In [1]:

```
import pandas as pd
import matplotlib.pyplot as plt
from tqdm import tqdm

from mpl_toolkits.mplot3d import axes3d
import matplotlib.pyplot as plt
import numpy as np
from matplotlib import cm
```

In [3]:

```
# Task 1
data = pd.read_csv("G:/Labs/bsuir-labs/11cem/ml/lab01/ex1data1.txt", header=None, sep=","

print(data.sort_values(by="Profit"))
```

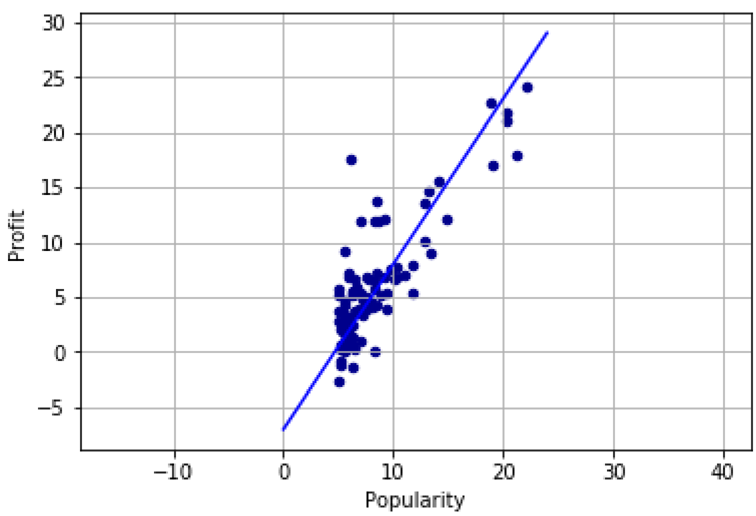
```
    Popularity    Profit
74      5.0269  -2.68070
55      6.3589  -1.42110
30      5.2524  -1.22000
61      5.1793  -0.74279
94      8.2934   0.14454
88      5.5204   0.15200
81      5.1884   0.20421
75      6.5479   0.29678
80      5.7292   0.47953
40      5.4069   0.55657
17      5.1301   0.56077
96      5.4369   0.61705
82      6.3557   0.67861
14      5.6407   0.71618
87      6.0020   0.92695
68      5.4994   1.01730
49      5.5416   1.01790
45      7.0931   1.04630
72      6.0062   1.27840
54      6.3328   1.42330
51      5.3077   1.83960
47      5.8014   1.84400
90      5.7077   1.84510
33      5.8918   1.84950
93      5.3054   1.98690
79      5.1077   2.05760
43      5.7737   2.44060
56      6.2742   2.47560
89      5.0594   2.82140
24      5.5649   3.08250
..         ...       ...
44      7.8247   6.73180
50      7.5402   6.75040
78     10.2740   6.75260
86      9.1802   6.79810
4       5.8598   6.82330
27     10.9570   7.04670
92      5.8707   7.20290
13      8.4084   7.22580
83      9.7687   7.54350
67     10.2360   7.77540
48     11.7000   8.00430
95     13.3940   9.05510
1       5.5277   9.13020
38     12.8360  10.11700
3       7.0032  11.85400
5       8.3829  11.88600
7       8.5781  12.00000
63     14.9080  12.05400
32      9.2482  12.13400
26     12.8280  13.50100
2       8.5186  13.66200
28     13.1760  14.69200
```

```
11      14.1640  15.50500
64      18.9590  17.05400
0        6.1101  17.59200
62      21.2790  17.92900
69      20.3410  20.99200
21      20.2700  21.76700
25      18.9450  22.63800
29      22.2030  24.14700

[97 rows x 2 columns]
```

In [8]:

```python
# Task 2
data.sort_values(by="Popularity").plot.scatter(x='Popularity', y='Profit', c='DarkBlue')
plt.grid()
plt.axis('equal')
x = range(0, 25, 1)
k = 1.5
b = -7
y = [i * k + b for i in x]
plt.plot(x, y, 'b-')

print("Therory function blue line f(x)=" + str(k) + "*x+" + str(b))

theroyes = [k * x_actual + b for x_actual in data.sort_values(by="Popularity").Popularity
```

```
Therory function blue line f(x)=1.5*x+-7
```



In [9]:

```python

J = 0
for y_theory, y_actual in zip(theroyes, data.sort_values(by="Popularity").Profit):
    J += (y_theory - y_actual) ** 2
J /= 2 * len(theroyes)

# Task 3
print("Loss func J(theta)=" + str(round(J, 2)))
```

