearson")
correlation_SalePrice <- sort(corr_matrix[,'SalePrice'],decreasing = TRUE)
correlation_SalePrice
```

```
##     SalePrice   OverallQual     GrLivArea     ExterQual   KitchenQual
##   1.000000000   0.790981601   0.708624478   0.682639242   0.659599721
##    GarageCars  TotBathrooms    GarageArea   TotalBsmtSF     X1stFlrSF
##   0.640409197   0.631731068   0.623431439   0.613580552   0.605852185
##      BsmtQual      FullBath  GarageFinish  TotRmsAbvGrd     YearBuilt
##   0.585207199   0.560663763   0.549246756   0.533723156   0.522897333
##   FireplaceQu   GarageYrBlt  YearRemodAdd    MasVnrArea    Fireplaces
##   0.520437606   0.508043287   0.507100967   0.472614499   0.466928837
##     HeatingQC    BsmtFinSF1  BsmtExposure   LotFrontage    WoodDeckSF
##   0.427648707   0.386419806   0.375044959   0.340871631   0.324413445
##     X2ndFlrSF   OpenPorchSF  BsmtFinType1      HalfBath    GarageQual
##   0.319333803   0.315856227   0.304907873   0.284107676   0.273839074
##       LotArea    GarageCond    CentralAir    PavedDrive  BsmtFullBath
```

```
##   0.263843354   0.263190784   0.251328164   0.231356952   0.227122233
##     BsmtUnfSF      BsmtCond  BedroomAbvGr        PoolQC   ScreenPorch
##   0.214479106   0.212607156   0.168213154   0.111695838   0.111446571
##    Functional      PoolArea    X3SsnPorch        Street     ExterCond
##   0.107618893   0.092403549   0.044583665   0.041035536   0.018899118
##  BsmtFinType2    BsmtFinSF2  BsmtHalfBath       MiscVal         Remod
##  -0.004329316  -0.011378121  -0.016844154  -0.021189580  -0.021932600
##  LowQualFinSF     LandSlope   OverallCond EnclosedPorch  KitchenAbvGr
##  -0.025606130  -0.051152248  -0.077855894  -0.128577958  -0.135907371
##      LotShape           Age
##  -0.267759314  -0.509078738
```

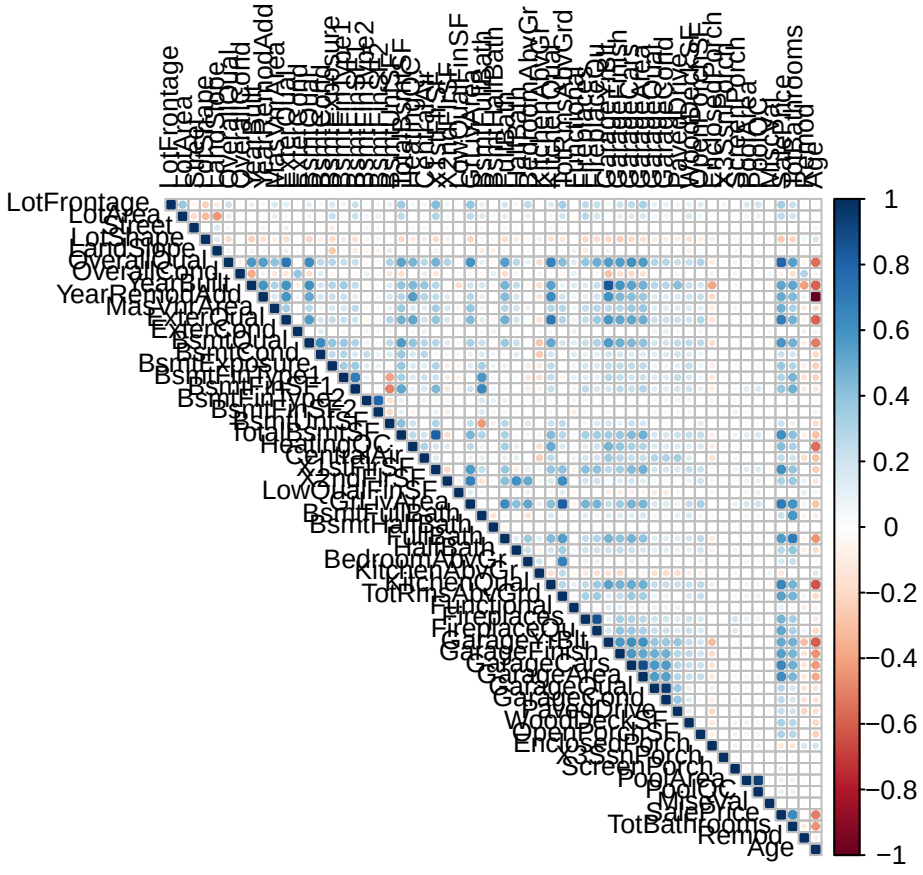
correlation Plot

```
library(corrplot)
```

```
## Warning: package 'corrplot' was built under R version 4.0.3
```

```
## corrplot 0.84 loaded
```

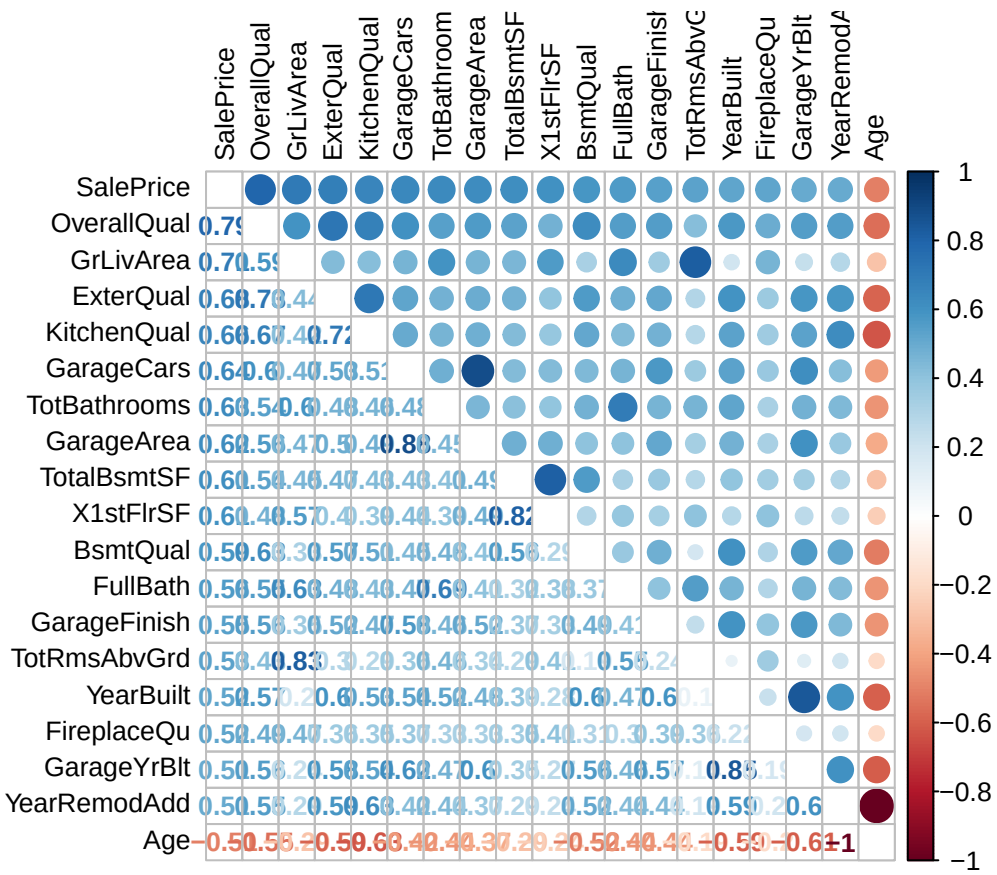
```
corrplot(corr_matrix,type = "upper",tl.col = "black",tl.cex = 0.8)
```



correlation Plot of variables vs SalePrice > 0.5

```
corr_sorted <- as.matrix(sort(corr_matrix[,'SalePrice'], decreasing = TRUE))
 #select only high correlations
Corr_High <- names(which(apply(corr_sorted, 1, function(x) abs(x)>0.5)))
corr_matrix <- corr_matrix[Corr_High, Corr_High]
```

```
corrplot.mixed(corr_matrix, tl.col="black", tl.pos = "lt", tl.cex = 0.8,cl.cex = 0.8, number.cex=0.8)
```



Removing highly correlated variables

