Intro ML Homework 2

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Github: https://github.com/jaskinkabir/Intro_ML/tree/main/HM2

In [59]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.preprocessing import MinMaxScaler, StandardScaler
from sklearn.model_selection import train_test_split
import warnings

path = 'housing.csv'
housing = pd.DataFrame(pd.read_csv(path))
housing.head()
```

Out[59]:

	price	area	bedrooms	bathrooms	stories	mainroad	guestroom	basement	hotw
0	13300000	7420	4	2	3	yes	no	no	
1	12250000	8960	4	4	4	yes	no	no	
2	12250000	9960	3	2	2	yes	no	yes	
3	12215000	7500	4	2	2	yes	no	yes	
4	11410000	7420	4	1	2	yes	yes	yes	

In [60]:
```
# List of variables to map

varlist =  ['mainroad', 'guestroom', 'basement', 'hotwaterheating', 'airconditionin

# Defining the map function
def binary_map(x):
    return x.map({'yes': 1, 'no': 0, 'unfurnished': 0, 'semi-furnished': 1, 'furnis

# Applying the function to the housing list
housing[varlist] = housing[varlist].apply(binary_map)
housing.head()
```

Out[60]:

	price	area	bedrooms	bathrooms	stories	mainroad	guestroom	basement	hotw
0	13300000	7420	4	2	3	1	0	0	
1	12250000	8960	4	4	4	1	0	0	
2	12250000	9960	3	2	2	1	0	1	
3	12215000	7500	4	2	2	1	0	1	
4	11410000	7420	4	1	2	1	1	1	

In [61]:

```
np.random.seed(10)
df_train, df_validate = train_test_split(housing, train_size=0.8, test_size=0.2, ra

y_train = df_train.pop('price')
X_train = df_train

y_validate = df_validate.pop('price')
X_validate = df_validate
X_train.head()
```

Out[61]:

	area	bedrooms	bathrooms	stories	mainroad	guestroom	basement	hotwaterheati
22	8050	3	1	1	1	1	1	
41	6360	3	2	4	1	0	0	
91	6750	2	1	1	1	1	1	
118	6420	3	1	1	1	0	1	
472	3630	4	1	2	1	0	0	

In [62]:

```
a_vars = ['area', 'bedrooms', 'bathrooms', 'stories', 'parking']
X_a = housing[a_vars]
X_train_df_a = X_train[a_vars]
X_validate_df_a = X_validate[a_vars]
X_train_df_a.head()
```

Out[62]:

	area	bedrooms	bathrooms	stories	parking
22	8050	3	1	1	1
41	6360	3	2	4	0
91	6750	2	1	1	2
118	6420	3	1	1	0
472	3630	4	1	2	3

In [63]:

```
def gen_data(df: pd.DataFrame):
    if isinstance(df, pd.DataFrame):
```

```
        data = df.to_numpy()
    data = df
    X0 = np.ones((data.shape[0], 1))
    X = np.hstack((X0, data))
    return X
X_train_a = gen_data(X_train_df_a)
X_validate_a = gen_data(X_validate_df_a)

Y_train = y_train.to_numpy().reshape(-1,1)
Y_validate = y_validate.to_numpy().reshape(-1,1)
```

In [64]:
```
# vars: Area, bedrooms, bathrooms, stories, mainroad, guestroom, basement, hotwater
b_vars = ['area', 'bedrooms', 'bathrooms', 'stories', 'mainroad', 'guestroom', 'bas
X_b = housing[b_vars]
X_train_df_b = X_train[b_vars]
X_validate_df_b = X_validate[b_vars]

X_train_b = gen_data(X_train_df_b)
X_validate_b = gen_data(X_validate_df_b)
```

In [65]:
```
norm_a = MinMaxScaler()
norm_a.fit(X_a)
std_a = StandardScaler()
std_a.fit(X_a)
norm_b = MinMaxScaler()
norm_b.fit(X_b)
std_b = StandardScaler()
std_b.fit(X_b)

X_scaled: dict[str, pd.DataFrame] = {
    "train_a_norm" : X_train_df_a,
    "train_a_std" : X_train_df_a,
    "validate_a_norm" : X_validate_df_a,
    "validate_a_std" : X_validate_df_a,

    "train_b_norm" : X_train_df_b,
    "train_b_std" : X_train_df_b,
    "validate_b_norm" : X_validate_df_b,
    "validate_b_std" : X_validate_df_b,
}

for key, value in X_scaled.items():
    if "_a_" in key:
        value = gen_data(norm_a.transform(value)) if "norm" in key else gen_data(st

    else:
        value = gen_data(norm_b.transform(value)) if "norm" in key else gen_data(st
    X_scaled[key] = value
```

In [66]:
```
def compute_cost(X, Y, theta):
    m = X.shape[0]
    predictions = X.dot(theta)
    errors = np.subtract(predictions, Y)
    sqrErrors = np.square(errors)
    J = (1/ (2*m) ) * np.sum(sqrErrors)
```

```
    return J
def compute_regularized_cost(X, Y, theta, lambda_val):
    m = X.shape[0]
    predictions = X.dot(theta)
    errors = np.subtract(predictions, Y)
    sqrErrors = np.square(errors)
    J = (1/ (2*m) ) * np.sum(sqrErrors) + lambda_val * np.sum(np.square(theta))

    return J

def grad_desc(X_train: np.ndarray, Y_train: np.ndarray, theta: np.ndarray, alpha: f
    m = len(Y_train)

    training_cost_history = np.zeros(iterations)
    validation_cost_history = np.zeros(iterations)

    for i in range(iterations):
        validation_cost_history[i] = compute_cost(X_val, Y_val, theta)

        predictions = X_train.dot(theta)
        errors = np.subtract(predictions, Y_train)

        gradient = (1/m)*(X_train.T.dot(errors)) + lambda_val * theta

        theta -= alpha * gradient

        sqrErrors = np.square(errors)
        training_cost_history[i]= (1/(2*m)) * np.sum(sqrErrors) + lambda_val * np.s

    return theta,training_cost_history, validation_cost_history
```

In [67]:

