STATGR5205: Code File

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2025-12-19

```
library(gt)
library(dplyr)
library(tidyr)
library(corrplot)
library(car)
library(MASS)
library(lmtest)
library(ggplot2)
library(caret)
```

```
file_path <- 'project_data.csv'
df <- read.csv(file_path, header=TRUE)
str(df)
```

```
'data.frame':   182 obs. of  7 variables:
 $ zip_code           : int  10001 10002 10003 10004 10005 10006 10007 10009 10010 10011 ...
 $ inspections        : int  182 3922 2576 18 27 5 133 3296 93 1208 ...
 $ population         : int  27004 76518 53877 4579 8801 3736 7506 58418 32410 50772 ...
 $ has_garage         : int  0 1 0 0 0 0 0 0 0 0 ...
 $ has_dropoff        : int  1 1 1 0 0 1 0 1 1 1 ...
 $ litter_basket_count: int  76 261 327 42 17 46 59 193 234 195 ...
 $ total_park_acres   : num  14.561 90.192 13.712 23.624 0.117 ...
```

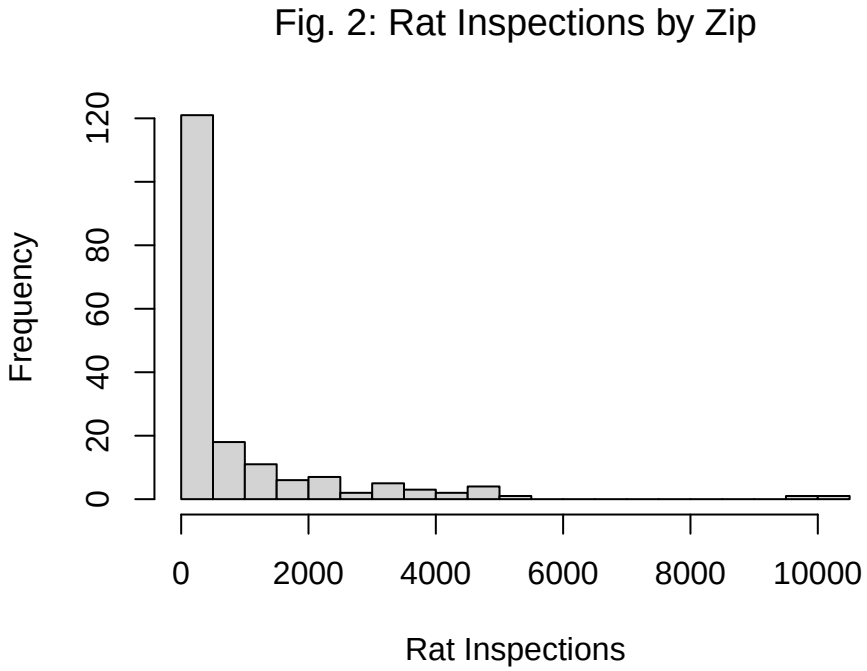
```
df <- df %>%
  rename(pop = population, garage = has_garage, dropoff = has_dropoff,
     baskets = litter_basket_count, park_acres = total_park_acres
  )
```

```
# ----- Summary Statistics of Continuous Variables ----- #
df %>%
  summarise(across(c(inspections, pop, baskets, park_acres),
     list(Median = median, Mean = mean, SD = sd, Min = min, Max = max))) %>%
  pivot_longer(everything(), names_to = c("Variable", "Statistic"),
     names_pattern = "(.+)_(\\w+)$", values_to = "Value") %>%
  pivot_wider(names_from = Statistic, values_from = Value) %>%
  gt() %>%
  tab_header(title = "Fig. 1: Descriptive Statistics") %>%
  fmt_number(columns = c(Median, Mean, SD, Min, Max), decimals = 2)
```

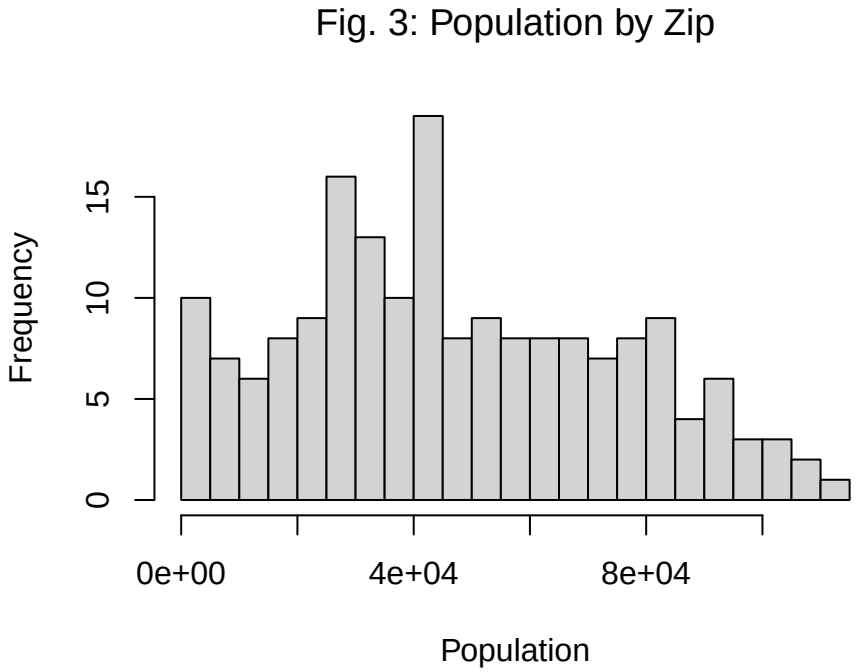
Fig. 1: Descriptive Statistics

Variable	Median	Mean	SD	Min	Max
inspections	183.00	855.35	1,527.77	1.00	10,373.00
pop	43,165.50	47,196.59	27,434.76	0.00	112,750.00
baskets	103.50	122.38	86.90	0.00	447.00
park_acres	105.24	464.02	784.66	0.00	5,558.26