```
# removing variables with high correlations between predictor # variables
dropVars <- c('GarageYrBlt', 'GarageArea', 'TotalBsmtSF', 'TotalRmsAbvGrd')
combined <- combined[,!names(combined) %in% dropVars]
```

Outlier analysis

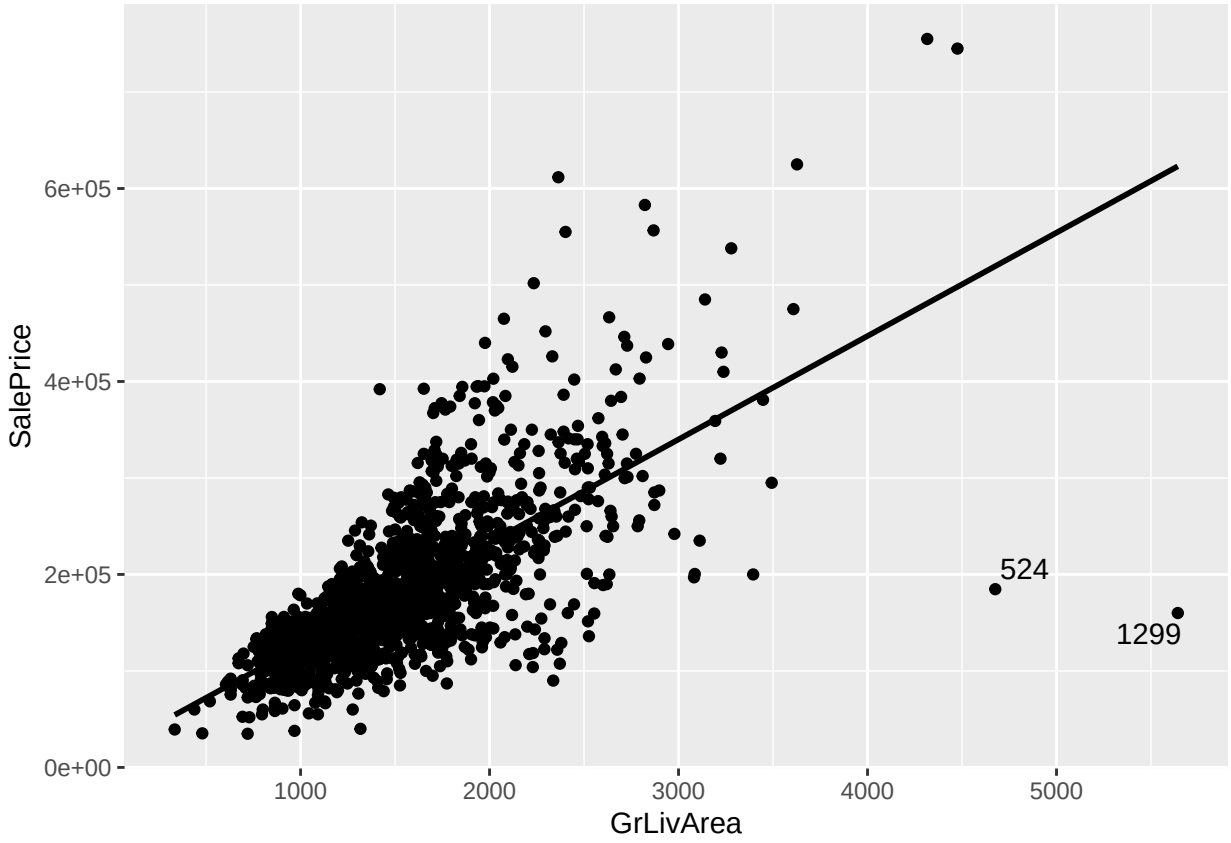
Detecting outliers

```
# we look for outliers in the most correlated variable with SalePrice which is GrLivArea.
library(ggrepel)
```

```
## Warning: package 'ggrepel' was built under R version 4.0.3
```

```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=GrLivArea  , y = SalePrice)) + geom_point()+geom_smooth(meth
```

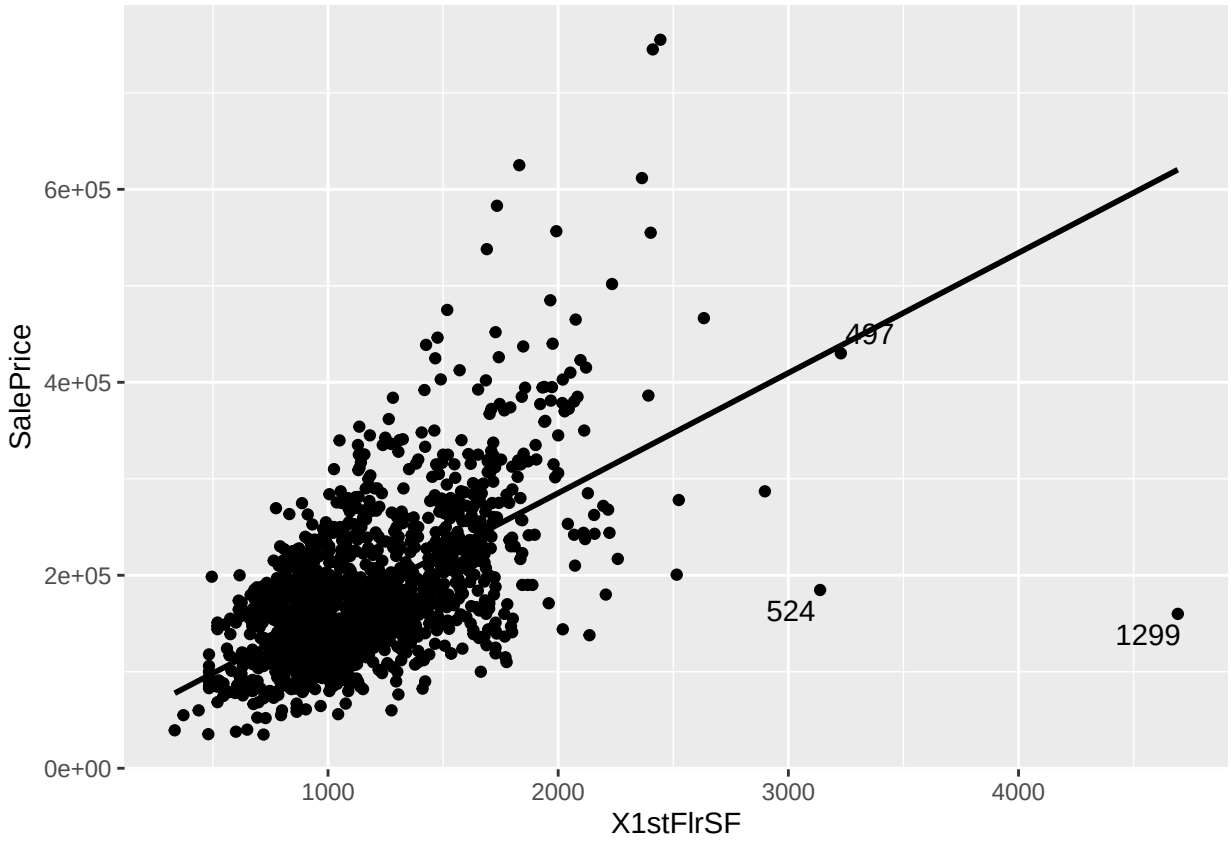
```
## `geom_smooth()` using formula 'y ~ x'
```




```
ggplot(combined[!is.na(combined$SalePrice),], aes(x=X1stFlrSF, y = SalePrice)) + geom_point()+geom_smooth(metho
```

```
## Warning: Use of ‘combined$X1stFlrSF‘ is discouraged. Use ‘X1stFlrSF‘ instead.
```