```
def print_model(X, Y, theta, name='Y', return_cost = False):

    cost = compute_cost(X,Y,theta)

    model_str = ""

    for i in range(theta.shape[0]-1, -1, -1):
        if i == 0:
            model_str += f"{round(theta[i,0], 3)}"
            break
        model_str += f"{round(theta[i,0], 3)}*X{i} + "

    print(f"Model:\n    {name} = {model_str}")
    cost = np.sqrt(cost)
    cost_str = "{:e}".format(round(cost,5))

    print(f"    cost = {cost_str}")
    if return_cost:
        return cost

def display_loss(iters, train_hist, val_hist, title):
    train_hist = np.sqrt(train_hist)
    val_hist = np.sqrt(val_hist)
    plt.plot(range(iters), train_hist, label = "Training")
```

```
    plt.plot(range(iters), val_hist, label = "Validation")
    plt.title(title)
    plt.xlabel("Iteration")
    plt.ylabel("Cost")
    plt.legend()
```

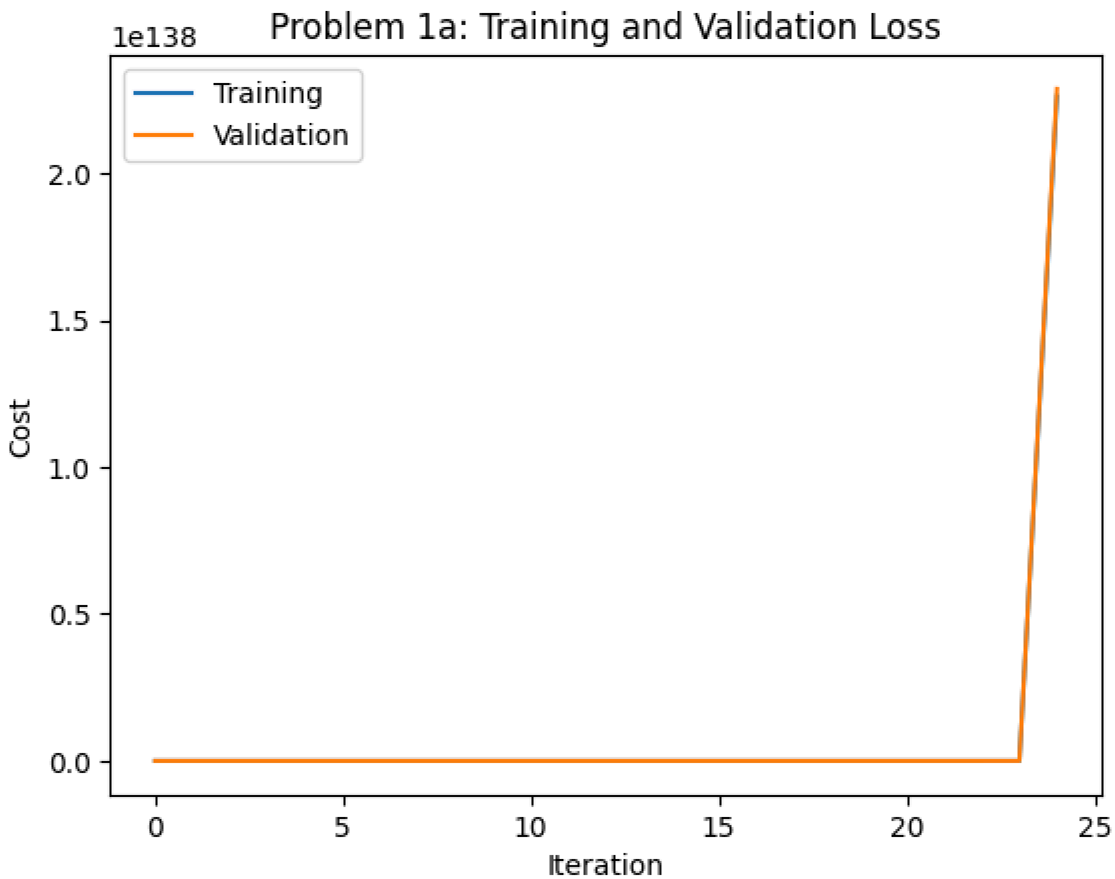
In [68]:

```
#Used to find max iters before overflow error
def find_iters(X_train_b, Y_train, theta, alpha, X_validate_b, Y_validate):
    alpha = 0.01
    for iterations in range(1,50):
        theta = np.zeros((X_train_b.shape[1], 1))
        with warnings.catch_warnings(record=True) as w:

            warnings.filterwarnings(
                action = 'default',
                module=__name__
            )

            theta, _, _ = grad_desc(X_train_b, Y_train, theta, alpha, iterations, X

            if w:
                print(w[-1].message)
                print(f"error at {iterations} iters")
                break
    return iterations
```

In [69]:

```
# Problem 1a

theta = np.zeros((X_train_a.shape[1], 1))

# 26 iters was found to be the maximum number of iterations before overflow occured
iterations_1 = 25
# Alpha of 0.01 minimizes cost
alpha = 0.01

theta, training_cost_history, validation_cost_history = grad_desc(X_train_a, Y_trai