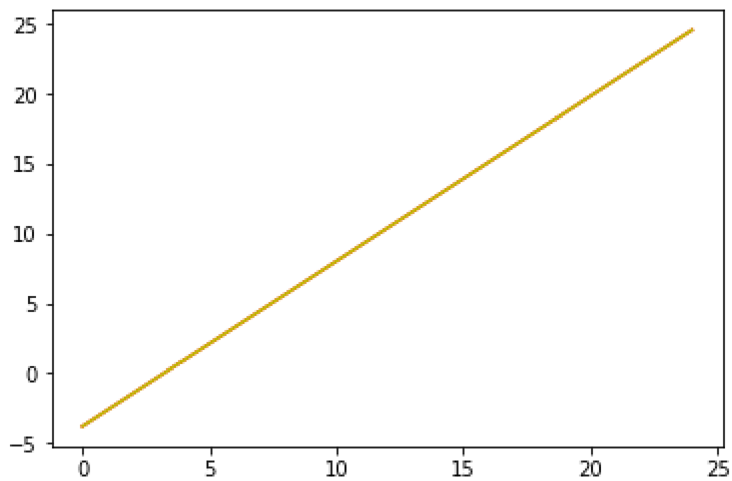
```
Loss func J(theta)=5.35
```

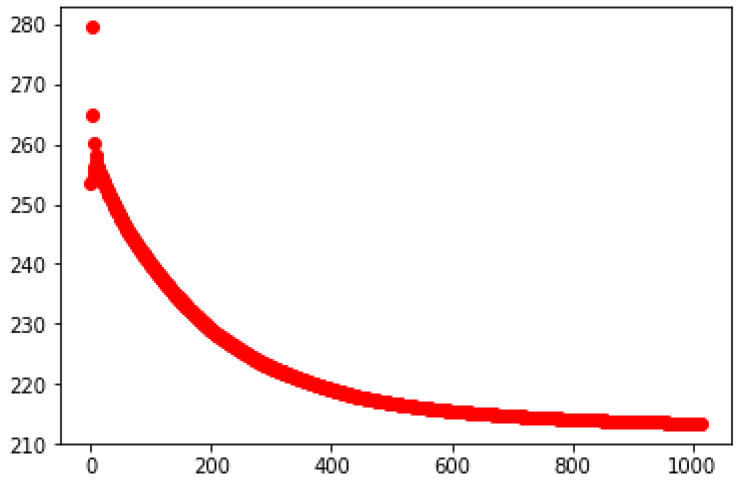
In [11]:

```
# Task 4


alpha = -0.01
tetha = [1, 0]
tetha_x = []
tetha_y = []
costs = []
iterations_count = 1015

def cost(k, b, x_actual, y_actual): # task - minimize cost
    theroyes = [k * x_i + b for x_i in x_actual]
    J = 0
    for y_theory, y_actual in zip(theroyes, y_actual):
        J += abs(y_theory - y_actual)
    return J

for i in tqdm(range(iterations_count)):
    theroyes = [tetha[0] * x_actual + tetha[1] for x_actual in data.sort_values(by="Popul
    sum_diff_k = 0
    sum_diff_b = 0
    for y_theory, y_actual, x_actual in zip(theroyes, data.sort_values(by="Popularity").P
                                            data.sort_values(by="Popularity").Popularity)
        sum_diff_k += (y_theory - y_actual) * x_actual * 2 / len(theroyes)
        sum_diff_b += 2 * (y_theory - y_actual) / len(theroyes)
    sum_diff_k *= alpha
    sum_diff_b *= alpha
    tetha = [tetha[0] + sum_diff_k, tetha[1] + sum_diff_b]
    tetha_x.append(tetha[0])
    tetha_y.append(tetha[1])
    costs.append(cost(tetha[0], tetha[1],data.sort_values(by="Popularity").Popularity,dat


print(tetha)
print(costs[-1])

x = range(0, 25, 1)
k = tetha[0]
b = tetha[1]
y = [i * k + b for i in x]
plt.plot(x, y, 'r-')

min_index = costs.index(min(costs))


x = range(0, 25, 1)
k = tetha_x[min_index]
b = tetha_y[min_index]
y = [i * k + b for i in x]
plt.plot(x, y, 'y-')

plt.show()
plt.plot(range(len(costs)),costs, 'ro')

plt.show()

# fig = plt.figure()
# ax = fig.gca(projection='3d')
```

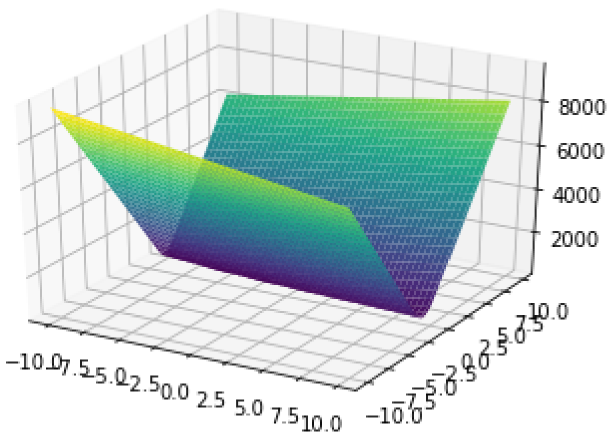
```
# ax.set_xlabel('x')
# ax.set_ylabel('y')
# ax.set_zlabel('cost')

# print(np.array(tetha_x).shape, np.array(tetha_y).shape)
x, y = np.array([x for x in np.arange(-10.0,10.0, 0.2)]), np.array([y for y in np.arange(

z = np.zeros(np.meshgrid(x, y)[0].shape)


#
for rowIndex in range(len(z)):
    for colIndex in range(len(z)):
        z[rowIndex][colIndex] = cost(x[rowIndex], y[colIndex], data.sort_values(by="Popul

x, y = np.meshgrid(x, y)

fig = plt.figure()
ax = plt.axes(projection='3d')

ax.plot_surface(x, y, z, cmap='viridis', edgecolor='none')

plt.show()
# df = pd.DataFrame({'x': tetha_x, 'y': tetha_y, 'z': costs})
# surf = ax.plot_trisurf(df.x, df.y, df.z, linewidth=0.1)

fig = plt.figure()
ax = plt.axes(projection='3d')
cset = ax.contour(x,y,z)

plt.show()
# task 5
fig, ax = plt.subplots()
CS = ax.contour(x,y,z)
ax.clabel(CS, inline=1, fontsize=10)

plt.show()
```

```
100%|██████████████████████████████████████████████████| 1015/1015 [00:01<00:00, 626.16it/s]

[1.1830723774610155, -3.79662516696715]
213.44138834583958
```