```
## ‘geom_smooth()‘ using formula ’y ~ x’
```



```r
mod <- lm(SalePrice ~ ., data = combined)
summary(mod)
```

```
##
## Call:
## lm(formula = SalePrice ~ ., data = combined)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -171545  -11140       0   11142  171545
##
## Coefficients: (5 not defined because of singularities)
##                                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)                    -1.464e+06  2.202e+05  -6.649 4.42e-11 ***
## MSSubClass1 story 1945-         1.463e+02  5.029e+03   0.029 0.976804
## MSSubClass1 story unf attic    -1.788e+04  1.844e+04  -0.969 0.332637
## MSSubClass1,5 story unf         4.020e+03  2.398e+04   0.168 0.866920
## MSSubClass1,5 story fin         3.591e+03  9.301e+03   0.386 0.699532
## MSSubClass2 story 1946+         6.490e+03  8.231e+03   0.788 0.430574
## MSSubClass2 story 1945-         6.880e+03  8.861e+03   0.776 0.437675
## MSSubClass2,5 story all ages   -2.186e+04  1.640e+04  -1.333 0.182697
## MSSubClasssplit/multi level    -9.647e+02  1.226e+04  -0.079 0.937289
## MSSubClassspli t foyer         -4.387e+03  1.120e+04  -0.392 0.695304
## MSSubClassduplex all style/age -5.137e+03  7.644e+03  -0.672 0.501731
## MSSubClass1 story PUD 1946+    -2.136e+04  1.569e+04  -1.362 0.173444
## MSSubClass2 story PUD 1946+    -1.592e+04  1.874e+04  -0.850 0.395698
## MSSubClassPUD multilevel       -1.393e+04  2.080e+04  -0.670 0.503098
## MSSubClass2 family conversion  -3.997e+04  2.747e+04  -1.455 0.145963
## MSZoningFV                      3.073e+04  1.292e+04   2.379 0.017488 *
## MSZoningRH                      3.086e+04  1.285e+04   2.402 0.016448 *
## MSZoningRL                      2.763e+04  1.102e+04   2.507 0.012317 *
## MSZoningRM                      2.383e+04  1.036e+04   2.300 0.021612 *
## LotFrontage                     8.897e+01  4.766e+01   1.867 0.062174 .
## LotArea                         4.585e-01  9.774e-02   4.691 3.02e-06 ***
## Street                          1.894e+04  1.243e+04   1.524 0.127653
## AlleyNone                      -2.189e+03  4.502e+03  -0.486 0.626894
## AlleyPave                      -2.115e+03  6.603e+03  -0.320 0.748780
## LotShape                        5.863e+02  1.452e+03   0.404 0.686472
## LandContourHLS                  1.269e+04  5.522e+03   2.298 0.021754 *
## LandContourLow                 -2.786e+03  6.748e+03  -0.413 0.679738
## LandContourLvl                  5.021e+03  3.952e+03   1.271 0.204084
## LotConfigCulDSac                1.021e+04  3.683e+03   2.772 0.005660 **
## LotConfigFR2                   -3.474e+03  4.308e+03  -0.806 0.420208
## LotConfigFR3                   -2.034e+04  1.348e+04  -1.508 0.131763
## LotConfigInside                 9.893e+01  1.942e+03   0.051 0.959375
## LandSlope                       7.942e+02  3.702e+03   0.215 0.830185
## NeighborhoodBlueste             2.047e+04  2.109e+04   0.971 0.331886
## NeighborhoodBrDale              1.455e+04  1.239e+04   1.174 0.240450
## NeighborhoodBrkSide             3.040e+03  1.004e+04   0.303 0.762103
## NeighborhoodClearCr            -9.648e+03  9.918e+03  -0.973 0.330825
## NeighborhoodCollgCr            -1.065e+04  7.735e+03  -1.377 0.168724
## NeighborhoodCrawfor             1.245e+04  9.257e+03   1.345 0.178935
## NeighborhoodEdwards            -1.217e+04  8.593e+03  -1.417 0.156831
## NeighborhoodGilbert            -1.158e+04  8.236e+03  -1.406 0.160066
## NeighborhoodIDOTRR             -3.573e+03  1.145e+04  -0.312 0.755102
## NeighborhoodMeadowV            -8.099e+02  1.313e+04  -0.062 0.950838
## NeighborhoodMitchel            -1.253e+04  8.705e+03  -1.439 0.150337
## NeighborhoodNAmes              -9.956e+03  8.387e+03  -1.187 0.235414
## NeighborhoodNoRidge             1.907e+04  9.037e+03   2.110 0.035024 *
## NeighborhoodNPkVill             2.156e+04  1.487e+04   1.450 0.147207
## NeighborhoodNridgHt             3.045e+04  7.828e+03   3.890 0.000106 ***
```

```
## NeighborhoodNWAmes            -1.385e+04  8.586e+03  -1.614 0.106836
## NeighborhoodOldTown           -5.865e+03  1.033e+04  -0.568 0.570317
## NeighborhoodSawyer            -2.221e+03  8.717e+03  -0.255 0.798959
## NeighborhoodSawyerW           -4.694e+03  8.364e+03  -0.561 0.574790
## NeighborhoodSomerst           -4.056e+02  9.660e+03  -0.042 0.966517
## NeighborhoodStoneBr            4.048e+04  8.928e+03   4.534 6.35e-06 ***
## NeighborhoodSWISU             -5.210e+03  1.038e+04  -0.502 0.615984
## NeighborhoodTimber            -1.116e+04  8.709e+03  -1.282 0.200243
## NeighborhoodVeenker            1.320e+03  1.117e+04   0.118 0.905994
## Condition1Feedr                3.573e+03  5.305e+03   0.674 0.500691
## Condition1Norm                 1.403e+04  4.399e+03   3.190 0.001460 **
## Condition1PosA                 6.305e+03  1.068e+04   0.590 0.555215
## Condition1PosN                 1.095e+04  7.895e+03   1.387 0.165639
## Condition1RRAe                -1.385e+04  9.307e+03  -1.488 0.136976
## Condition1RRAn                 1.641e+04  7.338e+03   2.237 0.025487 *
## Condition1RRNe                -7.230e+03  1.879e+04  -0.385 0.700462
## Condition1RRNn                 1.176e+04  1.359e+04   0.865 0.387095
## Condition2Feedr               -1.371e+04  2.680e+04  -0.512 0.609012
## Condition2Norm                -1.791e+04  2.378e+04  -0.753 0.451423
## Condition2PosA                 3.662e+04  3.683e+04   0.994 0.320324
## Condition2PosN                -2.385e+05  3.095e+04  -7.706 2.66e-14 ***
## Condition2RRAe                -9.697e+04  7.594e+04  -1.277 0.201900
## Condition2RRAn                -1.228e+04  3.498e+04  -0.351 0.725556
## Condition2RRNn                -1.159e+04  3.037e+04  -0.382 0.702837
## BldgType2fmCon                 3.002e+04  2.657e+04   1.130 0.258634
## BldgTypeDuplex                        NA         NA      NA       NA
## BldgTypeTwnhs                 -9.616e+03  1.671e+04  -0.576 0.564963
## BldgTypeTwnhsE                -2.688e+03  1.592e+04  -0.169 0.865949
## HouseStyle1.5Unf               9.961e+03  2.386e+04   0.417 0.676433
## HouseStyle1Story               1.603e+04  9.382e+03   1.709 0.087715 .
## HouseStyle2.5Fin               4.675e+03  1.803e+04   0.259 0.795474
## HouseStyle2.5Unf               9.736e+03  1.685e+04   0.578 0.563574
## HouseStyle2Story              -7.732e+03  8.646e+03  -0.894 0.371364
## HouseStyleSFoyer               3.944e+03  1.250e+04   0.315 0.752445
## HouseStyleSLvl                 9.322e+03  1.383e+04   0.674 0.500425
## OverallQual                    8.662e+03  1.086e+03   7.976 3.43e-15 ***
## OverallCond                    5.001e+03  9.163e+02   5.458 5.82e-08 ***
## YearBuilt                      3.054e+02  8.725e+01   3.501 0.000481 ***
## YearRemodAdd                  -1.548e+01  6.085e+01  -0.254 0.799194
## RoofStyleGable                -1.556e+02  1.945e+04  -0.008 0.993621
## RoofStyleGambrel              -1.960e+02  2.126e+04  -0.009 0.992645
## RoofStyleHip                   3.849e+03  1.950e+04   0.197 0.843565
## RoofStyleMansard               9.428e+03  2.269e+04   0.416 0.677799
## RoofStyleShed                  6.527e+04  4.013e+04   1.627 0.104070
## RoofMatlCompShg                6.703e+05  3.531e+04  18.983  < 2e-16 ***
## RoofMatlMembran                7.179e+05  4.817e+04  14.905  < 2e-16 ***
## RoofMatlMetal                  6.950e+05  4.848e+04  14.335  < 2e-16 ***
## RoofMatlRoll                   6.474e+05  4.448e+04  14.554  < 2e-16 ***
## RoofMatlTar&Grv                6.653e+05  4.032e+04  16.502  < 2e-16 ***
## RoofMatlWdShake                6.446e+05  3.876e+04  16.633  < 2e-16 ***
## RoofMatlWdShngl                7.474e+05  3.676e+04  20.331  < 2e-16 ***
## Exterior1stAsphShn            -2.127e+04  3.519e+04  -0.604 0.545685
## Exterior1stBrkComm            -8.461e+03  2.957e+04  -0.286 0.774825
## Exterior1stBrkFace             9.124e+03  1.352e+04   0.675 0.499803
## Exterior1stCBlock              5.726e+03  2.716e+04   0.211 0.833019
## Exterior1stCemntBd             7.069e+02  2.003e+04   0.035 0.971853
## Exterior1stHdBoard            -8.759e+03  1.363e+04  -0.643 0.520556
## Exterior1stImStucc            -4.031e+04  2.987e+04  -1.349 0.177485
## Exterior1stMetalSd             1.483e+03  1.548e+04   0.096 0.923722
## Exterior1stPlywood            -1.307e+04  1.350e+04  -0.968 0.333309
## Exterior1stStone               2.507e+03  2.545e+04   0.099 0.921540
```