display_loss(iterations_1, training_cost_history, validation_cost_history, "Problem
print_model(X_validate_a, Y_validate, theta)
```

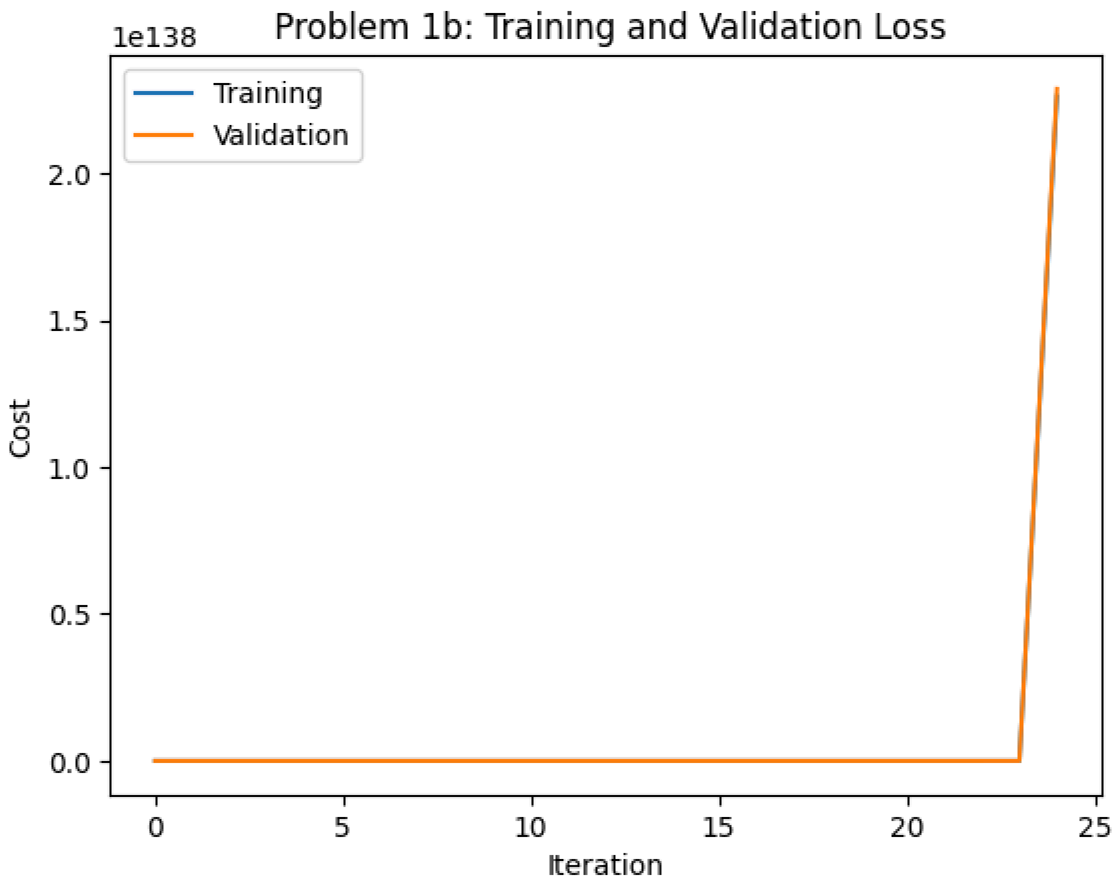
```
Model:
    Y = 2.5191760787463457e+136*X5 + 5.438777366196307e+136*X4 + 3.927495715894537e+
136*X3 + 8.801161606152165e+136*X2 + 1.783550252099942e+140*X1 + 2.951642835906598e+
136
    cost = 7.109740e+143
```



In [70]:

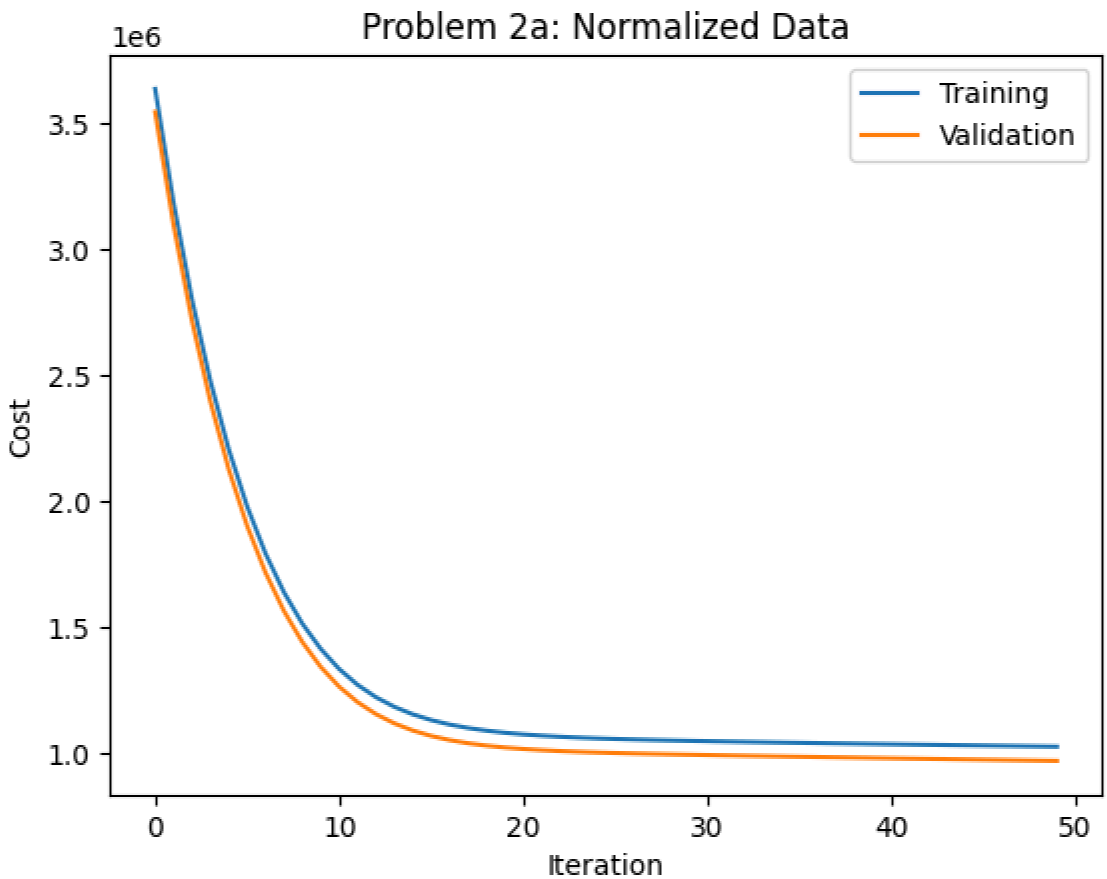
```
# Problem 1b


theta = np.zeros((X_train_b.shape[1], 1))

# 26 iters was found to be the maximum number of iterations before overflow occured
iterations_1 = 25
# Alpha of 0.01 minimizes cost
alpha = 0.01

theta, training_cost_history, validation_cost_history = grad_desc(X_train_b, Y_trai

display_loss(iterations_1, training_cost_history, validation_cost_history, " Proble
print_model(X_validate_b, Y_validate, theta)
```