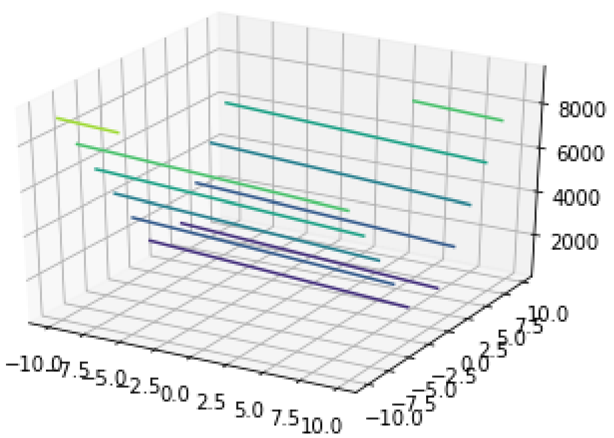




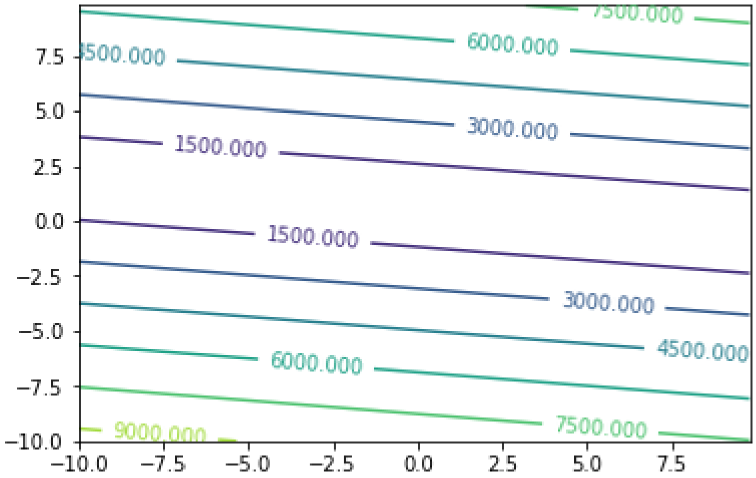
280
270
260
250
240
230
220
210
0
200
400
600
800
1000



8000
6000
4000
2000
−10.0
−7.5
−5.0
−2.5
0.0
2.5
5.0
7.5
10.0



8000
6000
4000
2000
−10.0
−7.5
−5.0
−2.5
0.0
2.5
5.0
7.5
10.0



In [12]:

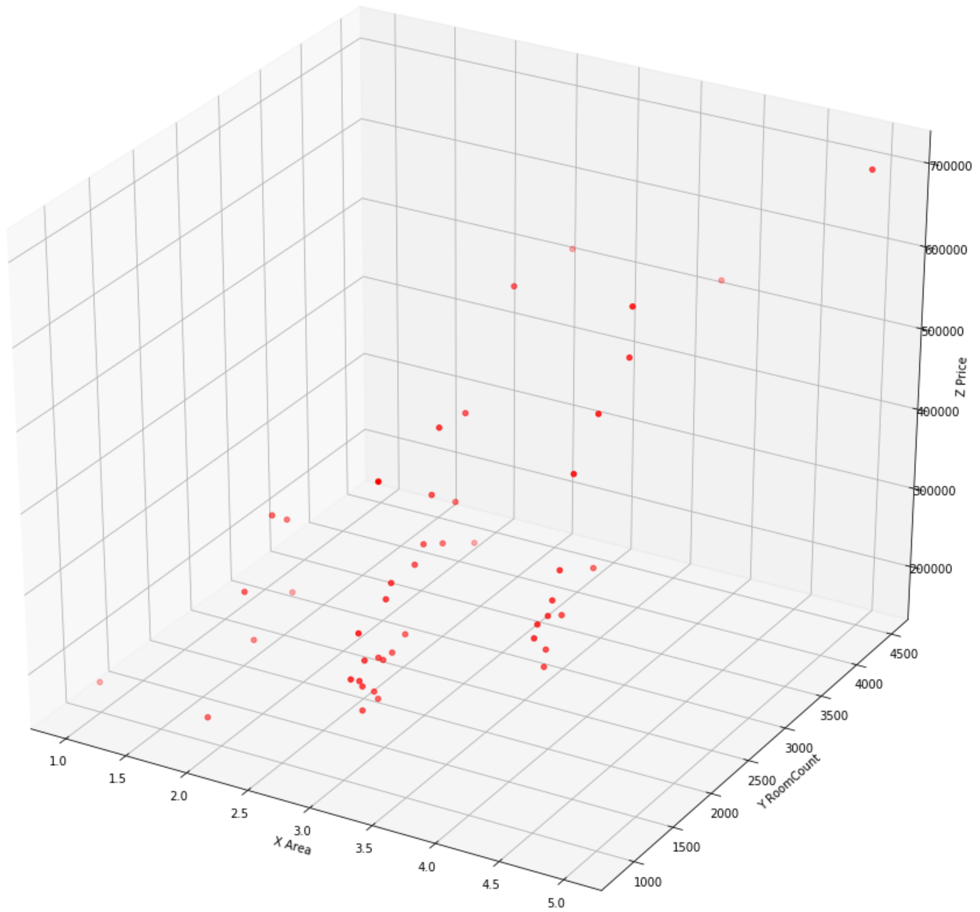
```
# task 6
# Загрузите набор данных ex1data2.txt из текстового файла.
data = pd.read_csv("G:/Labs/bsuir-labs/11cem/ml/lab01/ex1data2.txt", header=None, sep=","

print("data head")
print(data.head())
```

```
data head
   Area  RoomCount   Price
0  2104          3  399900
1  1600          3  329900
2  2400          3  369000
3  1416          2  232000
4  3000          4  539900
```

In [14]:

```
def show_plot():
    fig = plt.figure(figsize=(18, 16))
    ax = fig.add_subplot(111, projection='3d')
    print('initial data')
    ax.scatter(data.RoomCount, data.Area, data.Price, c='r', marker='o')
    ax.set_xlabel('X Area')
    ax.set_ylabel('Y RoomCount')
    ax.set_zlabel('Z Price')
    plt.show()


show_plot()
```

```
initial data
```



In [15]:

```
# task 7.1
# Произведите нормализацию признаков.


df = data
normalized_data = (df - df.min()) / (df.max() - df.min())
print("normalized head")
print(normalized_data.head())
```

```
normalized head
       Area  RoomCount     Price
0  0.345284       0.50  0.433962
1  0.206288       0.50  0.301887
2  0.426917       0.50  0.375660
3  0.155543       0.25  0.117170
4  0.592388       0.75  0.698113
```