```
## Exterior1stStucco             4.675e+02  1.480e+04   0.032 0.974811
## Exterior1stVinylSd            -8.154e+03  1.430e+04  -0.570 0.568745
## Exterior1stWd Sdng            -7.918e+03  1.311e+04  -0.604 0.545916
## Exterior1stWdShing            -1.160e+03  1.422e+04  -0.082 0.934988
## Exterior2ndAsphShn             7.105e+03  2.363e+04   0.301 0.763732
## Exterior2ndBrk Cmn             7.667e+03  2.183e+04   0.351 0.725455
## Exterior2ndBrkFace            -2.031e+03  1.383e+04  -0.147 0.883271
## Exterior2ndCBlock                     NA         NA      NA       NA
## Exterior2ndCmentBd             7.463e+03  1.966e+04   0.380 0.704369
## Exterior2ndHdBoard             2.595e+03  1.296e+04   0.200 0.841361
## Exterior2ndImStucc             2.227e+04  1.510e+04   1.474 0.140669
## Exterior2ndMetalSd            -2.038e+02  1.500e+04  -0.014 0.989161
## Exterior2ndOther              -3.058e+04  2.912e+04  -1.050 0.293873
## Exterior2ndPlywood             3.249e+03  1.261e+04   0.258 0.796736
## Exterior2ndStone              -9.748e+03  1.806e+04  -0.540 0.589553
## Exterior2ndStucco             -6.368e+03  1.431e+04  -0.445 0.656306
## Exterior2ndVinylSd             5.350e+03  1.370e+04   0.390 0.696327
## Exterior2ndWd Sdng             4.970e+03  1.251e+04   0.397 0.691153
## Exterior2ndWd Shng            -3.373e+03  1.316e+04  -0.256 0.797777
## MasVnrTypeBrkFace              7.268e+03  7.119e+03   1.021 0.307485
## MasVnrTypeNone                 1.424e+04  7.151e+03   1.992 0.046602 *
## MasVnrTypeStone                1.359e+04  7.572e+03   1.795 0.072833 .
## MasVnrArea                     3.317e+01  6.072e+00   5.463 5.67e-08 ***
## ExterQual                      5.161e+03  2.238e+03   2.306 0.021302 *
## ExterCond                     -2.525e+03  2.248e+03  -1.123 0.261468
## FoundationCBlock               2.248e+03  3.365e+03   0.668 0.504178
## FoundationPConc                4.117e+03  3.643e+03   1.130 0.258637
## FoundationSlab                 1.426e+04  9.681e+03   1.473 0.140929
## FoundationStone                6.633e+03  1.195e+04   0.555 0.578985
## FoundationWood                -2.555e+04  1.586e+04  -1.610 0.107574
## BsmtQual                       2.752e+03  1.824e+03   1.509 0.131534
## BsmtCond                      -4.608e+03  2.268e+03  -2.032 0.042414 *
## BsmtExposure                   5.263e+03  8.991e+02   5.854 6.15e-09 ***
## BsmtFinType1                  -9.471e+01  5.397e+02  -0.175 0.860729
## BsmtFinSF1                     3.547e+01  5.077e+00   6.987 4.60e-12 ***
## BsmtFinType2                   1.062e+02  1.363e+03   0.078 0.937919
## BsmtFinSF2                     2.157e+01  8.466e+00   2.548 0.010945 *
## BsmtUnfSF                      1.482e+01  4.586e+00   3.230 0.001269 **
## HeatingGasA                   -1.267e+03  2.682e+04  -0.047 0.962336
## HeatingGasW                   -4.472e+03  2.763e+04  -0.162 0.871426
## HeatingGrav                    9.331e+02  2.882e+04   0.032 0.974178
## HeatingOthW                   -4.114e+04  3.305e+04  -1.245 0.213382
## HeatingWall                    4.010e+03  3.114e+04   0.129 0.897555
## HeatingQC                      1.039e+03  1.021e+03   1.018 0.308974
## CentralAir                    -3.401e+02  4.132e+03  -0.082 0.934418
## ElectricalFuseF               -2.601e+03  6.131e+03  -0.424 0.671456
## ElectricalFuseP                3.687e+03  1.771e+04   0.208 0.835115
## ElectricalMix                  1.224e+04  2.764e+04   0.443 0.658040
## ElectricalSBrkr               -3.426e+03  3.168e+03  -1.081 0.279710
## X1stFlrSF                      4.918e+01  5.651e+00   8.702  < 2e-16 ***
## X2ndFlrSF                      6.521e+01  5.974e+00  10.916  < 2e-16 ***
## LowQualFinSF                   2.407e+01  1.979e+01   1.216 0.224252
## GrLivArea                             NA         NA      NA       NA
## BsmtFullBath                   1.516e+03  2.085e+03   0.727 0.467210
## BsmtHalfBath                   3.817e+02  3.195e+03   0.119 0.904938
## FullBath                       3.128e+03  2.332e+03   1.341 0.180162
## HalfBath                       2.945e+03  2.225e+03   1.324 0.185852
## BedroomAbvGr                  -6.328e+03  1.465e+03  -4.320 1.68e-05 ***
## KitchenAbvGr                  -1.446e+04  6.503e+03  -2.224 0.026321 *
## KitchenQual                    6.907e+03  1.741e+03   3.968 7.67e-05 ***
## TotRmsAbvGrd                   2.828e+03  1.010e+03   2.800 0.005188 **
```