```
Model:
    Y = 7.970833567858981e+135*X11 + 2.5191780578038154e+136*X10 + 1.003227256061338
6e+136*X9 + 1.6384988887492037e+135*X8 + 1.0884862411168729e+136*X7 + 5.806913272122
383e+135*X6 + 2.675815178198042e+136*X5 + 5.438781651600359e+136*X4 + 3.927498807751
445e+136*X3 + 8.801168536401044e+136*X2 + 1.7835516508148312e+140*X1 + 2.95164516035
68797e+136
    cost = 7.109746e+143
```



In [71]:
```
X_train = X_scaled["train_a_norm"]
X_validate = X_scaled["validate_a_norm"]

theta = np.zeros((X_train.shape[1], 1))

iterations = 1000
alpha = .1

theta, training_cost_history, validation_cost_history = grad_desc(X_train, Y_train,

tr_cost_2a_norm = training_cost_history
vl_cost_2a_norm = validation_cost_history

show_iters = 50
display_loss(show_iters, training_cost_history[:show_iters], validation_cost_histor
cost_2_a_norm = print_model(X_validate, Y_validate, theta, return_cost=True)
val_2_a_norm = validation_cost_history
```

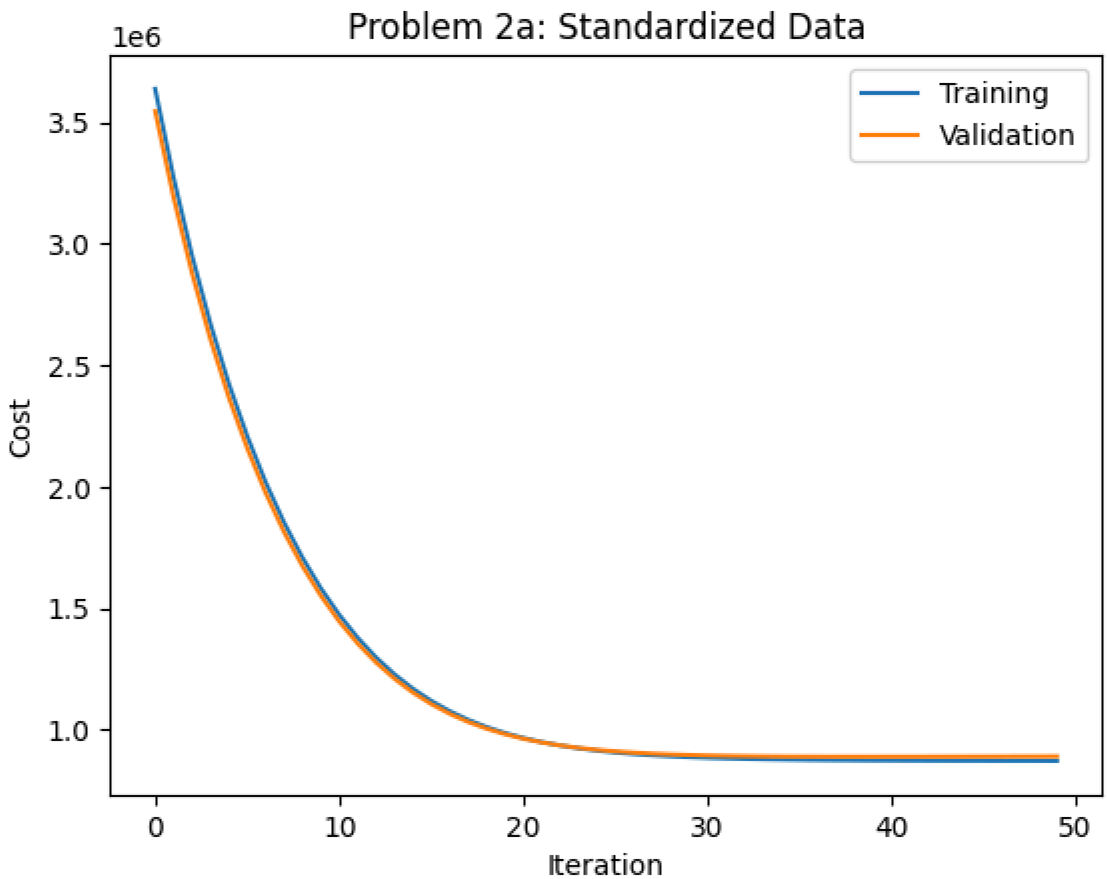
```
Model:
    Y = 1131909.199*X5 + 1580247.153*X4 + 3539905.434*X3 + 917849.464*X2 + 4361355.4
16*X1 + 2340929.343
    cost = 8.802639e+05
```



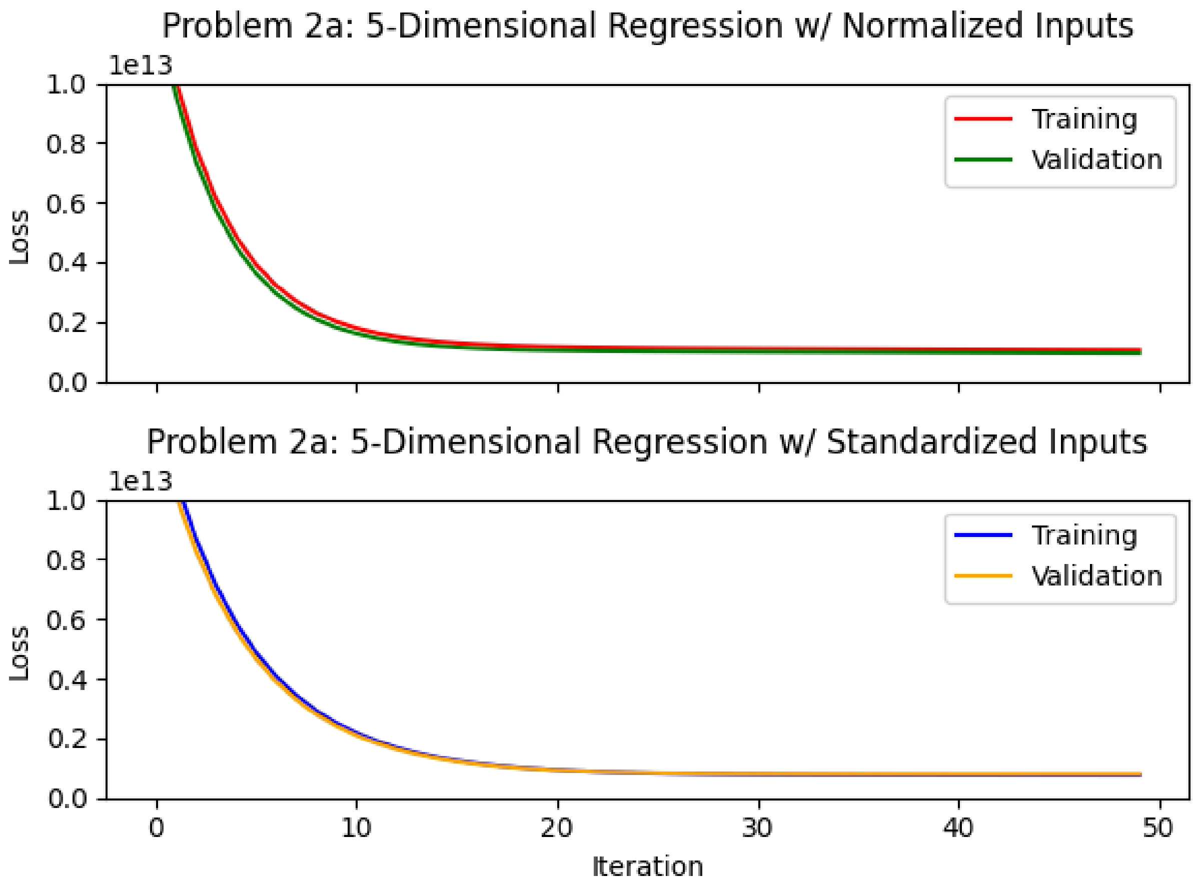
In [72]:

