Showing the relation between λ and L_s.

In [ ]:
```
import numpy as np
import matplotlib.pyplot as plt
import math as math
```

In [ ]:
```
no_input=int(input(("Please enter how many inputs of values do you have?")))

print(f"You have {no_input} sets of values. Please enter your values one by one"
```

```
You have 4 sets of values. Please enter your values one by one
```

For M/M/1

In [ ]:
```
lamda=[]
meu=[]
ro=[]
for i in range (0,no_input):
    divisor=False
    while divisor==False:
        z=float(input(f'Enter value {i+1} of arrival rate'))
        x=float(input(f'Enter value {i+1} of service rate'))
        if ((z/x)<1):
            lamda.append(z)
            meu.append(x)
            ro.append(z/x)
            divisor=True
        else:
            print("The ratio of available rate and service rate must be less tha
print(lamda,meu,ro)
```

```
[20.0, 22.0, 24.0, 26.0] [27.0, 27.0, 27.0, 27.0] [0.7407407407407407, 0.81481481
48148148, 0.8888888888888888, 0.9629629629629629]
```

In [ ]:
```
l_s=[]
for roo in ro:
    y=(roo/(1-roo))
    l_s.append(y)

print(l_s)
```

```
[2.8571428571428563, 4.399999999999999, 7.9999999999999964, 25.99999999999996]
```

Now for M/M/1/N

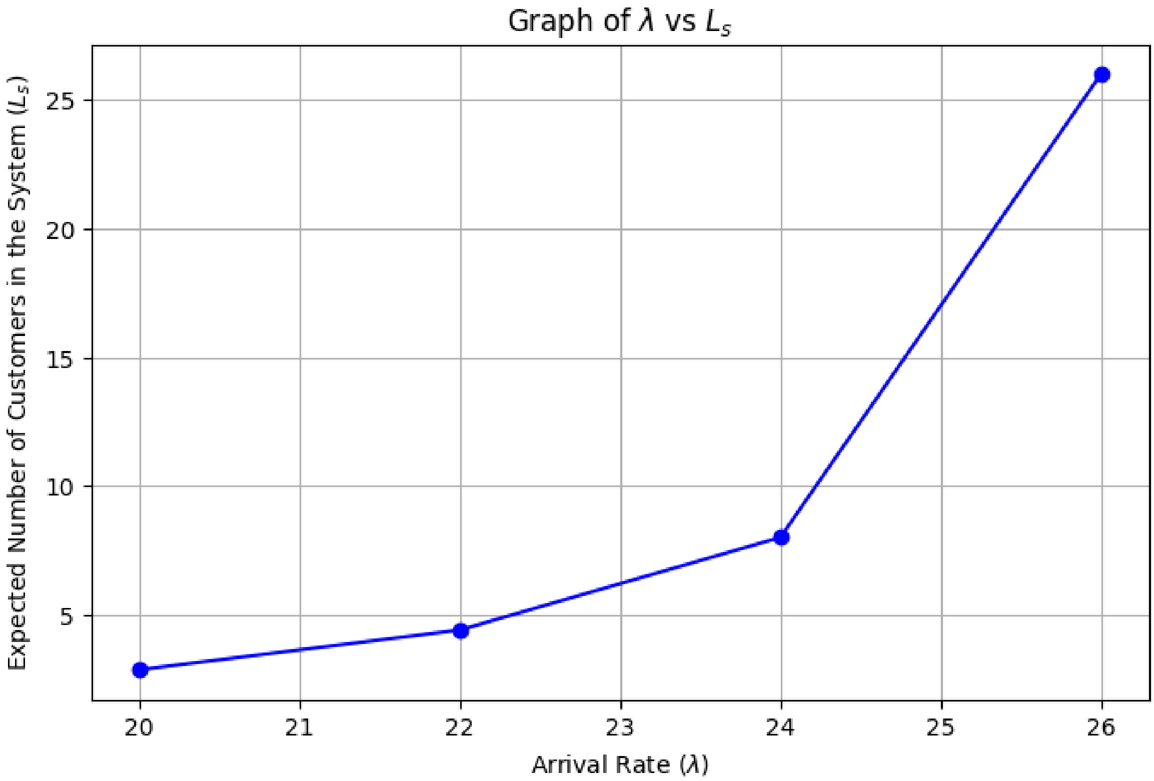
In [ ]:
```
n=int(input('Give fixed number of services'))
print(f'fixed number of service is {n}')
l_sn=[]

for roo in ro:
    a=(roo*((1-(n+1)*roo**(n))+n*roo**(n+1)))/((1-roo)*(1-roo**(n+1)))
    l_sn.append(a)
print(l_sn)
```

```
fixed number of service is 60
[2.8571421732785107, 4.399770952591624, 7.953724053938914, 19.219020125203944]
```