```
## Functional                  6.108e+03  1.204e+03   5.073 4.52e-07 ***
## Fireplaces                  5.792e+03  2.332e+03   2.483 0.013150 *
## FireplaceQu                -1.740e+03  8.458e+02  -2.057 0.039922 *
## GarageTypeAttchd            1.169e+04  1.162e+04   1.007 0.314299
## GarageTypeBasment           1.708e+04  1.355e+04   1.260 0.207759
## GarageTypeBuiltIn           1.268e+04  1.216e+04   1.043 0.297215
## GarageTypeCarPort           1.587e+04  1.517e+04   1.047 0.295505
## GarageTypeDetchd            1.709e+04  1.158e+04   1.476 0.140315
## GarageTypeNone              4.098e+04  1.630e+04   2.514 0.012053 *
## GarageFinish                2.661e+02  1.291e+03   0.206 0.836677
## GarageCars                  7.823e+03  1.702e+03   4.596 4.74e-06 ***
## GarageQual                  6.741e+03  3.982e+03   1.693 0.090692 .
## GarageCond                 -1.446e+03  4.219e+03  -0.343 0.731824
## PavedDrive                 -2.067e+02  1.758e+03  -0.118 0.906408
## WoodDeckSF                  1.107e+01  6.189e+00   1.788 0.074032 .
## OpenPorchSF                 8.935e+00  1.223e+01   0.731 0.465206
## EnclosedPorch              -4.583e-01  1.325e+01  -0.035 0.972409
## X3SsnPorch                  3.464e+01  2.394e+01   1.447 0.148136
## ScreenPorch                 4.401e+01  1.308e+01   3.365 0.000789 ***
## PoolArea                   -5.134e+01  5.820e+01  -0.882 0.377873
## PoolQC                      2.578e+04  8.932e+03   2.887 0.003962 **
## FenceGdWo                   9.896e+03  5.197e+03   1.904 0.057095 .
## FenceMnPrv                  1.192e+04  4.248e+03   2.805 0.005111 **
## FenceMnWw                   4.704e+03  8.701e+03   0.541 0.588834
## FenceNone                   9.503e+03  3.855e+03   2.465 0.013833 *
## MiscFeatureNone             8.661e+03  1.051e+05   0.082 0.934329
## MiscFeatureOthr             3.623e+04  9.510e+04   0.381 0.703271
## MiscFeatureShed             1.029e+04  1.006e+05   0.102 0.918532
## MiscFeatureTenC            -6.300e+04  9.832e+04  -0.641 0.521818
## MiscVal                     2.425e-01  6.596e+00   0.037 0.970681
## MoSold2                    -1.152e+04  4.985e+03  -2.312 0.020954 *
## MoSold3                    -6.868e+03  4.333e+03  -1.585 0.113227
## MoSold4                    -5.717e+03  4.164e+03  -1.373 0.169940
## MoSold5                    -3.687e+03  3.947e+03  -0.934 0.350409
## MoSold6                    -6.938e+03  3.889e+03  -1.784 0.074637 .
## MoSold7                    -5.202e+03  3.953e+03  -1.316 0.188441
## MoSold8                    -1.055e+04  4.214e+03  -2.503 0.012449 *
## MoSold9                    -8.938e+03  4.838e+03  -1.848 0.064902 .
## MoSold10                   -1.524e+04  4.526e+03  -3.369 0.000779 ***
## MoSold11                   -8.383e+03  4.590e+03  -1.826 0.068037 .
## MoSold12                   -9.555e+03  4.913e+03  -1.945 0.052023 .
## YrSold2007                 -1.712e+03  2.098e+03  -0.816 0.414765
## YrSold2008                  6.630e+02  2.182e+03   0.304 0.761317
## YrSold2009                 -1.097e+03  2.100e+03  -0.523 0.601368
## YrSold2010                 -3.274e+02  2.613e+03  -0.125 0.900283
## SaleTypeCon                 2.841e+04  1.882e+04   1.509 0.131464
## SaleTypeConLD               1.864e+04  1.042e+04   1.789 0.073904 .
## SaleTypeConLI               6.878e+03  1.238e+04   0.555 0.578749
## SaleTypeConLw               2.404e+03  1.272e+04   0.189 0.850082
## SaleTypeCWD                 1.803e+04  1.370e+04   1.316 0.188501
## SaleTypeNew                 4.111e+04  1.636e+04   2.512 0.012115 *
## SaleTypeOth                 1.023e+04  1.560e+04   0.656 0.512209
## SaleTypeWD                  1.885e+03  4.452e+03   0.423 0.672013
## SaleConditionAdjLand        1.302e+04  1.536e+04   0.848 0.396788
## SaleConditionAlloca         7.372e+03  9.328e+03   0.790 0.429484
## SaleConditionFamily        -4.761e+01  6.513e+03  -0.007 0.994169
## SaleConditionNormal         7.621e+03  3.082e+03   2.473 0.013538 *
## SaleConditionPartial       -1.349e+04  1.574e+04  -0.857 0.391340
## TotBathrooms                       NA         NA      NA       NA
## Remod                       3.629e+03  1.840e+03   1.972 0.048841 *
## Age                                NA         NA      NA       NA
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 24350 on 1234 degrees of freedom
## Multiple R-squared:  0.9206, Adjusted R-squared:  0.9061
## F-statistic: 63.56 on 225 and 1234 DF,  p-value: < 2.2e-16
```

```
cooksd <- cooks.distance(mod)
```

```
# All outliers
influential <- as.numeric(names(cooksd)[(cooksd > 10*mean(cooksd, na.rm=T))])  # influential row numbers
influential <- na.omit(influential)
influential
```

```
##  [1]   10   89   94  186  198  524  589  692  770  826 1045 1183 1187 1268 1444
## attr(,"na.action")
##  [1]  4  7  8  9 11 13 16 18 19 23 24 26 27 28 29 30 31
## attr(,"class")
## [1] "omit"
```

Deleting outliers

```
combined <- combined[-influential,]
```

Preparing data for modelling

Methods used in: https://topepo.github.io/caret/pre-processing.html

```
df <- df[,!names(df) %in% "Id"]
true_num_vars <- names(Filter(is.numeric,df))
num_vars <- names(Filter(is.numeric,combined)) #index vector numeric variables
factor_vars <- names(Filter(is.factor,combined))
cat('numeric variables: ', length(num_vars),' and categorical variables:',length(factor_vars),'\n')
```

```
## numeric variables:  54  and categorical variables: 25
```

Standardizing numerical predictor variables

```
library(caret)
```

```
## Warning: package 'caret' was built under R version 4.0.3
```

```
## Loading required package: lattice
```

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

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

```
library(DescTools)
```

```
## Warning: package 'DescTools' was built under R version 4.0.3
```

```
##
## Attaching package: 'DescTools'
```

```
## The following objects are masked from 'package:caret':
##
##     MAE, RMSE
```

```
nvarnames <- true_num_vars[!(true_num_vars %in% c('MSSubClass', 'MoSold', 'YrSold', 'SalePrice', 'OverallQual',
num_df <- combined[, names(combined) %in% nvarnames]
factor_df <- combined[, !(names(combined) %in% nvarnames)]
factor_df <- factor_df[, names(factor_df) != 'SalePrice']

cat('There are', length(num_df), 'numeric variables, and', length(factor_df), 'factor variables')
```

```
## There are 28 numeric variables, and 50 factor variables
```

```
for(i in 1:ncol(num_df)){
        if (abs(Skew(num_df[,i]))>0.8){
                num_df[,i] <- log(num_df[,i] +1)
        }
}

Prenum <- preProcess(num_df, method=c("center", "scale"))
print(Prenum)
```

```
## Created from 1445 samples and 28 variables
##
## Pre-processing:
##   - centered (28)
##   - ignored (0)
##   - scaled (28)
```

```
df_norm <- predict(Prenum, num_df)
dim(df_norm)
```

```
## [1] 1445   28
```

```
DFdummies <- as.data.frame(model.matrix(~.-1, factor_df))
dim(DFdummies)
```

```
## [1] 1445  203
```

```
ZerocolTest <- which(colSums(DFdummies[1:nrow(combined[!is.na(combined$SalePrice),]),])==0)
colnames(DFdummies[ZerocolTest])
```

```
## [1] "Condition2PosN"
```

```
DFdummies <- DFdummies[,-ZerocolTest] #removing predictors
fewOnes <- which(colSums(DFdummies[1:nrow(combined[!is.na(combined$SalePrice),]),])<10)
colnames(DFdummies[fewOnes])
```

```
##  [1] "MSSubClass1 story unf attic" "LotConfigFR3"
##  [3] "NeighborhoodBlueste"         "NeighborhoodNPkVill"
##  [5] "Condition1PosA"              "Condition1RRNe"
##  [7] "Condition1RRNn"              "Condition2Feedr"
##  [9] "Condition2PosA"              "Condition2RRAe"
## [11] "Condition2RRAn"              "Condition2RRNn"
## [13] "HouseStyle2.5Fin"            "RoofStyleMansard"
## [15] "RoofStyleShed"               "RoofMatlMembran"
## [17] "RoofMatlMetal"               "RoofMatlRoll"
## [19] "RoofMatlWdShake"             "RoofMatlWdShngl"
## [21] "Exterior1stAsphShn"          "Exterior1stBrkComm"
## [23] "Exterior1stCBlock"           "Exterior1stImStucc"
## [25] "Exterior1stStone"            "Exterior2ndAsphShn"
## [27] "Exterior2ndBrk Cmn"          "Exterior2ndCBlock"
## [29] "Exterior2ndImStucc"          "Exterior2ndOther"
## [31] "Exterior2ndStone"            "FoundationStone"
## [33] "FoundationWood"              "HeatingGrav"
## [35] "HeatingOthW"                 "HeatingWall"
## [37] "ElectricalFuseP"             "ElectricalMix"
## [39] "GarageTypeCarPort"           "MiscFeatureOthr"
## [41] "MiscFeatureTenC"             "SaleTypeCon"
## [43] "SaleTypeConLD"               "SaleTypeConLI"
## [45] "SaleTypeConLw"               "SaleTypeCWD"
## [47] "SaleTypeOth"                 "SaleConditionAdjLand"
## [49] "Age"
```