```
X_train = X_scaled["train_a_std"]
X_validate = X_scaled["validate_a_std"]

theta = np.zeros((X_train.shape[1], 1))

iterations = 1000
alpha = .1

theta, training_cost_history, validation_cost_history = grad_desc(X_train, Y_train,

tr_cost_2a_std = training_cost_history
vl_cost_2a_std = validation_cost_history

display_loss(show_iters, training_cost_history[:show_iters], validation_cost_histor
cost_2a_std = print_model(X_validate, Y_validate, theta, return_cost=True)
```

```
Model:
    Y = 287090.845*X5 + 456136.395*X4 + 640887.326*X3 + 80271.97*X2 + 736562.243*X1
+ 4773808.357
    cost = 8.934580e+05
```

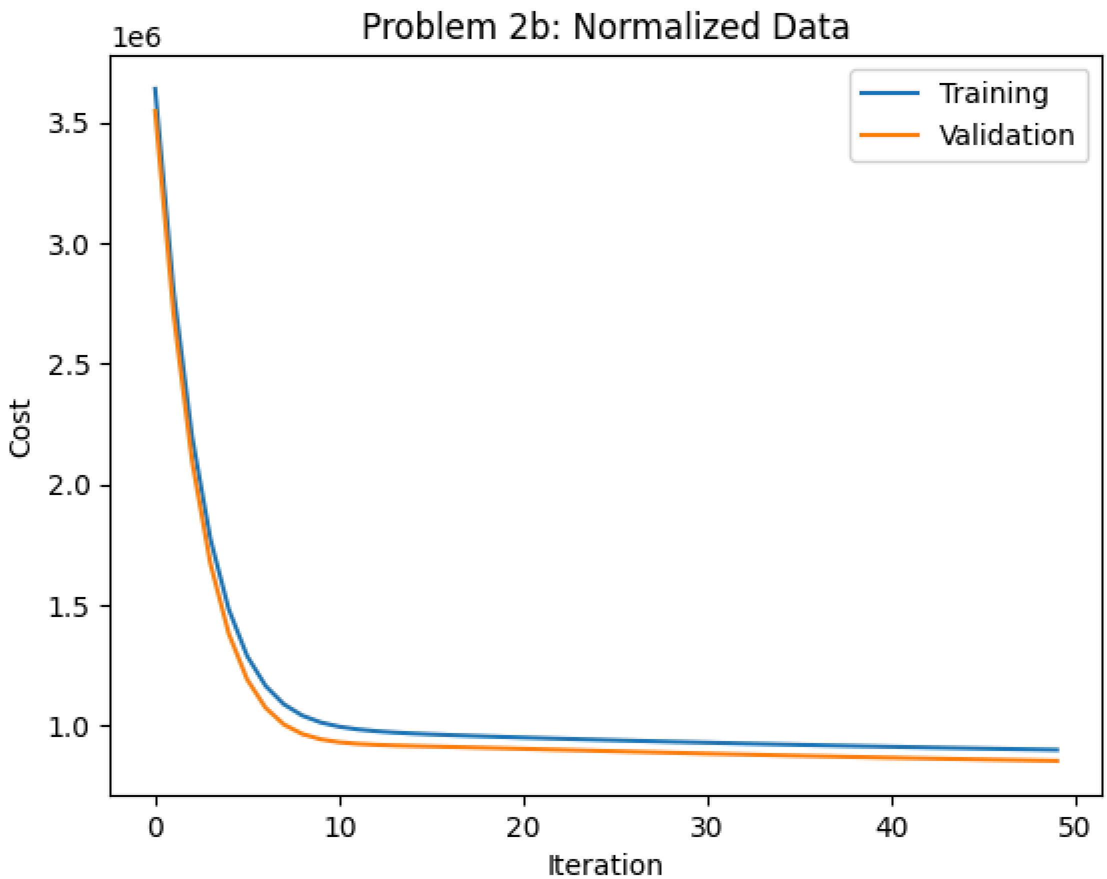


In [73]:
```
ax1 = plt.subplot(2,1,1)
ax1.plot(range(show_iters), tr_cost_2a_norm[:show_iters], label = "Training", color
ax1.plot(range(show_iters), vl_cost_2a_norm[:show_iters], label = "Validation", col
ax1.set_title("Problem 2a: 5-Dimensional Regression w/ Normalized Inputs")
ax1.set_ylim(0,1e13)
ax1.set_ylabel("Loss")
ax1.tick_params('x',labelbottom=False)
plt.legend()
ax2 = plt.subplot(2,1,2, sharex=ax1)
ax2.plot(range(show_iters), tr_cost_2a_std[:show_iters], label = "Training", color
ax2.plot(range(show_iters), vl_cost_2a_std[:show_iters], label = "Validation", colo
ax2.set_title("Problem 2a: 5-Dimensional Regression w/ Standardized Inputs")
ax2.set_xlabel("Iteration")
ax2.set_ylabel("Loss")
ax2.set_ylim(0,1e13)
plt.legend()
plt.tight_layout()
```



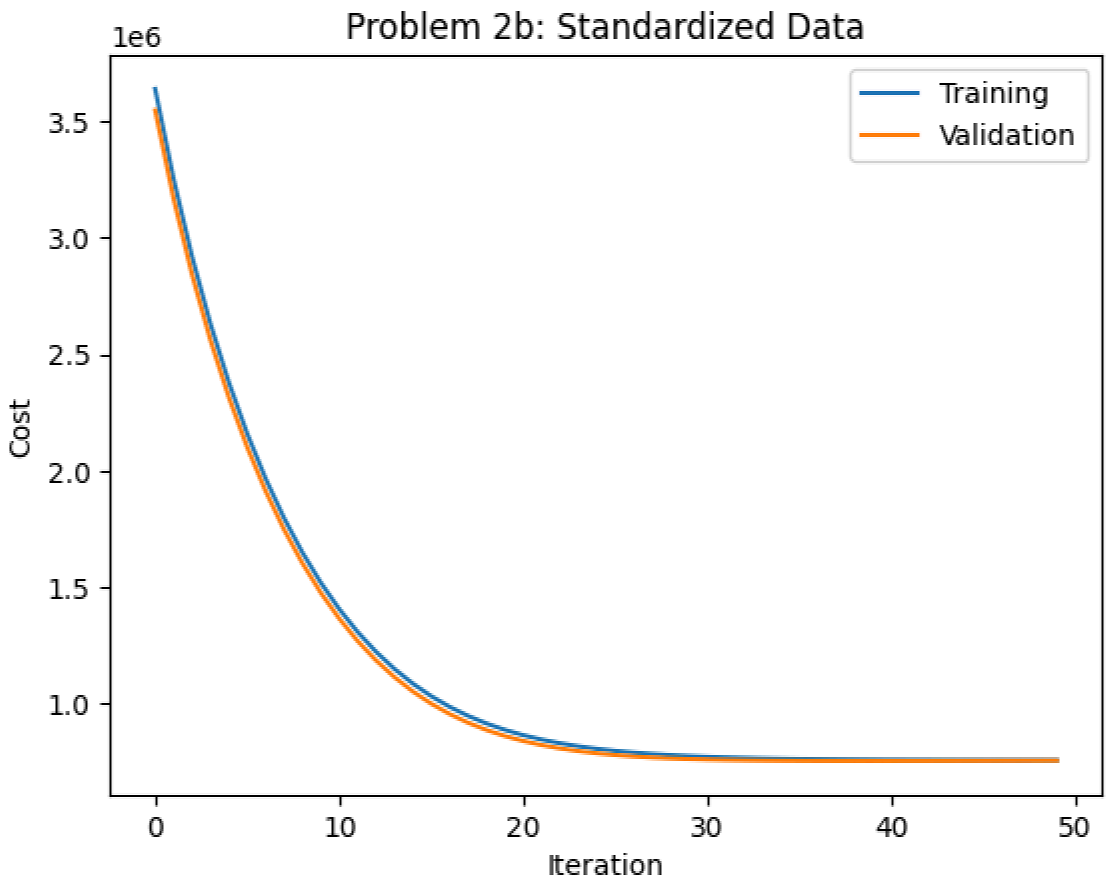
In [74]:
```
X_train = X_scaled["train_b_norm"]
X_validate = X_scaled["validate_b_norm"]

theta = np.zeros((X_train.shape[1], 1))

iterations = 1000
alpha = .1

theta, training_cost_history, validation_cost_history = grad_desc(X_train, Y_train,

tr_cost_2b_norm = training_cost_history
vl_cost_2b_norm = validation_cost_history

display_loss(show_iters, training_cost_history[:show_iters], validation_cost_histor
cost_2b_norm = print_model(X_validate, Y_validate, theta, return_cost=True)
```