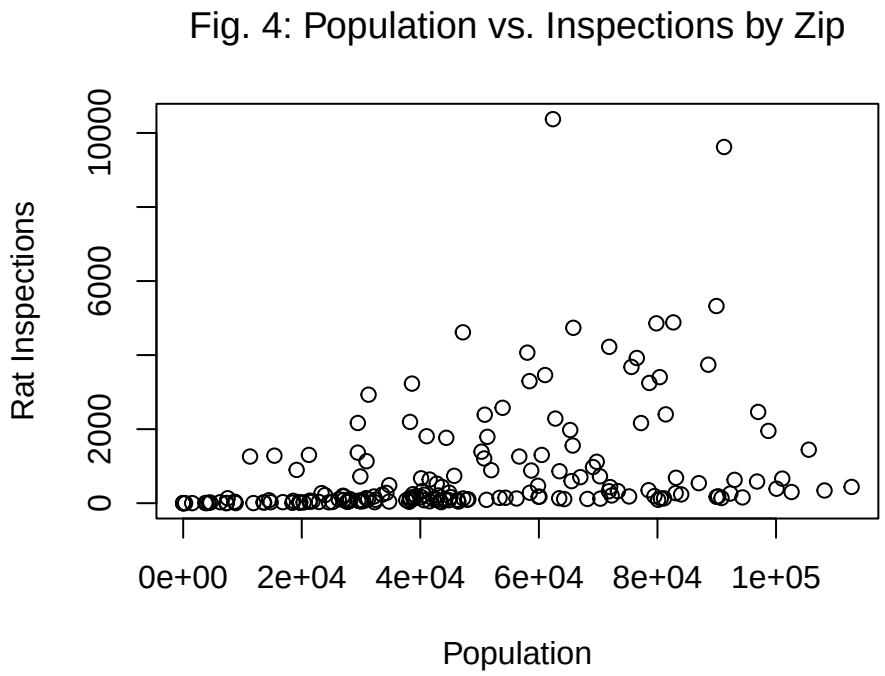
```r
# ----- Exploratory Data Analysis ----- #
hist(df$inspections, main = "Fig. 2: Rat Inspections by Zip",
     xlab = "Rat Inspections", ylab = "Frequency", breaks = 20, font.main = 1)
```



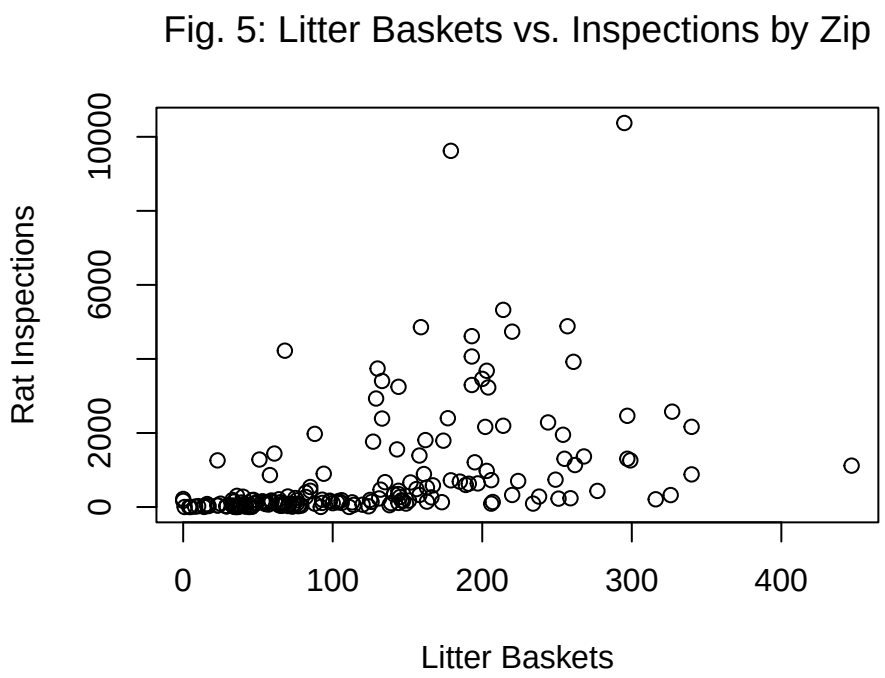

```r
hist(df$pop, main = "Fig. 3: Population by Zip",
     xlab = "Population", ylab = "Frequency", breaks = 20, font.main = 1)
```



```r
plot(df$pop, df$inspections, xlab='Population', ylab='Rat Inspections',
     main='Fig. 4: Population vs. Inspections by Zip', font.main = 1)
```

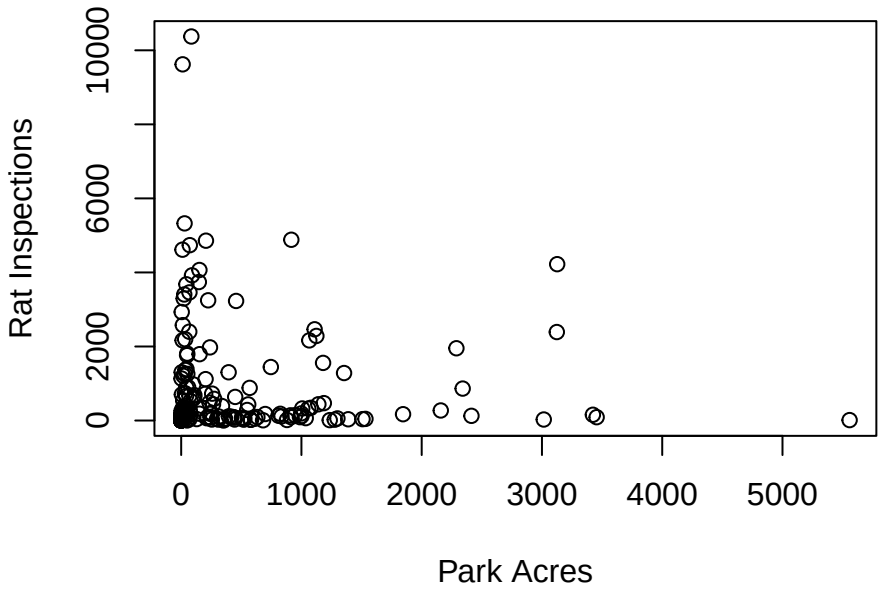



```r
plot(df$baskets, df$inspections, xlab='Litter Baskets', ylab='Rat Inspections',
     main='Fig. 5: Litter Baskets vs. Inspections by Zip', font.main = 1)
```