```
DFdummies <- DFdummies[,-fewOnes] #removing predictors
dim(DFdummies)
```

```
## [1] 1445  153
```

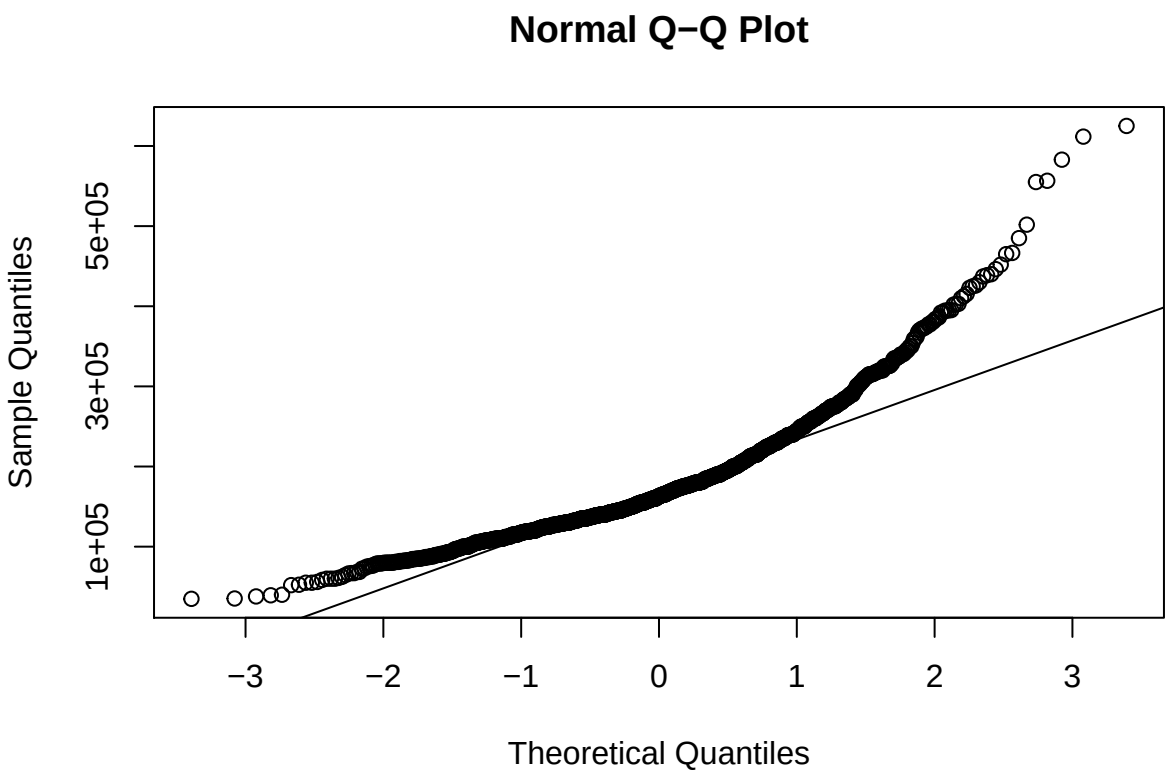
```
final <- cbind(num_df, DFdummies)
```

Transforming SalePrice variable

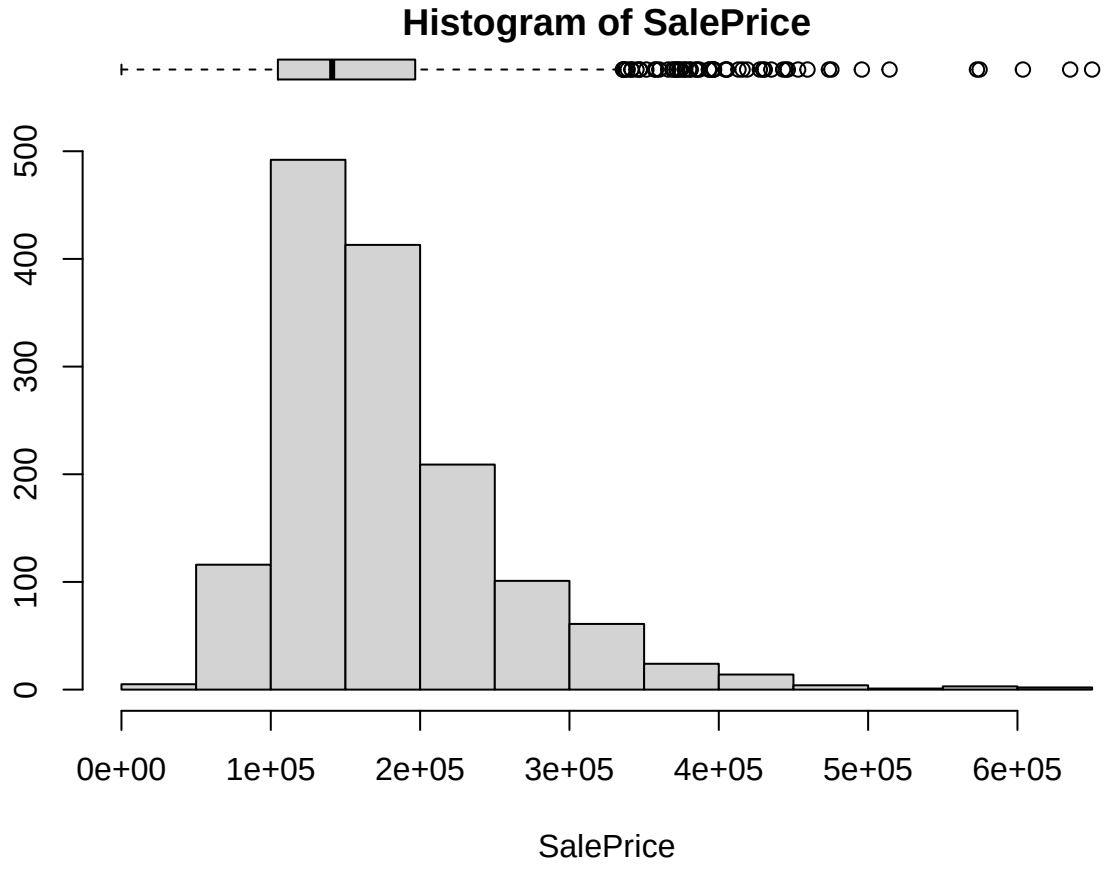
```
Skew(combined$SalePrice)
```

```
## [1] 1.536502
```

```
qqnorm(combined$SalePrice)
qqline(combined$SalePrice)
```



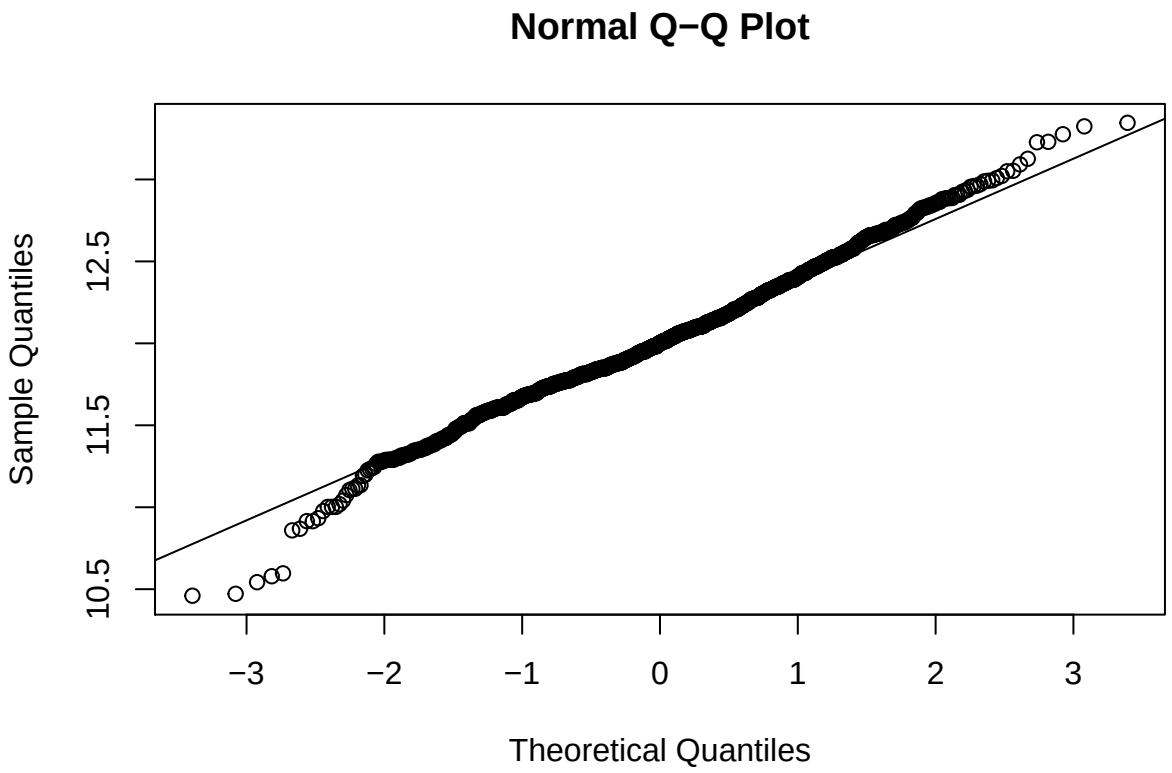