```
Model:
    Y = 632916.665*X11 + 869426.322*X10 + 903634.471*X9 + 911766.975*X8 + 291138.238
*X7 + 426045.355*X6 + 663633.568*X5 + 1228013.929*X4 + 3170896.407*X3 + 838031.019*X
2 + 3070889.327*X1 + 1660438.026
    cost = 7.523226e+05
```

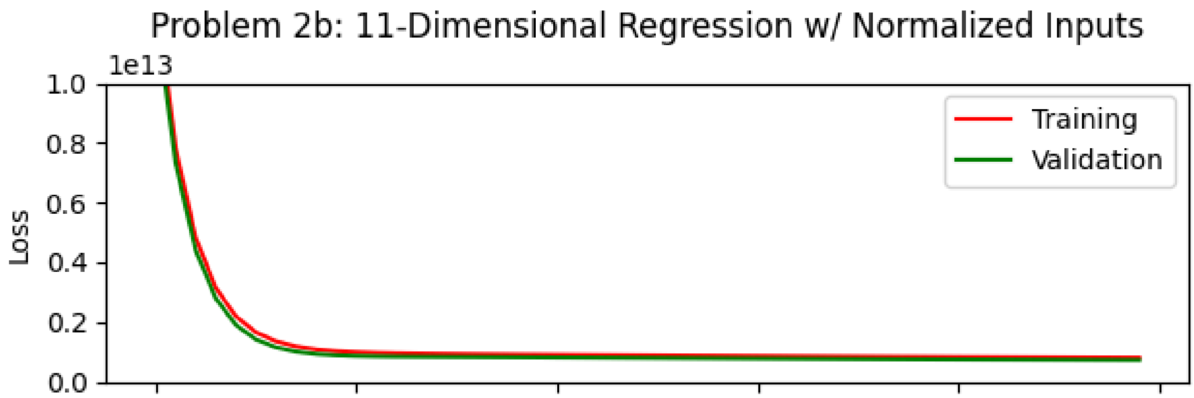


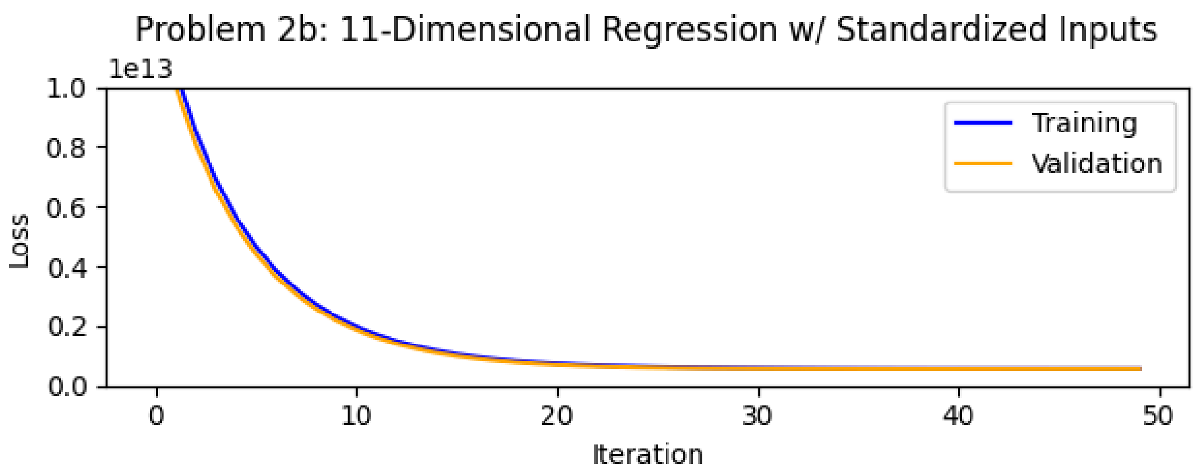
In [75]:
```
X_train = X_scaled["train_b_std"]
X_validate = X_scaled["validate_b_std"]

theta = np.zeros((X_train.shape[1], 1))

iterations = 1000
alpha = .1

theta, training_cost_history, validation_cost_history = grad_desc(X_train, Y_train,

tr_cost_2b_std = training_cost_history
vl_cost_2b_std = validation_cost_history

display_loss(show_iters, training_cost_history[:show_iters], validation_cost_histor
cost_2b_std = print_model(X_validate, Y_validate, theta, return_cost=True)
```

```
Model:
    Y = 256952.091*X11 + 222311.464*X10 + 405398.464*X9 + 188006.755*X8 + 145156.012
*X7 + 148023.343*X6 + 212628.153*X5 + 361494.885*X4 + 578151.302*X3 + 73581.346*X2 +