Graph without curve fitting

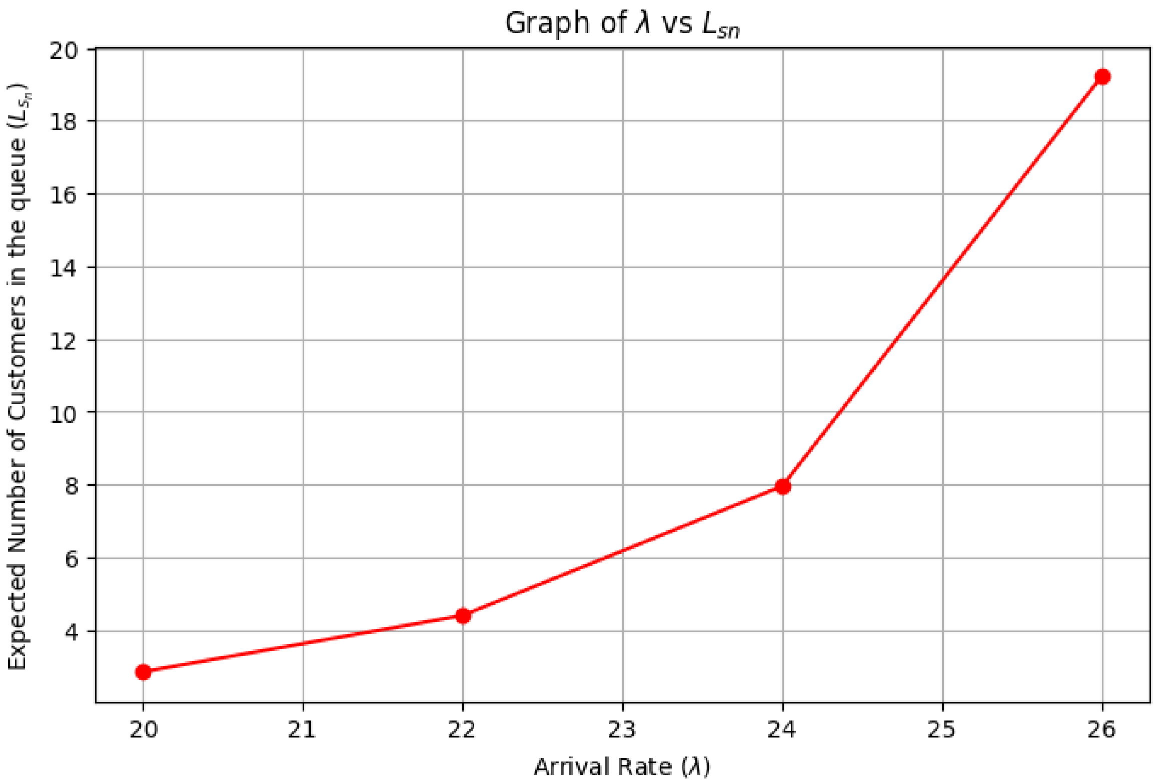
Graph of λ vs L_s

In [ ]:
```
plt.figure(figsize=(8, 5))
plt.plot(lamda, l_s, marker='o', linestyle='-', color='b')
plt.xlabel('Arrival Rate ($\lambda$)')
plt.ylabel('Expected Number of Customers in the System ($L_s$)')
plt.title('Graph of $\lambda$ vs $L_s$')
plt.grid(True)
plt.show()
```



Graph of λ vs L_{s_n}

In [ ]:
```
plt.figure(figsize=(8, 5))
plt.plot(lamda, l_sn, marker='o', linestyle='-', color='r')
plt.xlabel('Arrival Rate ($\lambda$)')
plt.ylabel('Expected Number of Customers in the queue ($L_{s_n}$)')
plt.title('Graph of $\lambda$ vs $L_{sn}$')
plt.grid(True)
plt.show()
```