In [ ]:

```
# task 7.2

# Повлияло ли это на скорость сходимости градиентного спуска? Ответ дайте в виде графика.
```

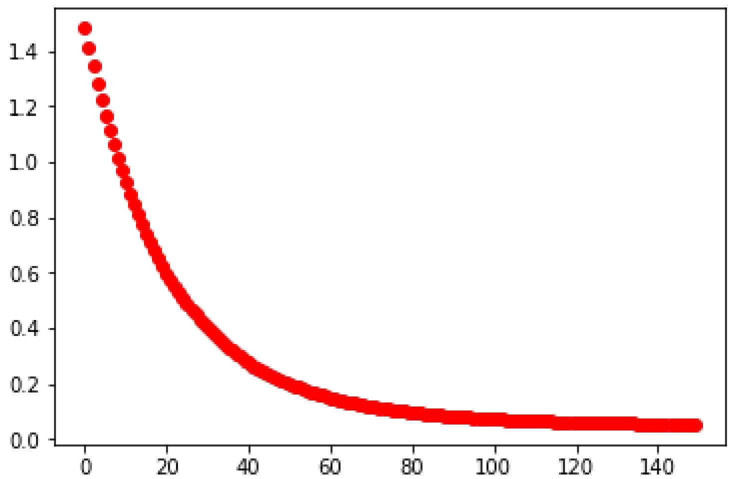
```
ответ, да. без нормализации нет сходимости. коэффициенты выходят за вычислительный
диапазон
скорость с нормализацией 150it, без нормализации inf
```

In [17]:

```
from matplotlib.animation import FuncAnimation

# task 8
# Реализуйте функции потерь J(ϑ) и градиентного спуска для случая многомерной линейной ре

# Regular Gradient
def Gradient(data, tetha_start = [1,1,1], alpha = -0.01, iterations = 150):
    tetha = np.array(tetha_start)
    tethas_history = [np.array(tetha_start)]
    costs = []
    x = np.array(data.iloc[:, 0:2])
    x1 = np.array(data.RoomCount)
    x2 = np.array(data.Area)
    y_actual = np.array(data.Price)
    for i in range(iterations):

        theroyes = [tetha[0] * x1_actual + x2_actual * tetha[1] + tetha[2] for x1_actual,
        sum_diff_x1 = 0
        sum_diff_x2 = 0
        sum_diff_b = 0
        for y_theory, y_actual, x1_actual, x2_actual in zip(theroyes, data.Price, data.Ro
            sum_diff_x1 += (y_theory - y_actual) * x1_actual * 2 / len(theroyes)
            sum_diff_x2 += (y_theory - y_actual) * x2_actual * 2 / len(theroyes)
            sum_diff_b += 2 * (y_theory - y_actual) / len(theroyes)
        sum_diff_x1 *= alpha
        sum_diff_x2 *= alpha
        sum_diff_b *= alpha
        tetha = [tetha[0] + sum_diff_x1, tetha[1] + sum_diff_x2, tetha[2] + sum_diff_b]
        tethas_history.append(tetha)
        y_theory = x.dot(tetha[0:2]) + tetha[2]
        j = 0.5 * ((y_theory - y_actual).T).dot((y_theory - y_actual))/len(y_theory)
        costs.append(j)
    print('regular cost function')
    plt.plot(range(len(costs)), costs, 'ro')
    print("costs head(last 5)")
    print(costs[:5])
    print("costs tail(last 5)")
    print(costs[-5:])
    plt.show()
    print("koefs")
    print(tethas_history[-1])
    return tethas_history
print("normalized_data cost function")



tetha = Gradient(normalized_data)

print("denormalized_data cost function")
Gradient(data, iterations=1500)

def ShowGradientResult(data, feature, tetha, tetha_ind, indicator ='b-'):
    x = np.arange(0, 1, 0.01)
    k = tetha[0]
    b = tetha[2]
    y = [i * k + b for i in x]
    print("result linear function model")
    plt.plot(x, y, indicator)
```

```python
def ShowAnimatedGradientResult(data, feature, tetha, tetha_ind):
    fig = plt.figure()
    ax = plt.axes(xlim=(0, 4), ylim=(-2, 2))

    normalized_data.plot.scatter(x=feature, y='Price', c='DarkBlue')
    plt.grid()
    plt.axis('equal')
    x = np.arange(0, 1, 0.01)
    k = tetha[0][0]
    b = tetha[0][2]
    y = [i * k + b for i in x]
    print("result linear function model")
    line, = plt.plot(x, y, 'b-')

    def animate(i):
        x = np.arange(0, 1, 0.01)
        k = tetha[i][0]
        b = tetha[i][2]
        y = [i * k + b for i in x]
        line.set_data(x, y)
        return line,

    anim = FuncAnimation(fig, animate, frames=len(tetha), interval=20, blit=True, repeat=

    plt.show()
    plt.cla()
    plt.clf()
    plt.close()


ShowAnimatedGradientResult(normalized_data, 'Area', tetha, 1)
ShowAnimatedGradientResult(normalized_data, 'RoomCount', tetha, 0)
```

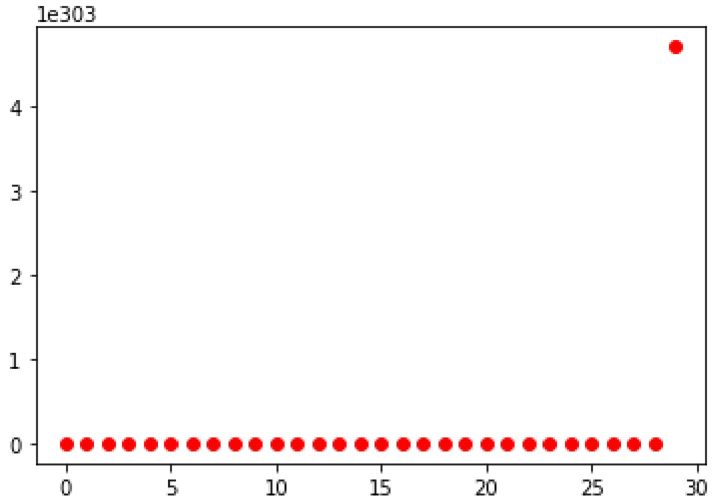
```
normalized_data cost function
regular cost function
costs head(last 5)
[1.483838664503587, 1.4143520313816322, 1.348438715571916, 1.28590807241249
2, 1.2265798386826812]
costs tail(last 5)
[0.05414863749250609, 0.053973482216053456, 0.053803998323570856, 0.05364000
445505742, 0.05348132557840613]
```