537675.374*X1 + 4784210.274
    cost = 7.602334e+05
```



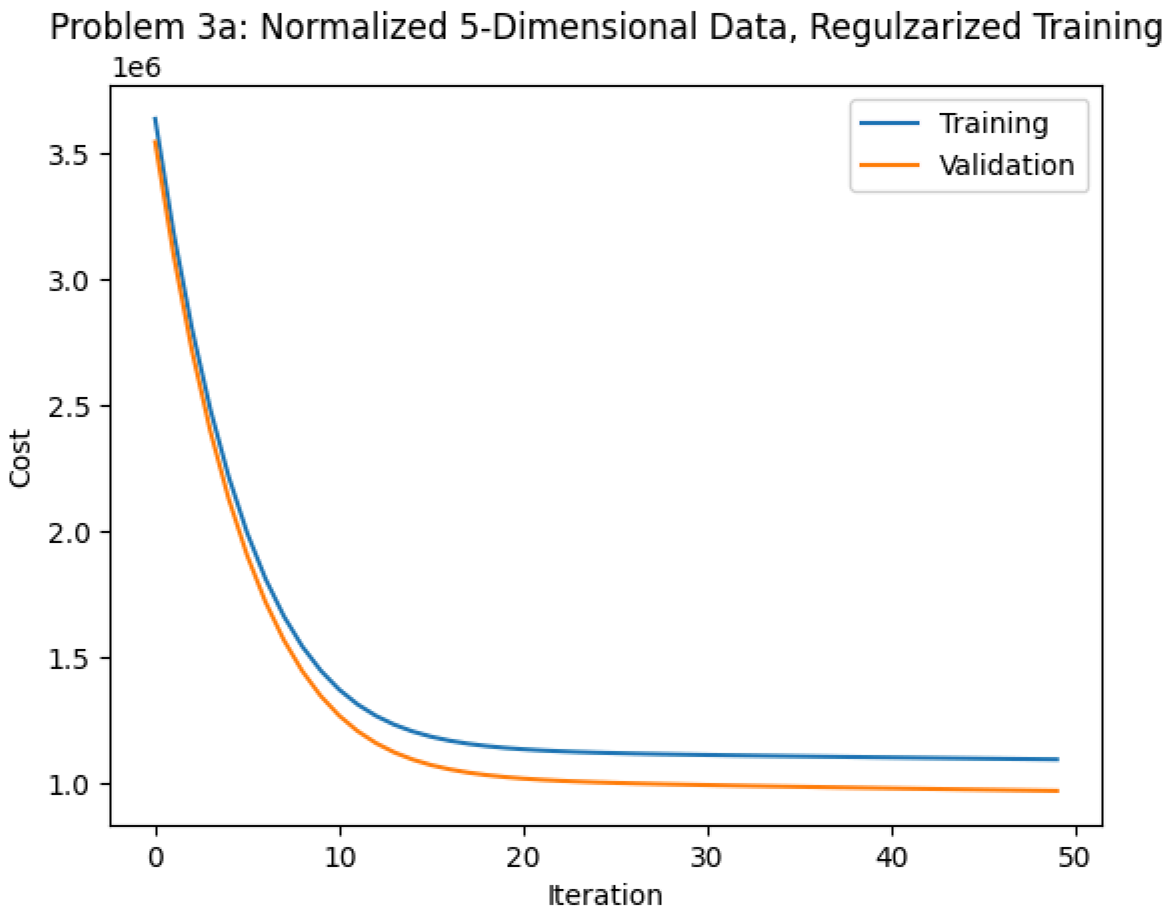
In [76]:
```
ax1 = plt.subplot(2,1,1)
ax1.plot(range(show_iters), tr_cost_2b_norm[:show_iters], label = "Training", color
ax1.plot(range(show_iters), vl_cost_2b_norm[:show_iters], label = "Validation", col
ax1.set_title("Problem 2b: 11-Dimensional Regression w/ Normalized Inputs")
ax1.set_ylim(0,1e13)
ax1.set_ylabel("Loss")
ax1.tick_params('x',labelbottom=False)
plt.legend()
ax2 = plt.subplot(2,1,2, sharex=ax1)
ax2.plot(range(show_iters), tr_cost_2b_std[:show_iters], label = "Training", color
ax2.plot(range(show_iters), vl_cost_2b_std[:show_iters], label = "Validation", colo
ax2.set_title("Problem 2b: 11-Dimensional Regression w/ Standardized Inputs")
ax2.set_xlabel("Iteration")
ax2.set_ylabel("Loss")
ax2.set_ylim(0,1e13)
plt.legend()
plt.tight_layout()
```





In [77]:
```
# Problem 3a
# Train on X_train_a_norm