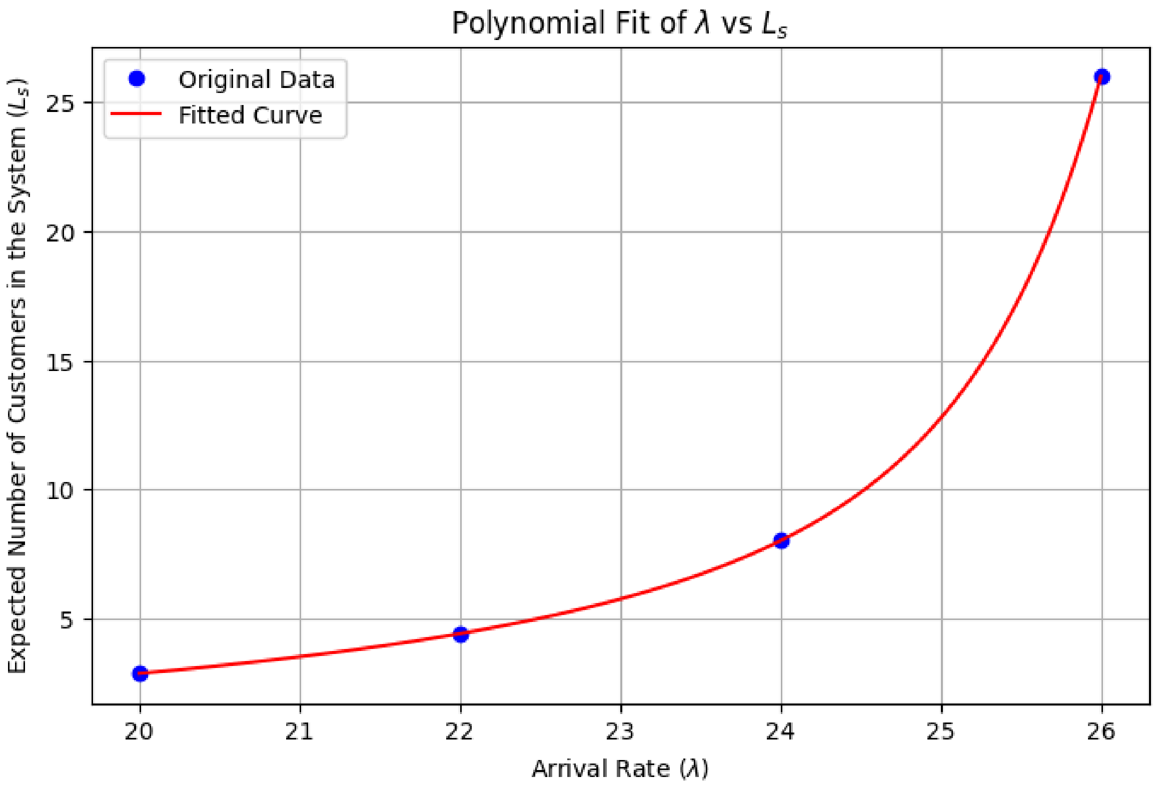
PLOTTING AND FITTING THE CURVE

Graph of λ vs L_s

In [ ]:

```
degree = 50
coeffs = np.polyfit(lamda, l_s, degree)
polynomial = np.poly1d(coeffs)

# fitting curve ko lagi
lamda_fine = np.linspace(min(lamda), max(lamda), 100)
l_s_fitted = polynomial(lamda_fine)

plt.figure(figsize=(8, 5))
plt.plot(lamda, l_s, 'bo', label='Original Data')
plt.plot(lamda_fine, l_s_fitted, 'r-', label='Fitted Curve')
plt.xlabel('Arrival Rate ($\lambda$)')
plt.ylabel('Expected Number of Customers in the System ($L_s$)')
plt.title('Polynomial Fit of $\lambda$ vs $L_s$')
plt.legend()
plt.grid(True)
plt.show()
```

```
C:\Users\user\AppData\Local\Temp\ipykernel_10736\1581807314.py:2: RankWarning: Po
lyfit may be poorly conditioned
  coeffs = np.polyfit(lamda, l_s, degree)
```