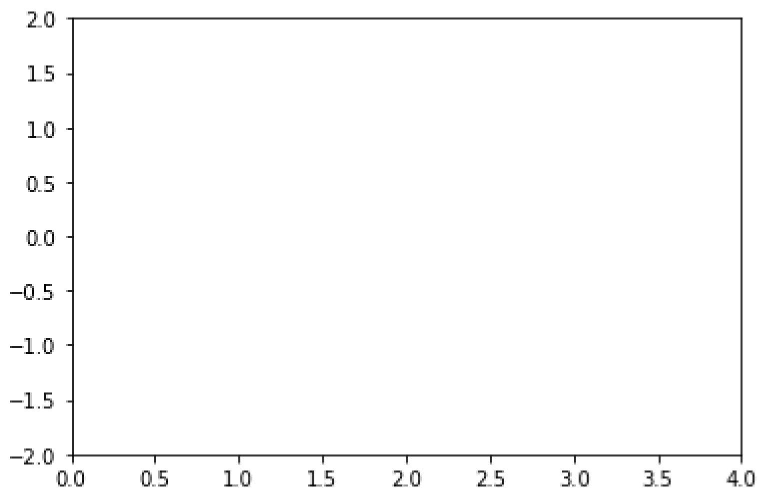
```
koefs
[0.37337692250869814, 0.6532001077511221, -0.06905567859836187]
denormalized_data cost function
```

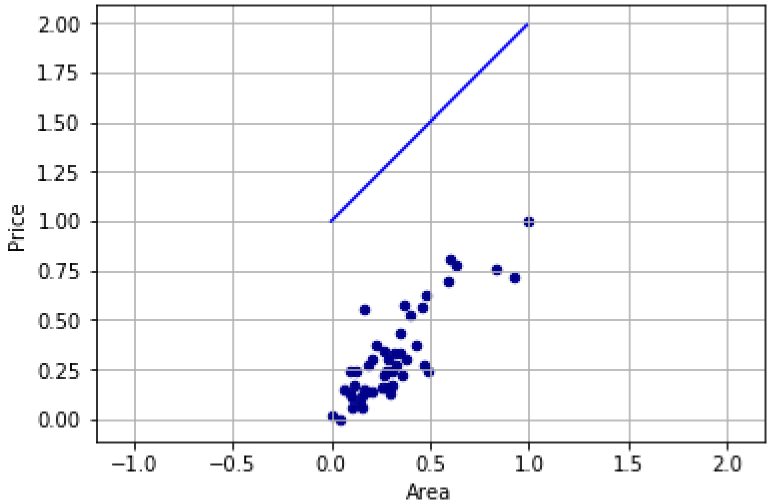
```
c:\users\harwister\appdata\local\programs\python\python36\lib\site-packages
\ipykernel_launcher.py:17: RuntimeWarning: overflow encountered in multiply
c:\users\harwister\appdata\local\programs\python\python36\lib\site-packages
\ipykernel_launcher.py:22: RuntimeWarning: overflow encountered in double_sc
alars
c:\users\harwister\appdata\local\programs\python\python36\lib\site-packages
\ipykernel_launcher.py:23: RuntimeWarning: overflow encountered in double_sc
alars
c:\users\harwister\appdata\local\programs\python\python36\lib\site-packages
\ipykernel_launcher.py:24: RuntimeWarning: overflow encountered in double_sc
alars
c:\users\harwister\appdata\local\programs\python\python36\lib\site-packages
\ipykernel_launcher.py:28: RuntimeWarning: invalid value encountered in doub
le_scalars
```

```
regular cost function
costs head(last 5)
[4608301025121981.0, 3.8967843491565355e+25, 3.328132594949761e+35, 2.842462
5669641633e+45, 2.4276657296915424e+55]
costs tail(last 5)
[nan, nan, nan, nan, nan]
```