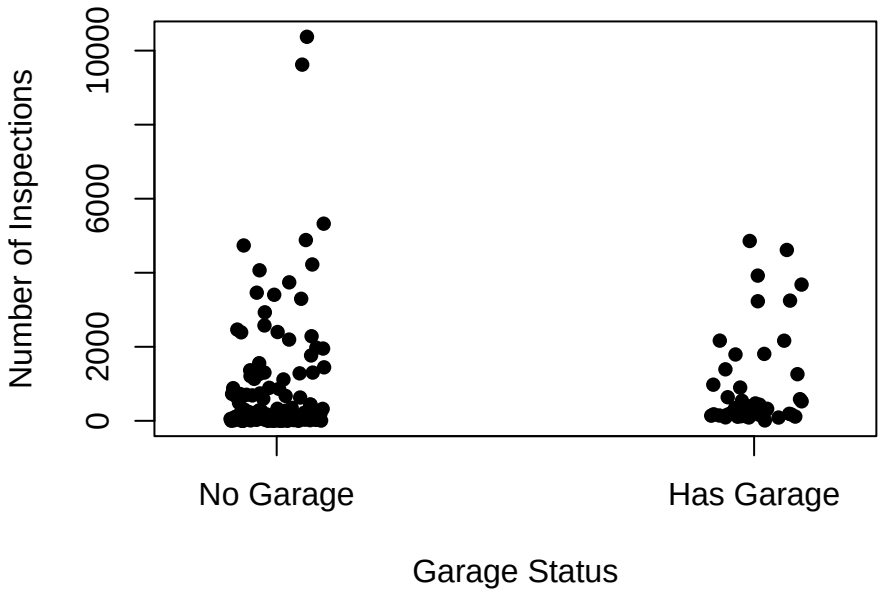
```r
plot(df$park_acres, df$inspections, xlab='Park Acres', ylab='Rat Inspections',
     main='Fig. 6: Park Acres vs. Inspections by Zip', font.main = 1)
```

Fig. 6: Park Acres vs. Inspections by Zip

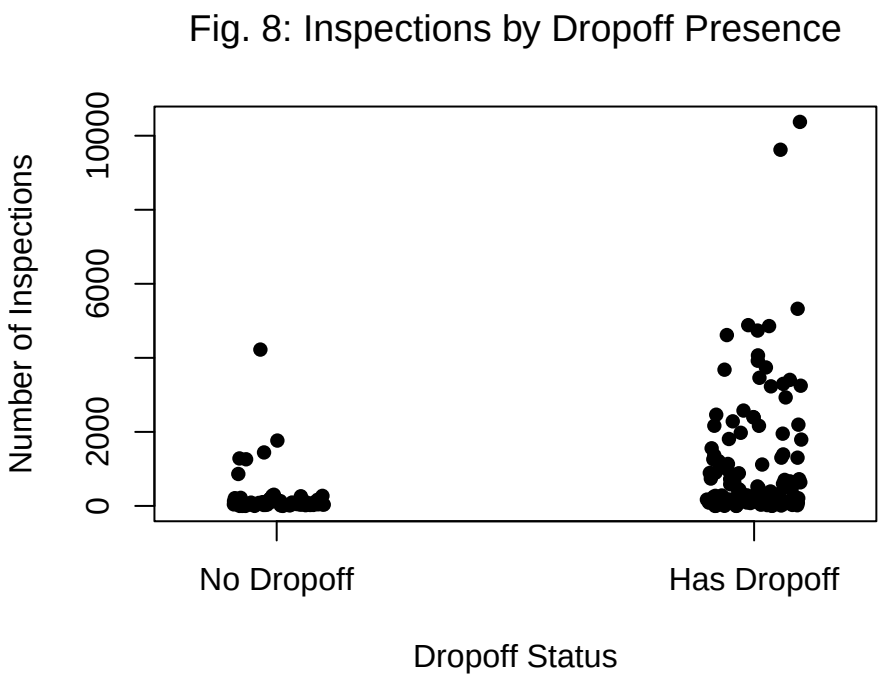



```r
df$has_garage_label <- factor(df$garage, levels = c(0, 1),
     labels = c("No Garage", "Has Garage"))

stripchart(inspections ~ has_garage_label, vertical=TRUE, method='jitter', pch=16,
     data = df, main = "Fig. 7: Inspections by Garage Presence", font.main = 1,
     xlab = "Garage Status", ylab = "Number of Inspections")
```

Fig. 7: Inspections by Garage Presence



```r
df$has_dropoff_label <- factor(df$dropoff, levels = c(0, 1),
     labels = c("No Dropoff", "Has Dropoff"))

stripchart(inspections ~ has_dropoff_label, vertical=TRUE, method='jitter', pch=16,
     data = df, main = "Fig. 8: Inspections by Dropoff Presence", font.main = 1,
     xlab = "Dropoff Status", ylab = "Number of Inspections")
```

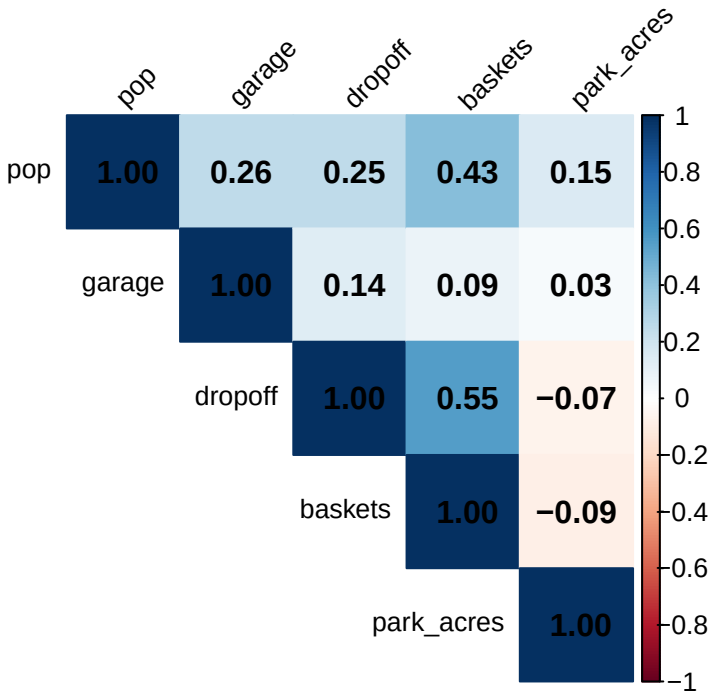



```r
# ----- Initial Regression Model ----- #
model <- lm(inspections ~ pop + garage + dropoff + baskets + park_acres, data=df)
summary(model)
```

```
Call:
lm(formula = inspections ~ pop + garage + dropoff + baskets +
    park_acres, data = df)

Residuals:
    Min      1Q  Median      3Q     Max
-1997.8  -633.4  -234.7   241.0  8250.1

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept) -4.737e+02  2.283e+02  -2.075 0.039485 *
pop          1.221e-02  4.273e-03   2.857 0.004797 **
garage      -1.085e+02  2.474e+02  -0.439 0.661379
dropoff      2.390e+02  2.520e+02   0.949 0.344166
baskets      5.436e+00  1.503e+00   3.618 0.000388 ***
park_acres  -8.829e-02  1.315e-01  -0.671 0.502983
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1352 on 176 degrees of freedom
Multiple R-squared:  0.2389,    Adjusted R-squared:  0.2173
F-statistic: 11.05 on 5 and 176 DF,  p-value: 2.869e-09
```

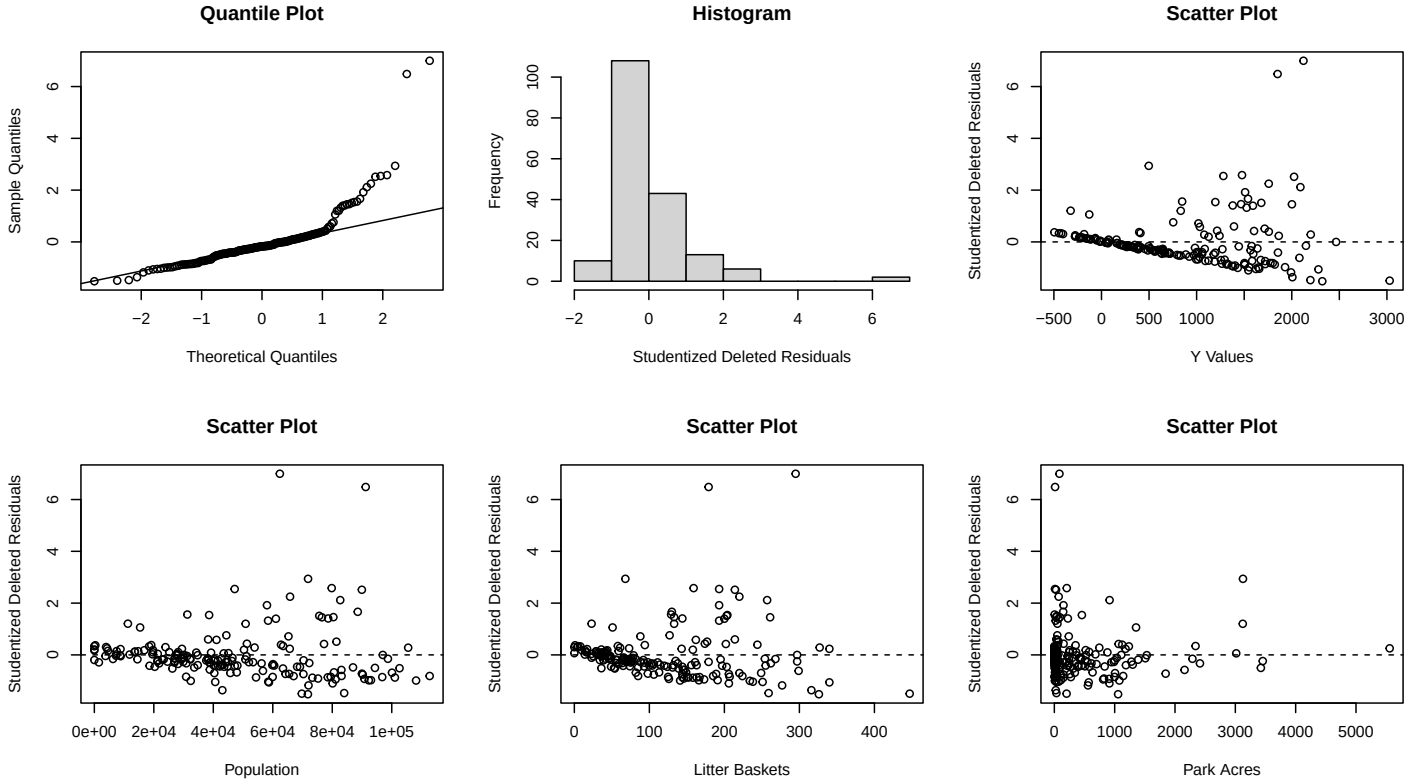
```r
# ----- Correlation Matrix ----- #
X <- model.matrix(model)[, -1]
cor_matrix <- cor(X)
corrplot(cor_matrix, method = "color", type = "upper", font.main = 1,
   addCoef.col = "black", tl.col = "black", tl.cex = 0.8, tl.srt = 45,
   title = "Fig. 9: Correlation Matrix of Predictor Variables", mar = c(0, 0, 2, 0))
```

Fig. 9: Correlation Matrix of Predictor Variables




```r
# ----- Residual Analysis of Initial Model ----- #
stud_res <- rstudent(model)
y_hat <- fitted(model)

par(mfrow = c(2, 3), oma = c(0, 0, 2, 0))

qqnorm(stud_res, main = 'Quantile Plot')
qqline(stud_res, col='black')

hist(stud_res, main = 'Histogram',
     xlab = 'Studentized Deleted Residuals', breaks = 10)

plot(y_hat, stud_res, main = 'Scatter Plot',
     xlab = 'Y Values', ylab = 'Studentized Deleted Residuals')
abline(h=0, col='black', lty=2)

plot(df$pop, stud_res, main = 'Scatter Plot',
     xlab = 'Population', ylab = 'Studentized Deleted Residuals')
abline(h=0, col='black', lty=2)

plot(df$baskets, stud_res, main = 'Scatter Plot',
     xlab = 'Litter Baskets', ylab = 'Studentized Deleted Residuals')
abline(h=0, col='black', lty=2)

plot(df$park_acres, stud_res, main = 'Scatter Plot',
     xlab = 'Park Acres', ylab = 'Studentized Deleted Residuals')
abline(h=0, col='black', lty=2)

mtext("Fig. 10: Residual Plots", outer = TRUE, cex = 1.75)
```

Fig. 10: Residual Plots




```
par(mfrow = c(1, 1))
```

```
# ----- Test for Homogeneity of Variance ----- #
bptest(model, studentize = TRUE)
```

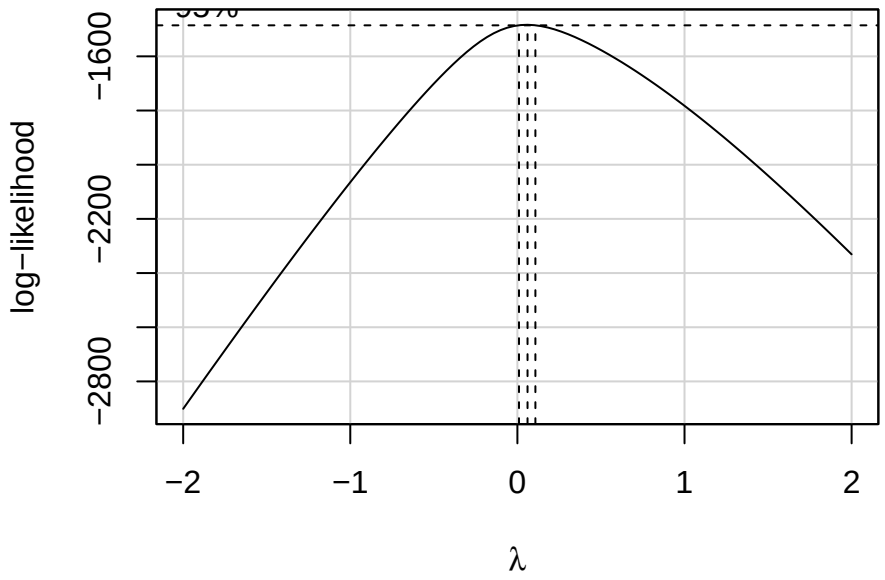
```
    studentized Breusch-Pagan test

data:  model
BP = 14.859, df = 5, p-value = 0.01098
```

```
# ----- Test for Normality ----- #
shapiro.test(rstudent(model))
```

```
    Shapiro-Wilk normality test

data:  rstudent(model)
W = 0.71671, p-value < 2.2e-16
```

```
# ----- Box Cox Transformation ----- #
result <- boxCox(model, main = "Fig. 11: Box-Cox Transformation", font.main = 1)
```

Fig. 11: Box−Cox Transformation




```
lambda <- result$x[which.max(result$y)]
lambda
```

```
[1] 0.06060606
```

```
# ----- Taking the Log of Inspections ----- #
any(df$inspections <= 0)
```

```
[1] FALSE
```

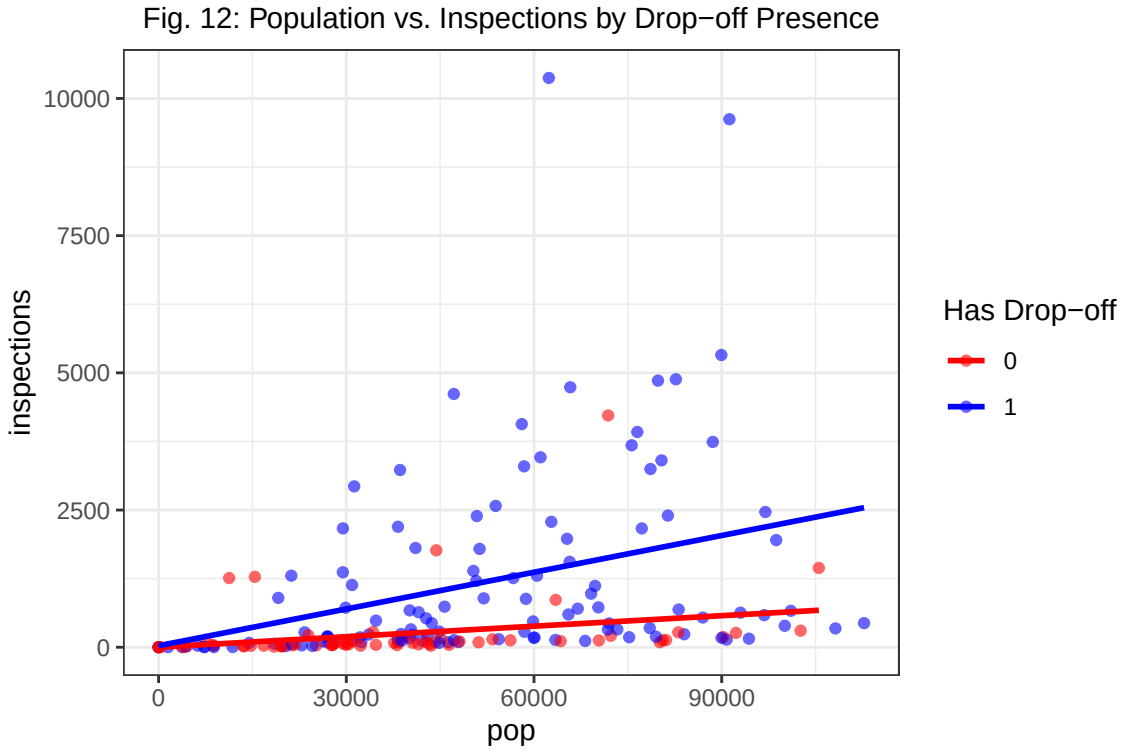
```
df$log_inspections <- log(df$inspections)

log_model <- lm(log_inspections ~ pop + garage + dropoff + baskets + park_acres, data=df)
summary(log_model)
```

```
Call:
lm(formula = log_inspections ~ pop + garage + dropoff + baskets +
    park_acres, data = df)

Residuals:
    Min      1Q  Median      3Q     Max
-3.3802 -0.7866 -0.0315  0.8773  3.9197

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  2.471e+00  2.238e-01  11.042  < 2e-16 ***
pop          3.156e-05  4.188e-06   7.537 2.45e-12 ***
garage       2.913e-01  2.425e-01   1.202    0.231
dropoff      3.664e-01  2.470e-01   1.484    0.140
baskets      8.949e-03  1.473e-03   6.076 7.41e-09 ***
park_acres  -1.297e-04  1.289e-04  -1.006    0.316
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 1.325 on 176 degrees of freedom
Multiple R-squared:  0.5724,    Adjusted R-squared:  0.5602
F-statistic: 47.11 on 5 and 176 DF,  p-value: < 2.2e-16
```

```r
# ----- Examining Interaction Effects ----- #
ggplot(df, aes(x = pop, y = inspections, color = factor(dropoff))) +
  geom_point(alpha = 0.6) +
  geom_smooth(method = "lm", se = FALSE) +
  labs(color = "Has Drop-off",
    title = "Fig. 12: Population vs. Inspections by Drop-off Presence") +
  theme_bw() + theme(plot.title = element_text(hjust = 0.5, size = 11)) +
  scale_color_manual(values = c("red", "blue"))
```

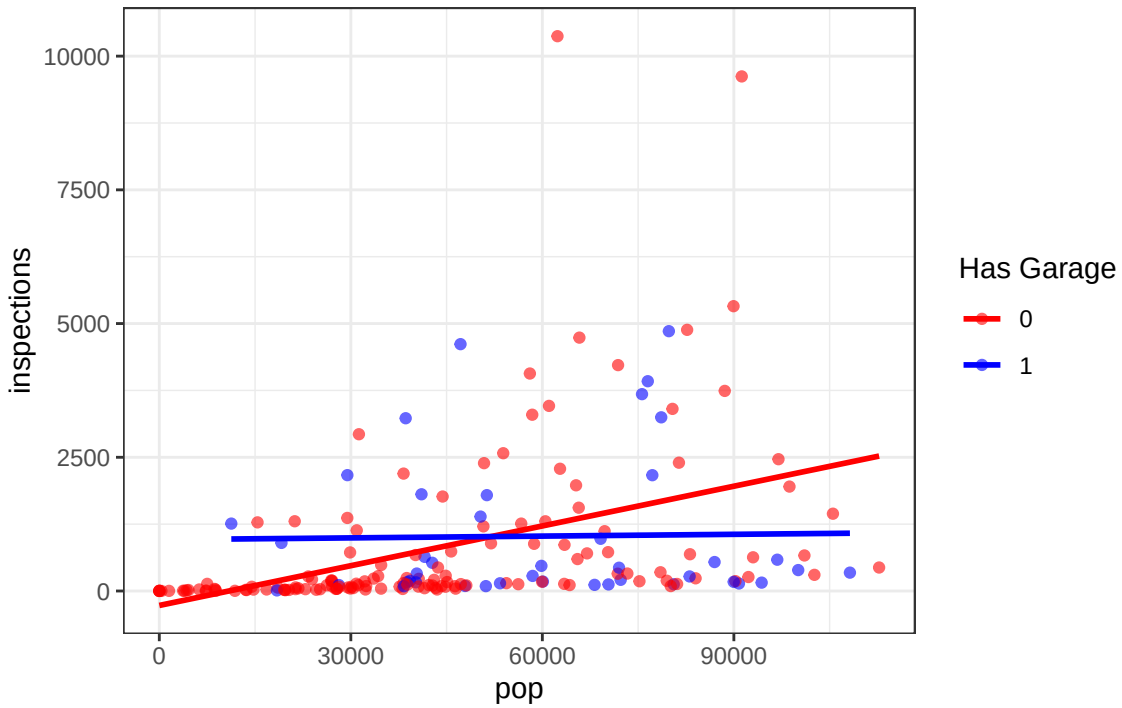
```
`geom_smooth()` using formula = 'y ~ x'
```




```r
ggplot(df, aes(x = pop, y = inspections, color = factor(garage))) +
  geom_point(alpha = 0.6) +
  geom_smooth(method = "lm", se = FALSE) +
  labs(
    color = "Has Garage",
    title = "Fig. 13: Population vs. Inspections by Garage Presence") +
  theme_bw() +
  theme(plot.title = element_text(hjust = 0.5, size = 11)) +
  scale_color_manual(values = c("red", "blue"))
```

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

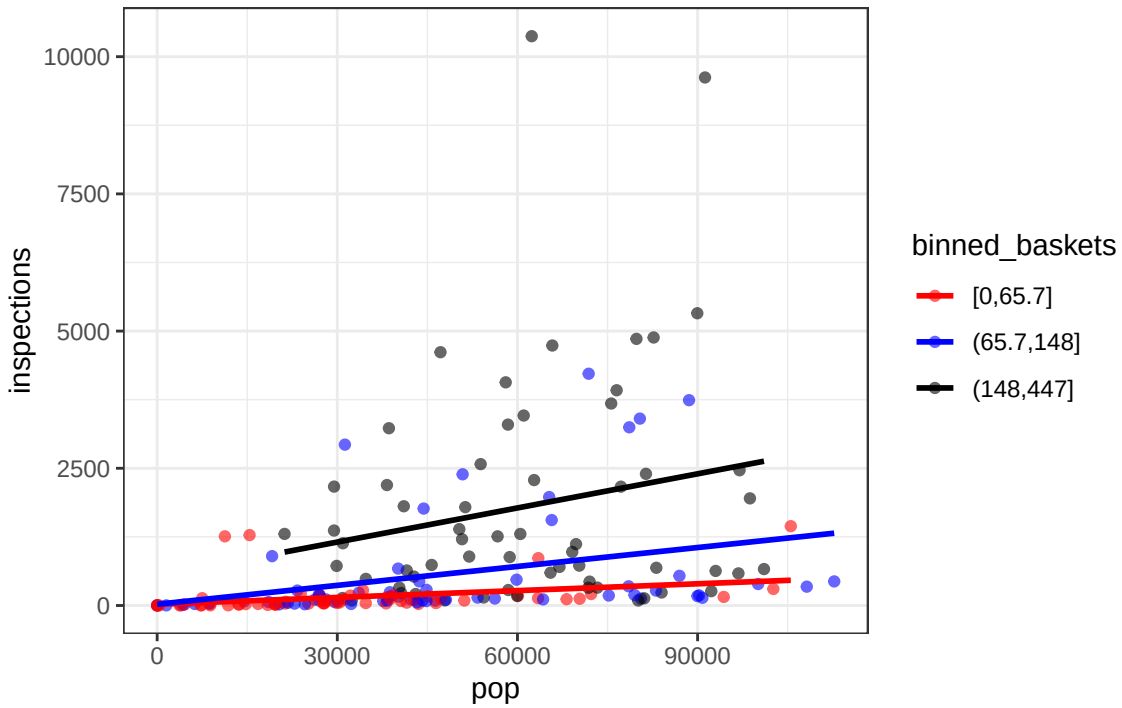
Fig. 13: Population vs. Inspections by Garage Presence




```
df$binned_baskets = cut(df$baskets,
  breaks = quantile(df$baskets, probs = c(0, .33, .66, 1)),
  include.lowest = TRUE
)
ggplot(df, aes(x = pop, y = inspections, color = binned_baskets)) +
  geom_point(alpha = 0.6) +
  geom_smooth(method = "lm", se = FALSE) +
  labs(
    title = "Fig. 14: Population vs. Inspections by Baskets") + theme_bw() +
  theme(plot.title = element_text(hjust = 0.5, size = 11)) +
  scale_color_manual(values = c("red", "blue", "black"))
```

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

Fig. 14: Population vs. Inspections by Baskets




```r
# ----- Centered Model with Interactions ----- #
df$pop_c <- scale(df$pop, scale = FALSE)
df$baskets_c <- scale(df$baskets, scale = FALSE)

centered_log_int_model <- lm(log_inspections ~ pop_c*baskets_c + pop_c*garage + pop_c*dropoff, data = df)
summary(centered_log_int_model)
```

```
Call:
lm(formula = log_inspections ~ pop_c * baskets_c + pop_c * garage +
    pop_c * dropoff, data = df)

Residuals:
    Min      1Q  Median      3Q     Max
-2.6838 -0.8749 -0.0424  0.7894  3.8343

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)      5.181e+00  1.897e-01  27.314  < 2e-16 ***
pop_c            2.275e-05  6.835e-06   3.329  0.00106 **
baskets_c        8.746e-03  1.392e-03   6.285 2.55e-09 ***
garage           4.703e-01  2.410e-01   1.951  0.05267 .
dropoff          4.400e-01  2.304e-01   1.910  0.05782 .
pop_c:baskets_c -2.247e-07  5.345e-08  -4.204 4.18e-05 ***
pop_c:garage    -3.992e-05  9.040e-06  -4.416 1.76e-05 ***
pop_c:dropoff    2.184e-05  8.166e-06   2.675  0.00818 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.215 on 174 degrees of freedom
Multiple R-squared:  0.6445,    Adjusted R-squared:  0.6302
F-statistic: 45.06 on 7 and 174 DF,  p-value: < 2.2e-16
```

```r
vif_values <- vif(centered_log_int_model)
```

```
there are higher-order terms (interactions) in this model
consider setting type = 'predictor'; see ?vif
```

```r
mean(vif_values)
```

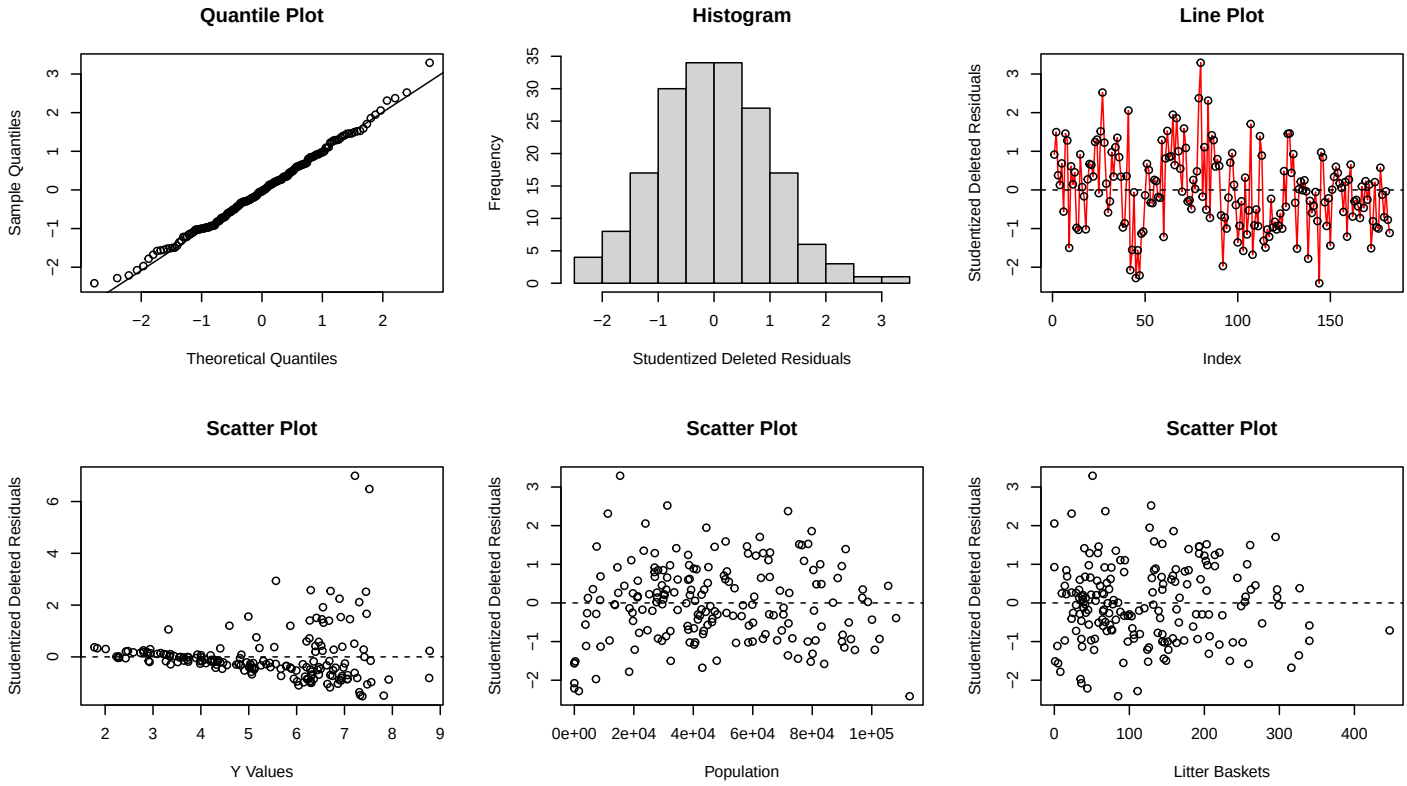
```
[1] 2.241026
```

```r
# ----- ANOVA ----- #
anova(log_model, centered_log_int_model)
```

```
Analysis of Variance Table

Model 1: log_inspections ~ pop + garage + dropoff + baskets + park_acres
Model 2: log_inspections ~ pop_c * baskets_c + pop_c * garage + pop_c *
    dropoff
  Res.Df    RSS Df Sum of Sq      F    Pr(>F)
1    176 308.86
2    174 256.76  2    52.099 17.653 1.046e-07 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# ----- Residual Analysis for Final Model ----- #
final_stud_res <- rstudent(centered_log_int_model)
final_y_hat <- fitted(centered_log_int_model)

par(mfrow = c(2, 3), oma = c(0, 0, 2, 0))

qqnorm(final_stud_res, main = 'Quantile Plot')
qqline(final_stud_res, col='black')

hist(final_stud_res, main = 'Histogram',
     xlab = 'Studentized Deleted Residuals', breaks = 10)

plot(final_stud_res, type = 'l', main = 'Line Plot',
    ylab = 'Studentized Deleted Residuals', col='red')
points(final_stud_res, col = 'black')
abline(h=0, col='black', lty=2)

plot(final_y_hat, stud_res, main = 'Scatter Plot',
     xlab = 'Y Values', ylab = 'Studentized Deleted Residuals')
abline(h=0, col='black', lty=2)

plot(df$pop, final_stud_res, main = 'Scatter Plot',
     xlab = 'Population', ylab = 'Studentized Deleted Residuals')
abline(h=0, col='black', lty=2)

plot(df$baskets, final_stud_res, main = 'Scatter Plot',
     xlab = 'Litter Baskets', ylab = 'Studentized Deleted Residuals')
abline(h=0, col='black', lty=2)

mtext("Fig. 15: Residual Plots", outer = TRUE, cex = 1.75)
```