Graph of λ vs L_{s_n}

In [ ]:
```
degree = 50
coeffs = np.polyfit(lamda, l_sn, degree)
polynomial = np.poly1d(coeffs)
# fitting curve ko lagi
lamda_fine2 = np.linspace(min(lamda), max(lamda), 100)
l_sn_fitted = polynomial(lamda_fine2)

plt.figure(figsize=(8, 5))
plt.plot(lamda, l_sn, 'bo', label='Original Data')
plt.plot(lamda_fine2, l_sn_fitted, 'b-', label='Fitted Curve')
plt.xlabel('Arrival Rate ($\lambda$)')
plt.ylabel('Expected Number of Customers in the queue ($L_{sn}$)')
plt.title('Polynomial Fit of $\lambda$ vs $L_{sn}$')
plt.legend()
plt.grid(True)
plt.show()
```

```
C:\Users\user\AppData\Local\Temp\ipykernel_10736\3959033233.py:2: RankWarning: Po
lyfit may be poorly conditioned
  coeffs = np.polyfit(lamda, l_sn, degree)
```

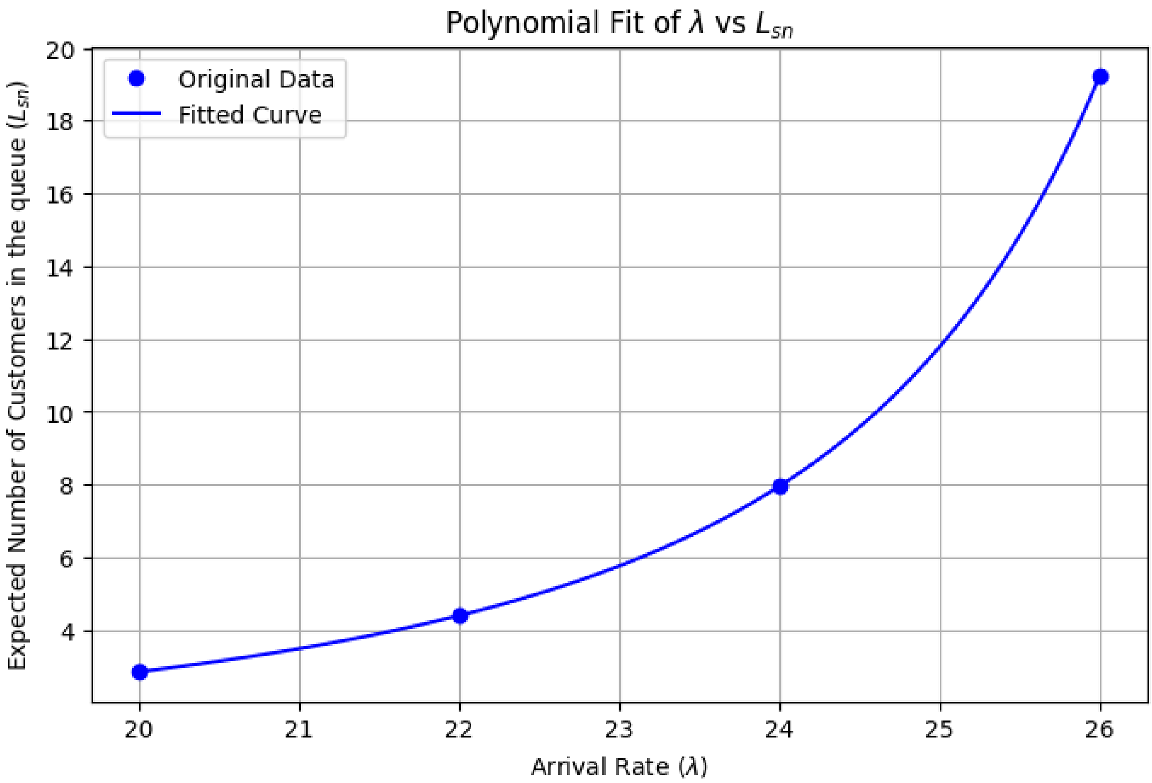
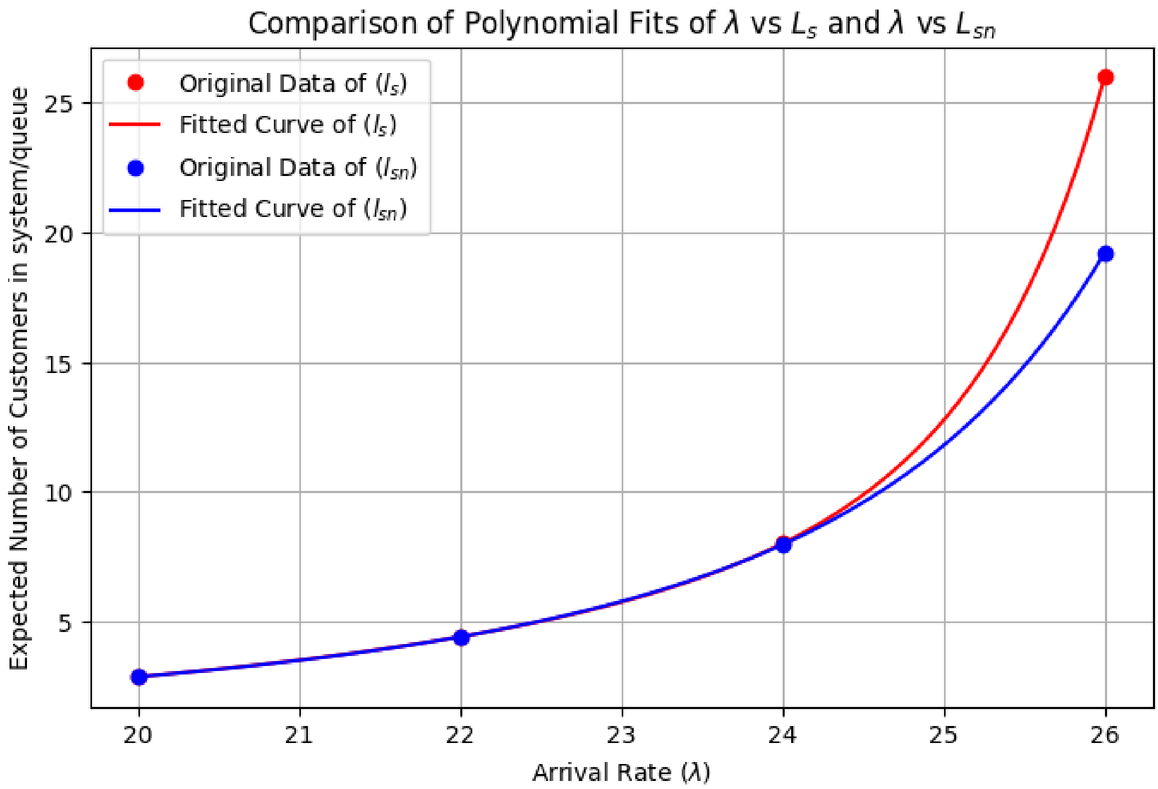