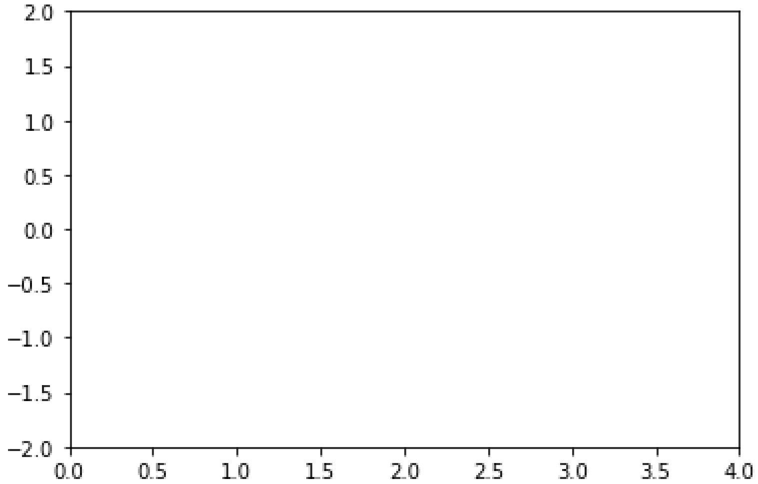


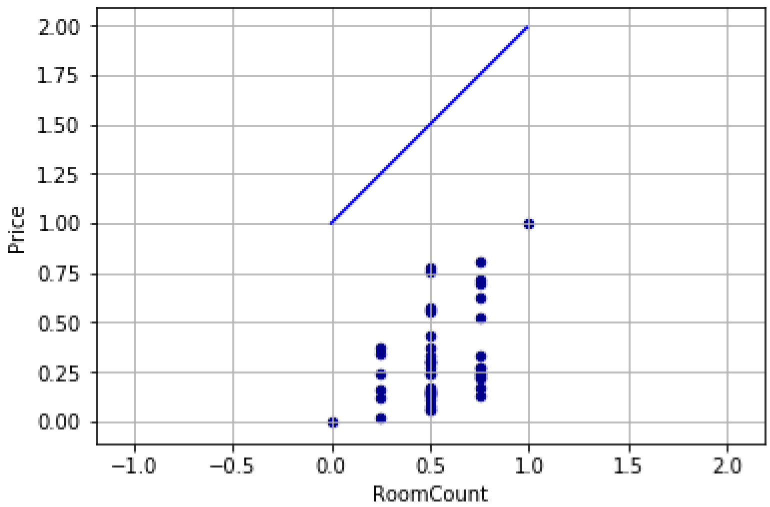

```
koefs
[nan, nan, nan]
result linear function model
```

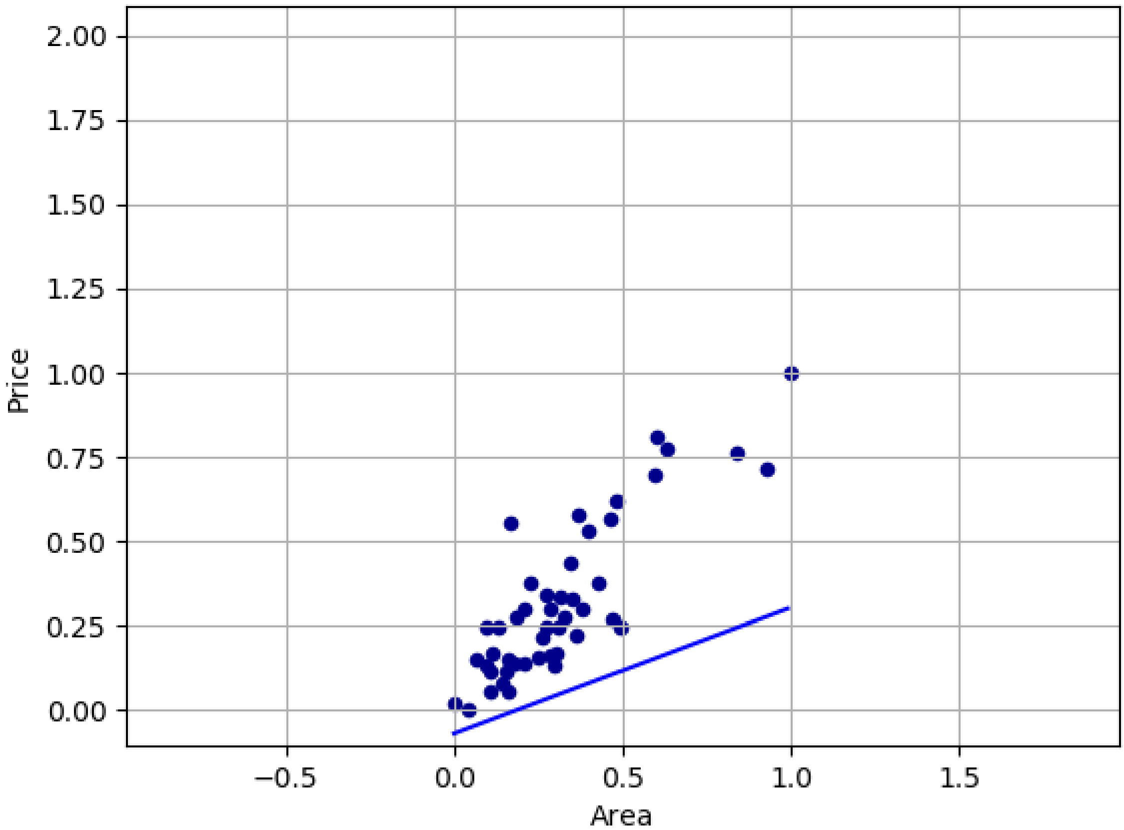


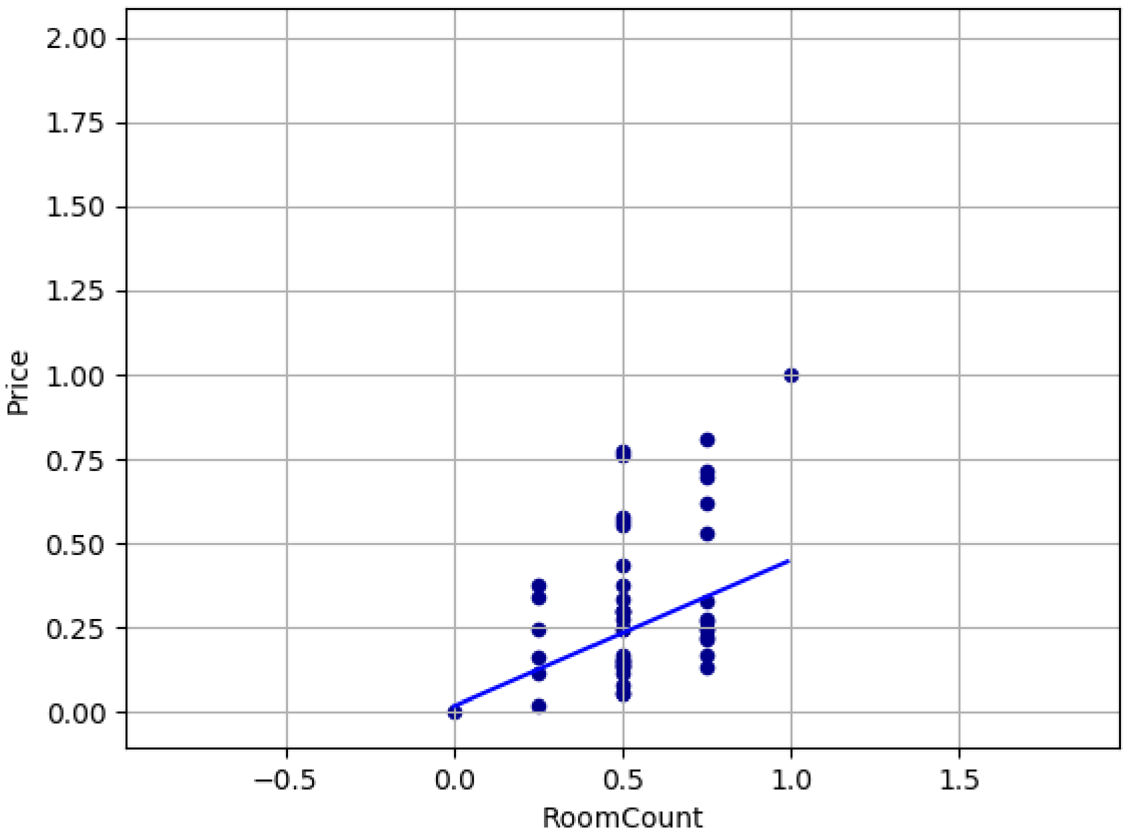


result linear function model





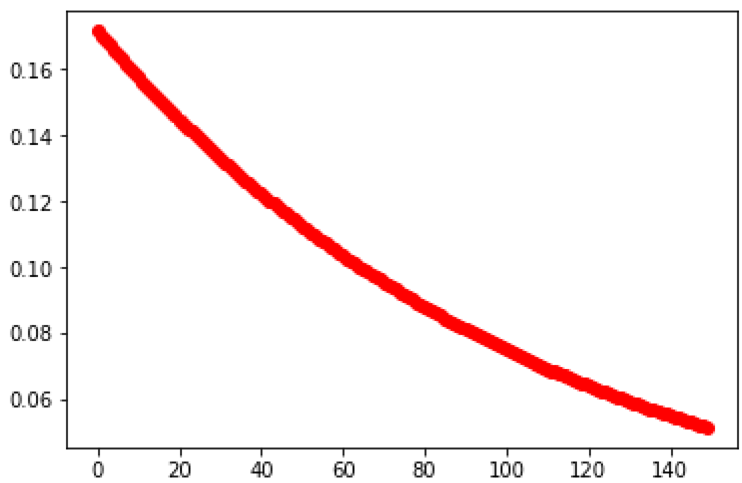

2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Price
−0.5
0.0
0.5
1.0
1.5
Area


2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Price
−0.5
0.0
0.5
1.0
1.5
RoomCount

In [18]:

```
# vectorized descent
# task 8.2
# градиентного спуска для случая многомерной линейной регрессии с использованием векториз

def VectorizedGradient(X, Y, theta, iterations=150, alpha=-0.01):
    thetas = [theta]
    costs = []
    for i in range(iterations):
        theta += alpha * ((X.dot(theta) - Y).T.dot(X)).T / len(Y)
        thetas.append(theta)
        cost = (X.dot(theta) - Y).T.dot(X.dot(theta) - Y) / (2 * len(X))
        if len(costs) == 0 or cost < costs[-1]:
            costs.append(cost)
    print("vectorized cost function")
    plt.plot(range(len(costs)), costs, 'ro')
    print("costs head(last 5)")
    print(costs[:5])
    # task 9 Покажите, что векторизация дает прирост производительности.
    # сходится быстрее при одинаковых параметрах
    print("costs tail(last 5)")
    print(costs[-5:])
    plt.show()
    print("tetha")
    print(thetas[-1])


X = np.array(normalized_data.iloc[:, 0:2])
Y = np.array(normalized_data.Price)
theta = [1, 1]
# task 9
# Покажите, что векторизация дает прирост производительности.

VectorizedGradient(X, Y, theta)
```

```
vectorized cost function
costs head(last 5)
[0.17165261454222386, 0.17018906246382567, 0.16873874708492856, 0.1673015485
9764626, 0.1658773482785399]
costs tail(last 5)
[0.05314803072266046, 0.05275562463821956, 0.05236676040703475, 0.0519814059
7449124, 0.05159952957611665]
```