```
layout(mat = matrix(c(1,2),2,1, byrow=TRUE), height = c(1,8))
par(mar=c(0, 3.1, 1.1, 2.1))
boxplot(combined$SalePrice , horizontal=TRUE , xaxt="n", frame=F, main=sprintf('Histogram of SalePrice'))
par(mar=c(4, 3.1, 1.1, 2.1))
hist(combined$SalePrice,main='', xlab = "SalePrice", ylab = "count")
```



```
combined$SalePrice <- log(combined$SalePrice)
Skew(combined$SalePrice)
```

```
## [1] 0.04044969
```

```
qqnorm(combined$SalePrice)
qqline(combined$SalePrice)
```




```
layout(mat = matrix(c(1,2),2,1, byrow=TRUE), height = c(1,8))
par(mar=c(0, 3.1, 1.1, 2.1))
boxplot(combined$SalePrice , horizontal=TRUE , xaxt="n", frame=F, main=sprintf('Histogram of SalePrice'))
par(mar=c(4, 3.1, 1.1, 2.1))
hist(combined$SalePrice,main='', xlab = "SalePrice", ylab = "count")
```


```
final_df <- final
final_df$SalePrice <- combined$SalePrice
```

Train and test data

```
library(caret)
set.seed(1)
train_rows <- createDataPartition(y=final_df[,'SalePrice'], list=FALSE, p=.8)
train_dummy <- final_df[train_rows,]
test_dummy <- final_df[-train_rows,]
stopifnot(nrow(train_dummy) + nrow(test_dummy) == nrow(final_df))
write.csv(train_dummy, "../data/processed/train_data_with_dummy.csv")
write.csv(test_dummy, "../data/processed/test_data_with_dummy.csv")

train_rows <- createDataPartition(y=combined[,'SalePrice'], list=FALSE, p=.8)
train <- combined[train_rows,]
test <- combined[-train_rows,]
stopifnot(nrow(train) + nrow(test) == nrow(combined))
write.csv(train, "../data/processed/train_data.csv")
write.csv(test, "../data/processed/test_data.csv")
```

Modelling

Ridge regression

Multiple linear regression

Variable selection

install.packages("randomForest")

http://r-statistics.co/Variable-Selection-and-Importance-With-R.html

Random forest model

```
library(randomForest)
```

```
## Warning: package 'randomForest' was built under R version 4.0.3
```

```
## randomForest 4.6-14
```

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

```
##
## Attaching package: 'randomForest'
```

```
## The following object is masked from 'package:gridExtra':
##
##     combine
```

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

```
set.seed(2018)
fit <- randomForest(SalePrice~.,data = train, ntree = 500, mtry = 8, importance = TRUE)
fit
```

```
##
## Call:
##  randomForest(formula = SalePrice ~ ., data = train, ntree = 500,      mtry = 8, importance = TRUE)
##                Type of random forest: regression
##                      Number of trees: 500
## No. of variables tried at each split: 8
##
##           Mean of squared residuals: 0.01952665
##                     % Var explained: 87.39
```

Variable importance plot

```
library(dplyr)
```

```
## Warning: package 'dplyr' was built under R version 4.0.3
```

```
##
## Attaching package: 'dplyr'
```

```
## The following object is masked from 'package:randomForest':
##
##     combine
```

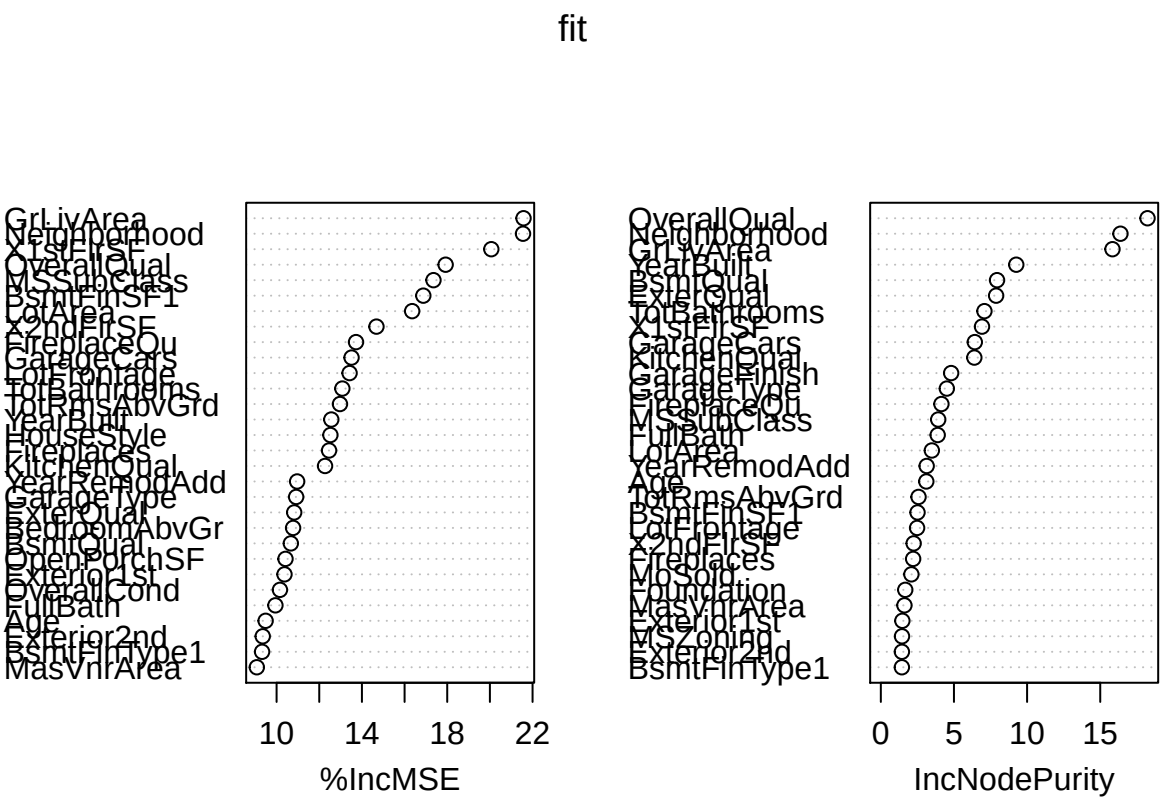
```
## The following object is masked from 'package:gridExtra':
##
##     combine
```

```
## The following objects are masked from 'package:plyr':
##
##     arrange, count, desc, failwith, id, mutate, rename, summarise,
##     summarize

## The following objects are masked from 'package:stats':
##
##     filter, lag

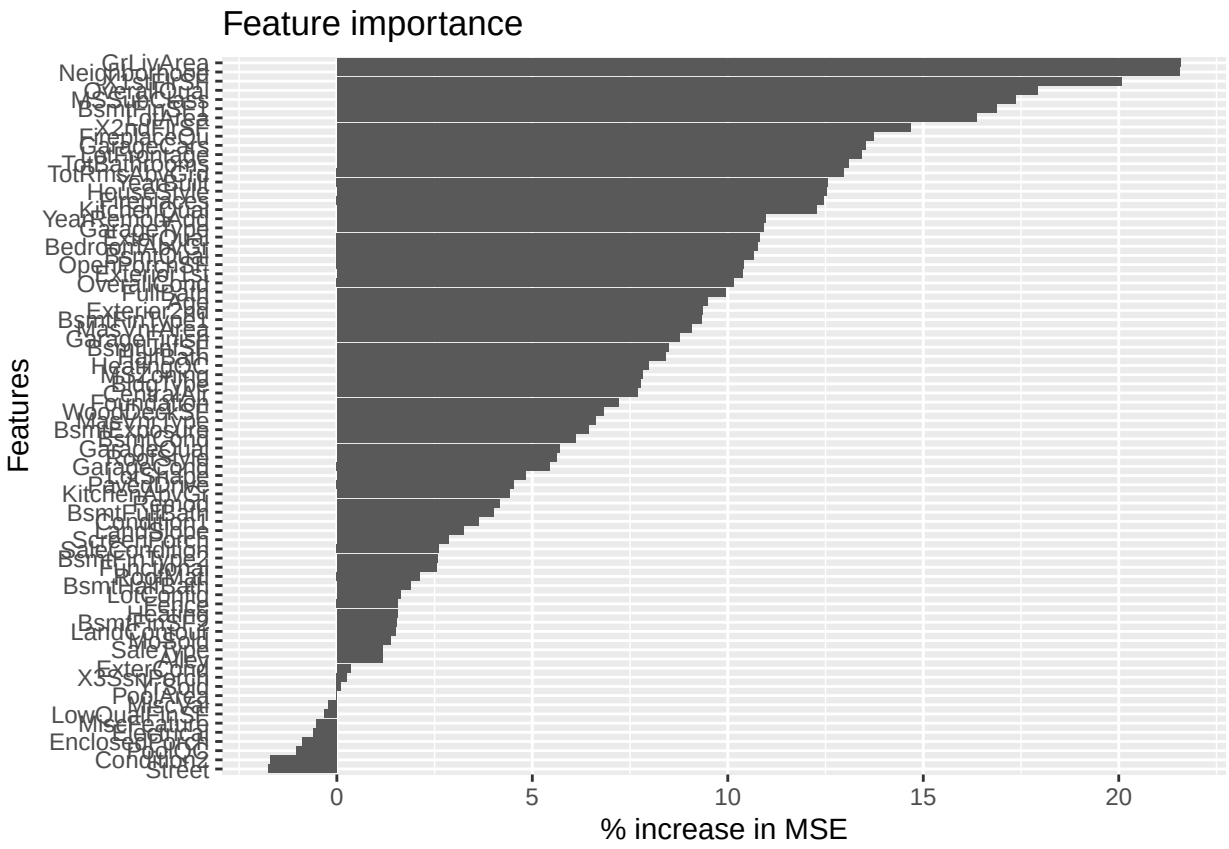
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
library(ggplot2)
library(randomForest)
varImpPlot(fit)
```




```
feat_imp_df<-importance(fit) %>% data.frame() %>% mutate(feature= row.names(.))

ggplot(feat_imp_df, aes(x = reorder(feature,X.IncMSE),
                        y = X.IncMSE)) +
    geom_bar(stat='identity') +
    coord_flip() +
  labs(y = "% increase in MSE", x = "Features", title = "Feature importance")
```



Top 20 Important variables

```
imp_vars <-importance(fit)
imp_vars <- sort(imp_vars[,1],decreasing = TRUE)
imp_vars <- imp_vars[1:20]
imp_vars
```

```
##    GrLivArea Neighborhood    X1stFlrSF  OverallQual   MSSubClass   BsmtFinSF1
##     21.57615     21.55200     20.06574     17.92493     17.35446     16.87789
##      LotArea    X2ndFlrSF  FireplaceQu   GarageCars  LotFrontage TotBathrooms
##     16.35601     14.68092     13.72321     13.51319     13.42070     13.08208
## TotRmsAbvGrd    YearBuilt   HouseStyle   Fireplaces  KitchenQual YearRemodAdd
##     12.97067     12.56491     12.52261     12.45985     12.27068     10.96350
##   GarageType    ExterQual
##     10.91715     10.82503
```

RF model assesment

```
pred_values = exp(predict(fit,test[,!names(test) %in% "SalePrice"]))
actual_values = exp(test$SalePrice)
rmse_rf <- sqrt(mean((actual_values -pred_values)^2))
rmse_rf
```

```
## [1] 25086.3
```

```
rss <- sum((pred_values - actual_values) ^ 2)  ## residual sum of squares
tss <- sum((actual_values - mean(actual_values)) ^ 2)  ## total sum of squares
rsq_rf <- 1 - rss/tss
rsq_rf
```

```
## [1] 0.8805027
```

Gradient boosting

for gradient boosting tutorial https://xgboost.readthedocs.io/en/latest/R-package/xgboostPresentation.html

Default gradient boosting model

```
label_train <- train_dummy$SalePrice
```

```
library(xgboost)
```

```
## Warning: package 'xgboost' was built under R version 4.0.3
```

```
##
## Attaching package: 'xgboost'
```

```
## The following object is masked from 'package:dplyr':
##
##     slice
```

```
# train and test data for xgb model
dtrain <- xgb.DMatrix(data = as.matrix(train_dummy[,!names(train_dummy) %in% "SalePrice"]), label = label_train)
dtest <- xgb.DMatrix(data = as.matrix(test_dummy[,!names(test_dummy) %in% "SalePrice"]))
default_param<-list(
        objective = "reg:squarederror",
        booster = "gbtree",
        eta=0.3, #default = 0.3
        gamma=0,
        max_depth=6, #default=6
        min_child_weight=1, #default=1
        subsample=1,
        colsample_bytree=1
)
# cross validation for number of rounds
xgbcv <- xgb.cv( params = default_param, data = dtrain, nrounds = 500, nfold = 5, showsd = T, stratified = T, pr
```

```
## [1]  train-rmse:8.079474+0.005488    test-rmse:8.079386+0.033445
## Multiple eval metrics are present. Will use test_rmse for early stopping.
## Will train until test_rmse hasn't improved in 10 rounds.
##
## [41] train-rmse:0.025693+0.000582    test-rmse:0.133142+0.010485
## Stopping. Best iteration:
## [60] train-rmse:0.014405+0.000548    test-rmse:0.132703+0.010982
```

we got a train-rmse of 0.014953 and a test-rmse of 0.143685.

Tuning hyperparameters

```
set.seed(1)
grid = expand.grid(
nrounds = 50,
eta = c(0.1, 0.05, 0.01),
max_depth = c(2, 3, 4, 5, 6),
```

```
gamma = 0,
colsample_bytree=1,
min_child_weight=c(1, 2, 3, 4 ,5),
subsample=1
)
cv_control <-trainControl(method="cv", number=5)
calibration_model <- train(x=train_dummy[,!names(train_dummy) %in% "SalePrice"], y=train_dummy$SalePrice, method
```

```
## [15:49:30] WARNING: amalgamation/../src/objective/regression_obj.cu:174: reg:linear is now deprecated in favo
## [15:49:30] WARNING: amalgamation/../src/objective/regression_obj.cu:174: reg:linear is now deprecated in favo
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```

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```

```
calibration_model$bestTune
```

```
##    nrounds max_depth eta gamma colsample_bytree min_child_weight subsample
## 68      50         5 0.1     0                1                3         1
```

```
default_param<-list(
        objective = "reg:squarederror",
        booster = "gbtree",
        eta=0.1, #default = 0.3
        gamma=0,
        max_depth=5, #default=6
        min_child_weight=2, #default=1
        subsample=1,
        colsample_bytree=1
)
# cross validation for number of rounds
xgbcv <- xgb.cv( params = default_param, data = dtrain, nrounds = 500, nfold = 5, showsd = T, stratified = T, pr
```

```
## [1]  train-rmse:10.379434+0.003790   test-rmse:10.379425+0.017329
## Multiple eval metrics are present. Will use test_rmse for early stopping.
## Will train until test_rmse hasn't improved in 10 rounds.
##
## [41] train-rmse:0.186850+0.000559    test-rmse:0.210695+0.014535
## [81] train-rmse:0.056656+0.000625    test-rmse:0.124944+0.012943
## Stopping. Best iteration:
## [106]    train-rmse:0.046546+0.000846    test-rmse:0.123467+0.013547
```

After tuning the model parameters we got train-rmse: 0.047392 and test-rmse: 0.137014 which is an improvement on the test-rmse when compared to the default training prarmeter values.

```
xgb_model <- xgb.train(data = dtrain, params=default_param, nrounds = 61)
XGBpred <- exp(predict(xgb_model, dtest))
```

```
actual <- exp(test_dummy$SalePrice)
rmse <- sqrt(mean((actual -XGBpred)^2))
rmse
```

```
## [1] 21508.53
```

```r
rss <- sum((XGBpred - actual) ^ 2)  ## residual sum of squares
tss <- sum((actual - mean(actual)) ^ 2)  ## total sum of squares
rsq <- 1 - rss/tss
rsq
```

```
## [1] 0.8972486
```

```r
head(data.frame(actual,XGBpred))
```

```
##   actual   XGBpred
## 1 250000 291646.78
## 2 307000 266833.97
## 3 325300 335387.71
## 4 129900 128273.87
## 5  68500  72286.57
## 6  40000  80476.01
```

Results