Table of values λ vs L_s vs L_{sn}

In [ ]:
```
print(f"lambda\t|\tL_s\t|\tL_sn")
for lam,ser,que in zip(lamda,l_s,l_sn):
    print(f"{lam:.3f}\t|\t{ser:.3f}\t|\t{que:.3f}")
```

```
lambda  |       L_s     |       L_sn
20.000  |       2.857   |       2.857
22.000  |       4.400   |       4.400
24.000  |       8.000   |       7.954
26.000  |       26.000  |       19.219
```

In [ ]:
```
plt.figure(figsize=(8, 5))
plt.plot(lamda, l_s, 'ro', label='Original Data of ($l_s$)')
plt.plot(lamda_fine, l_s_fitted, 'r-', label='Fitted Curve of ($l_s$)')
plt.plot(lamda, l_sn, 'bo', label='Original Data of ($l_{sn}$)')
plt.plot(lamda_fine2, l_sn_fitted, 'b-', label='Fitted Curve of ($l_{sn}$)')
plt.xlabel('Arrival Rate ($\lambda$)')
plt.ylabel('Expected Number of Customers in system/queue')
plt.title('Comparison of Polynomial Fits of $\lambda$ vs $L_s$ and $\lambda$ vs
plt.legend()
plt.grid(True)
plt.show()
```