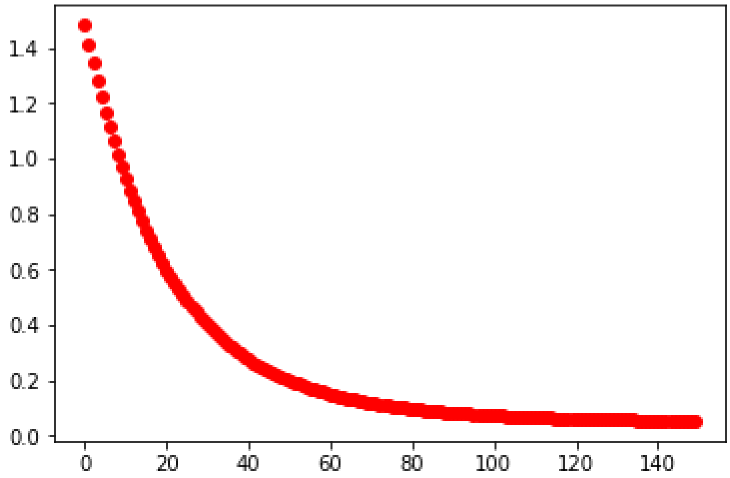


```
tetha
[0.78902327 0.6374514 ]
```

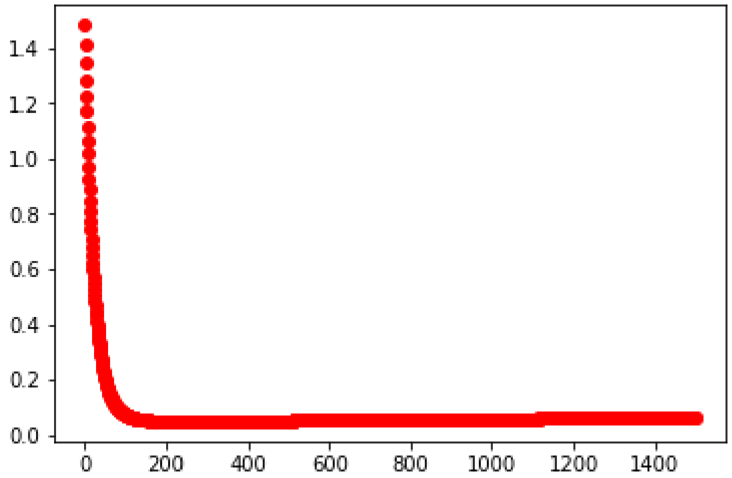
In [19]:

```
# task 10
# Попробуйте изменить параметр a (коэффициент обучения). Как при этом изменяется график ф


Gradient(normalized_data, alpha = -0.01, iterations = 150)

Gradient(normalized_data, alpha = -0.01, iterations = 1500)

Gradient(normalized_data, alpha = -0.1, iterations = 1500)

analytics_tetha = [0.6, 0.95, 0.0]
normalized_data.plot.scatter(x='RoomCount', y='Price', c='DarkBlue')
plt.grid()
plt.axis('equal')
ShowGradientResult(normalized_data, 'RoomCount', tetha[-1],0)
ShowGradientResult(normalized_data, 'RoomCount', analytics_tetha,0, indicator='r-')
plt.show()
```

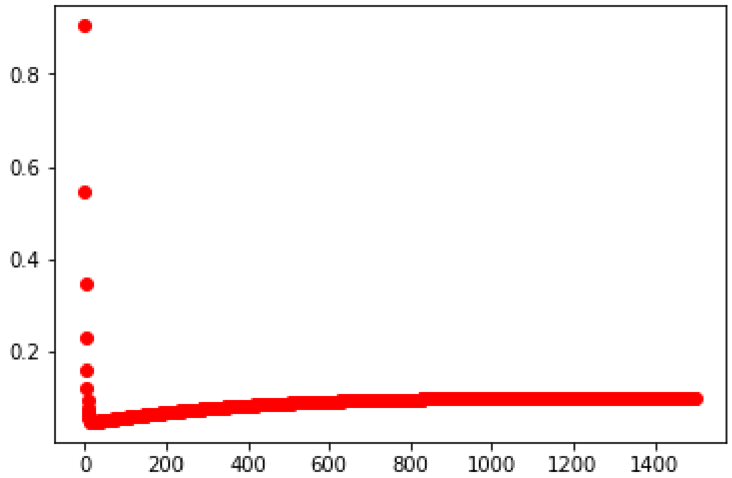
```
regular cost function
costs head(last 5)
[1.483838664503587, 1.4143520313816322, 1.348438715571916, 1.28590807241249
2, 1.2265798386826812]
costs tail(last 5)
[0.05414863749250609, 0.053973482216053456, 0.053803998323570856, 0.05364000
445505742, 0.05348132557840613]
```



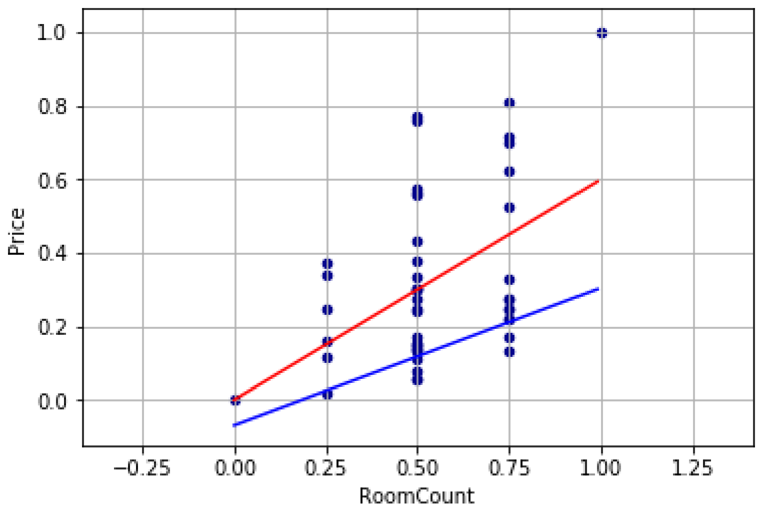

```
koefs
[0.37337692250869814, 0.6532001077511221, -0.06905567859836187]
regular cost function
costs head(last 5)
[1.483838664503587, 1.4143520313816322, 1.348438715571916, 1.28590807241249
2, 1.2265798386826812]
costs tail(last 5)
[0.06382591080234216, 0.06383665281910528, 0.06384739277339395, 0.0638581306
6490524, 0.06386886649333699]
```




```
koefs
[0.21001162608470994, 0.7594244065113257, -0.03427421538774822]
regular cost function
costs head(last 5)
[0.9045120623425623, 0.5459507946680531, 0.34514485860116884, 0.230135736312
1972, 0.16258592971177638]
costs tail(last 5)
[0.1025390237481926, 0.10254075932224847, 0.10254248915503794, 0.10254421326
548718, 0.10254593167246061]
```




```
koefs
[-0.06284370262988882, 0.9502553058356499, 0.05476969794480501]
result linear function model
result linear function model
```



In [20]:

```
normalized_data.plot.scatter(x='RoomCount', y='Price', c='DarkBlue')
plt.grid()
plt.axis('equal')
ShowGradientResult(normalized_data, 'Area', tetha[-1],1)
ShowGradientResult(normalized_data, 'Area', analytics_tetha,1, 'r-')
plt.show()
# task 11
```

```
result linear function model
result linear function model
```