Fig. 15: Residual Plots




```
par(mfrow = c(1, 1))
```

```
# ----- Test for Homogeneity of Variance ----- #
bptest(centered_log_int_model, studentize = TRUE)
```

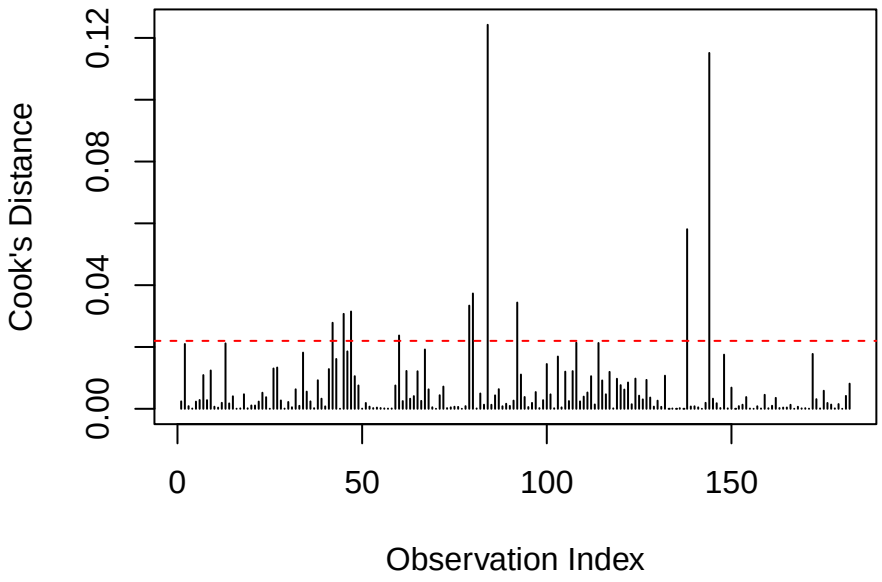
```
    studentized Breusch-Pagan test

data:  centered_log_int_model
BP = 6.0799, df = 7, p-value = 0.5304
```

```
# ----- Test for Normality ----- #
shapiro.test(rstudent(centered_log_int_model))
```

```
    Shapiro-Wilk normality test

data:  rstudent(centered_log_int_model)
W = 0.99487, p-value = 0.7877
```

```
# ----- Identifying Influential Cases ----- #
cooks_d <- cooks.distance(centered_log_int_model)

n <- nrow(df)
threshold <- 4 / n
influential <- which(cooks_d > threshold)

plot(cooks_d, type = "h", main = "Fig. 16: Cook's Distance",
     ylab = "Cook's Distance", xlab = "Observation Index", font.main = 1)
abline(h = 4/n, col = "red", lty = 2)
```

Fig. 16: Cook's Distance




```
print(paste("Number of influential observations:", length(influential)))
```

```
[1] "Number of influential observations: 10"
```

```
print(paste("Threshold:", round(threshold, 4)))
```

```
[1] "Threshold: 0.022"
```

```
print(paste("Max Cook's Distance:", round(max(cooks_d), 4)))
```

```
[1] "Max Cook's Distance: 0.1242"
```

```
# ----- K-Fold Cross Validation ----- #
train_control <- trainControl(method = "cv", number = 10)

cv_model <- train(log_inspections ~ pop_c*baskets_c + pop_c*garage + pop_c*dropoff,
   data = df, method = "lm", trControl = train_control)

print(cv_model)
```

```
Linear Regression

182 samples
  4 predictor

No pre-processing
Resampling: Cross-Validated (10 fold)
Summary of sample sizes: 163, 163, 165, 165, 164, 164, ...
Resampling results:

  RMSE      Rsquared   MAE
  1.230513  0.6257173  0.9912344

Tuning parameter 'intercept' was held constant at a value of TRUE
```

```r
# ----- Comparison to the Standard Model ----- #
cat("\n--- Standard Model ---\n")
```

```
--- Standard Model ---
```

```r
cat("R-squared:", summary(centered_log_int_model)$r.squared, "\n")
```

```
R-squared: 0.6444944
```

```r
cat("RMSE:", sqrt(mean(centered_log_int_model$residuals^2)), "\n")
```

```
RMSE: 1.18775
```

```r
cat("\n--- Cross-Validation ---\n")
```

```
--- Cross-Validation ---
```

```r
cat("R-squared:", cv_model$results$Rsquared, "\n")
```

```
R-squared: 0.6257173
```

```r
cat("RMSE:", cv_model$results$RMSE, "\n")
```

```
RMSE: 1.230513
```