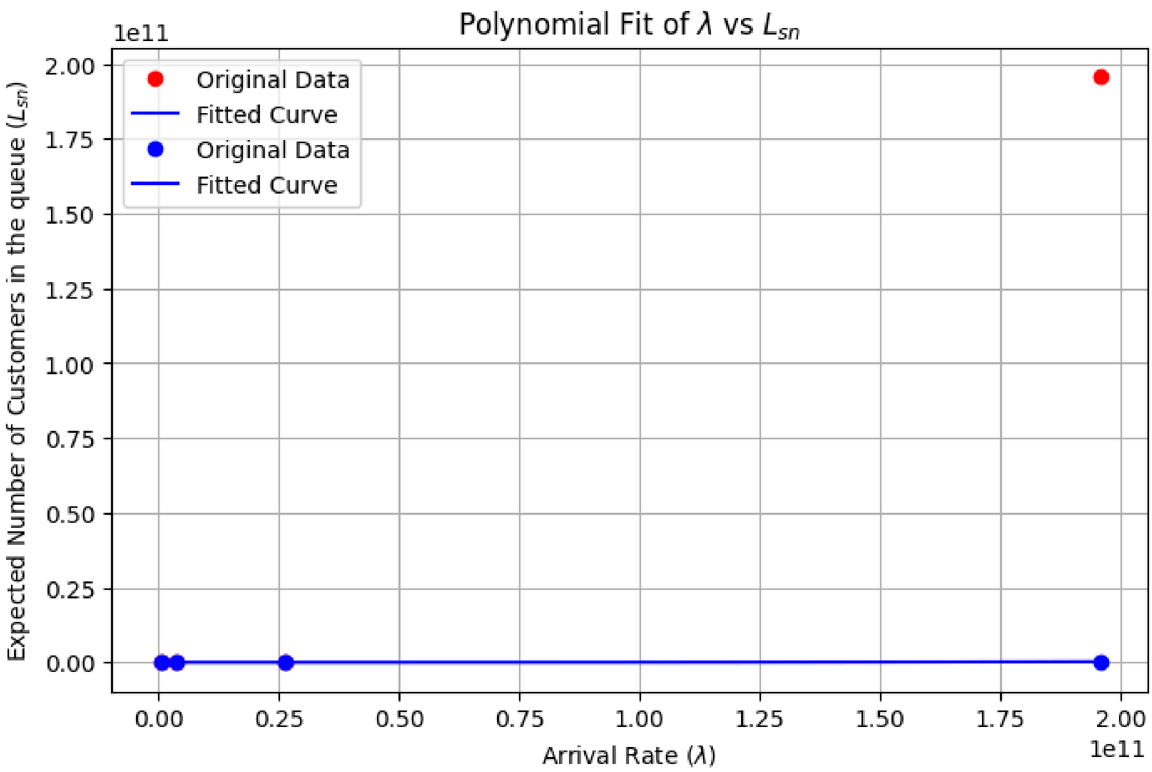
fit of exponential values

In [ ]:
```
exp_lamda=[]
exp_l_s=[]
exp_l_q=[]

for lam,ser,que in zip(lamda,l_s,l_sn):
    exp_lamda.append(np.exp(lam))
    exp_l_s.append(np.exp(ser))
    exp_l_q.append(np.exp(que))


print(exp_lamda,exp_l_s,exp_l_s)
```

```
[485165195.4097903, 3584912846.131592, 26489122129.84347, 195729609428.83878] [1
7.411708063327637, 81.450868664968, 2980.957987041718, 195729609428.83112] [17.41
1708063327637, 81.450868664968, 2980.957987041718, 195729609428.83112]
```

In [ ]:
```
degree = 3
coeffs = np.polyfit(exp_lamda, exp_l_q, degree)
polynomial = np.poly1d(coeffs)
# fitting curve ko lagi
lamda_fine_exp = np.linspace(min(exp_lamda), max(exp_lamda), 100)
l_s_fitted_exp = polynomial(lamda_fine_exp)
lamda_fine_exp2 = np.linspace(min(lamda), max(lamda), 100)
l_q_fitted_exp = polynomial(lamda_fine_exp2)
plt.figure(figsize=(8, 5))
plt.plot(exp_lamda, exp_l_s, 'ro', label='Original Data')
plt.plot(lamda_fine_exp, l_s_fitted_exp, 'b-', label='Fitted Curve')
plt.plot(exp_lamda, exp_l_q, 'bo', label='Original Data')
plt.plot(lamda_fine_exp2, l_q_fitted_exp, 'b-', label='Fitted Curve')
plt.xlabel('Arrival Rate ($\lambda$)')
plt.ylabel('Expected Number of Customers in the queue ($L_{sn}$)')
plt.title('Polynomial Fit of $\lambda$ vs $L_{sn}$')
```