X_train = X_scaled["train_a_norm"]
X_validate = X_scaled["validate_a_norm"]

theta = np.zeros((X_train.shape[1], 1))

iterations = 1000
alpha = .1

lambda_val = .008
theta, training_cost_history, validation_cost_history = grad_desc(X_train, Y_train,

cost = print_model(X_validate, Y_validate, theta, return_cost=True)

print(f"Percent improvement: {100*-(cost-cost_2_a_norm)/cost_2_a_norm}")
# print(f"Improved ? : {cost < cost_2_a}")
# print(f"Equal ? : {cost == cost_2_a}")

display_loss(show_iters, training_cost_history[:show_iters], validation_cost_histor
```

```
Model:
    Y = 1227908.778*X5 + 1592781.274*X4 + 2936639.327*X3 + 1088143.585*X2 + 3586242.
409*X1 + 2472595.853
    cost = 8.729269e+05
Percent improvement: 0.8335033919665579
```



In [78]:

```
# Problem 3a
# Train on X_train_a_std


X_train = X_scaled["train_a_std"]
X_validate = X_scaled["validate_a_std"]

theta = np.zeros((X_train.shape[1], 1))

iterations = 1000
alpha = .1

lambda_val = 0.015

theta, training_cost_history, validation_cost_history = grad_desc(X_train, Y_train,

cost = print_model(X_validate, Y_validate, theta, return_cost=True)

print(f"Percent improvement: {100*-(cost-cost_2a_std)/cost_2a_std}")
# print(f"Improved ? : {cost < cost_2_a}")
# print(f"Equal ? : {cost == cost_2_a}")
#display_loss(iterations, training_cost_history, validation_cost_history, "Problem
```

```
Model:
    Y = 290414.417*X5 + 452787.725*X4 + 634218.308*X3 + 81824.421*X2 + 725458.035*X1
+ 4703251.597
    cost = 8.920735e+05
Percent improvement: 0.15496723710144503
```

In [79]:
```
# Problem 3b
# Train on X_train_a_norm


X_train = X_scaled["train_b_norm"]
X_validate = X_scaled["validate_b_norm"]

theta = np.zeros((X_train.shape[1], 1))

iterations = 1000
alpha = .1

lambda_val = 0.010
#1.89% at lambda=0


theta, training_cost_history, validation_cost_history = grad_desc(X_train, Y_train,

cost = print_model(X_validate, Y_validate, theta, return_cost=True)

print(f"Percent improvement: {100*-(cost-cost_2b_norm)/cost_2b_norm}")
# print(f"Improved ? : {cost < cost_2_a}")
# print(f"Equal ? : {cost == cost_2_a}")
#display_loss(iterations, training_cost_history, validation_cost_history, "Problem
```

```
Model:
    Y = 638829.235*X11 + 925611.091*X10 + 947196.905*X9 + 813180.317*X8 + 315360.362
*X7 + 463601.861*X6 + 789481.647*X5 + 1231886.876*X4 + 2504939.893*X3 + 938067.602*X
2 + 2375346.708*X1 + 1689186.934
    cost = 7.498947e+05
Percent improvement: 0.32271650232865895
```

In [80]:
```
# Problem 3a
# Train on X_train_a_std


X_train = X_scaled["train_b_std"]
X_validate = X_scaled["validate_b_std"]

theta = np.zeros((X_train.shape[1], 1))

iterations = 1000
alpha = .1

lambda_val = 0.022
# Best is 15
#-0.96% at lambda = 0

theta, training_cost_history, validation_cost_history = grad_desc(X_train, Y_train,
```

```
cost = print_model(X_validate, Y_validate, theta, return_cost=True)

print(f"Percent improvement: {100*-(cost-cost_2b_std)/cost_2b_std}")
# print(f"Improved ? : {cost < cost_2_a}")
# print(f"Equal ? : {cost == cost_2_a}")
display_loss(show_iters, training_cost_history[:show_iters], validation_cost_histor
```

```
Model:
    Y = 253607.607*X11 + 228116.704*X10 + 396139.844*X9 + 187250.705*X8 + 145390.301
*X7 + 147197.3*X6 + 212292.698*X5 + 361055.748*X4 + 569748.729*X3 + 74164.081*X2 + 5
28002.074*X1 + 4680758.059
    cost = 7.563852e+05
Percent improvement: 0.5061820471657332
```