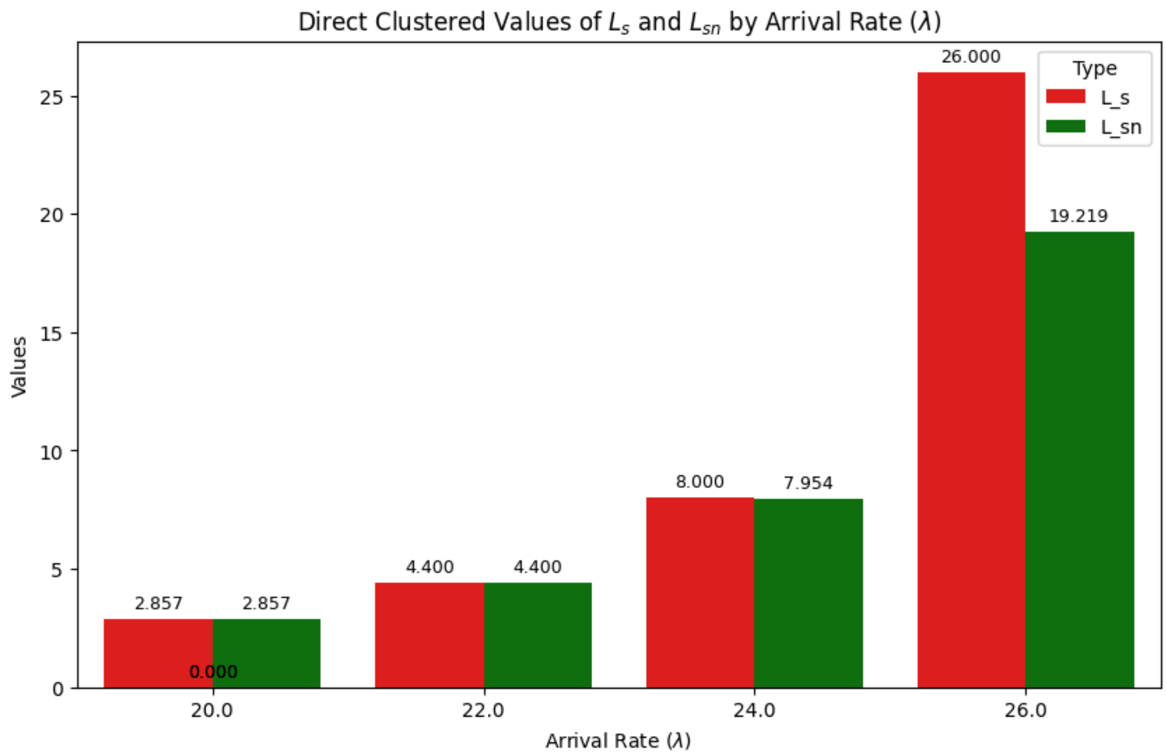
```
plt.legend()
plt.grid(True)
plt.show()
```



Clustered Plot of λ vs L_s , L_q

In [ ]:

```
import seaborn as sns
import pandas as pd
data_direct = pd.DataFrame({
    'Lambda': lamda,
    'L_s': l_s,
    'L_sn': l_sn
})

data_melted_direct = data_direct.melt(id_vars=["Lambda"], value_vars=["L_s", "L_

plt.figure(figsize=(10, 6))
bar_plot = sns.barplot(x="Lambda", y="Value", hue="Type", data=data_melted_direc
plt.title('Direct Clustered Values of $L_s$ and $L_{sn}$ by Arrival Rate ($\lamb
plt.xlabel('Arrival Rate ($\lambda$)')
plt.ylabel('Values')

for p in bar_plot.patches:
    bar_plot.annotate(format(p.get_height(), '.3f'),
                      (p.get_x() + p.get_width() / 2., p.get_height()),
                      ha = 'center', va = 'center',
                      size=9, xytext = (0, 8),
                      textcoords = 'offset points')

plt.show()
```


Direct Clustered Values of L_s and L_{sn} by Arrival Rate (λ)
Type
L_s
L_sn
26.000
19.219
8.000
7.954
4.400
4.400
2.857
2.857
0.000
Values
Arrival Rate (λ)
20.0
22.0
24.0
26.0
0
5
10
15
20
25

In [ ]: