In [110]:

```
import pandas as pd
import numpy as np
import seaborn as sns
from scipy.stats import norm
from tabulate import tabulate
import matplotlib.pyplot as plt
plt.style.use('ggplot')
import warnings
warnings.filterwarnings("ignore")
```

executed in 4ms, finished 06:09:29 2023-08-11

In [2]:

```
data = pd.read_csv("RAWdataforEdinburghMasters1.csv")
```

executed in 28ms, finished 03:25:45 2023-08-11

In [3]:

```
#dont need first two columns
data = data.drop(columns=data.columns[:2], axis=1)

data

#11216 datapoints
```

executed in 30ms, finished 03:25:45 2023-08-11

Out[3]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric	Pass/F
0	Container	24.0	0-36	25.0	2	56.0	31-60%	13.51	
1	Bulk Carrier	30.0	0-36	42.0	4	64.7	61-100%	17.84	
2	Products Tanker	30.0	0-36	22.0	6	52.3	31-60%	48.75	
3	Deck Cargo Ship	35.0	0-36	28.0	7	39.1	31-60%	37.64	
4	Wood Chips Carrier	35.0	0-36	31.0	1	60.2	61-100%	21.91	
...	...	...	...	...	...	...	...	...	
11211	Bulk Carrier	60.0	37-60	35.0	1	25.2	0-30%	0.01	
11212	Bulker	30.0	0-36	27.0	5	65.0	61-100%	9.62	
11213	Products Tanker	24.0	0-36	22.0	6	61.2	61-100%	22.44	
11214	Ro-Ro	60.0	37-60	32.0	7	12.0	0-30%	14.33	
11215	General Cargo	60.0	37-60	36.0	1	36.0	31-60%	10.77	

11216 rows × 10 columns

In [4]:

```
## pre-processing

#if there are some problematic datapoints

display(data[(data["Scheme Group"]=="0-36") & (data["Scheme"] > 36)])

display(data[(data["Scheme Group"]=="37-60") & (data["Scheme"] < 37)])

display(data[(data["Scheme Group"]=="37-60") & (data["Scheme"] > 60)])
```

executed in 33ms, finished 03:25:49 2023-08-11

Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric	Pass/Fail	Pro

Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric	Pass/Fail	Pro

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric	Pass
5316	Vehicles Carrier	67.0	37-60	24.0	5	58.9	31-60%	8.52	
5433	Combination Gas Tanker (LNG/LPG)	90.0	37-60	46.0	4	70.2	61-100%	13.25	

In [5]:

```
# delete these two problematic datapoints where their "scheme Group" does not match their "Scheme
data = data.drop(index=[5316, 5433])
```

executed in 11ms, finished 03:25:49 2023-08-11

In [6]:

```
##the number of data after removing those two datapoints
len(data)
```

executed in 15ms, finished 03:25:50 2023-08-11

Out[6]:

11214

In [7]:

```
##if there are any NAs in each columns
data.isna().any()
```

executed in 16ms, finished 03:25:50 2023-08-11

Out[7]:

```
Vessel Group           True
Scheme                 True
Scheme Group          False
In Service Period      True
Route Number          False
% Activity             True
Activity Group         True
Performance Metric    False
Pass/Fail             False
Product Code          False
dtype: bool
```

In [8]:

```
#delete any rows which contain NAs
data = data.dropna(axis=0)
data
```

executed in 25ms, finished 03:25:50 2023-08-11

Out[8]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric	Pass/F
0	Container	24.0	0-36	25.0	2	56.0	31-60%	13.51	
1	Bulk Carrier	30.0	0-36	42.0	4	64.7	61-100%	17.84	
2	Products Tanker	30.0	0-36	22.0	6	52.3	31-60%	48.75	
3	Deck Cargo Ship	35.0	0-36	28.0	7	39.1	31-60%	37.64	
4	Wood Chips Carrier	35.0	0-36	31.0	1	60.2	61-100%	21.91	
...	...	...	...	...	...	...	...	...	
11211	Bulk Carrier	60.0	37-60	35.0	1	25.2	0-30%	0.01	
11212	Bulker	30.0	0-36	27.0	5	65.0	61-100%	9.62	
11213	Products Tanker	24.0	0-36	22.0	6	61.2	61-100%	22.44	
11214	Ro-Ro	60.0	37-60	32.0	7	12.0	0-30%	14.33	
11215	General Cargo	60.0	37-60	36.0	1	36.0	31-60%	10.77	

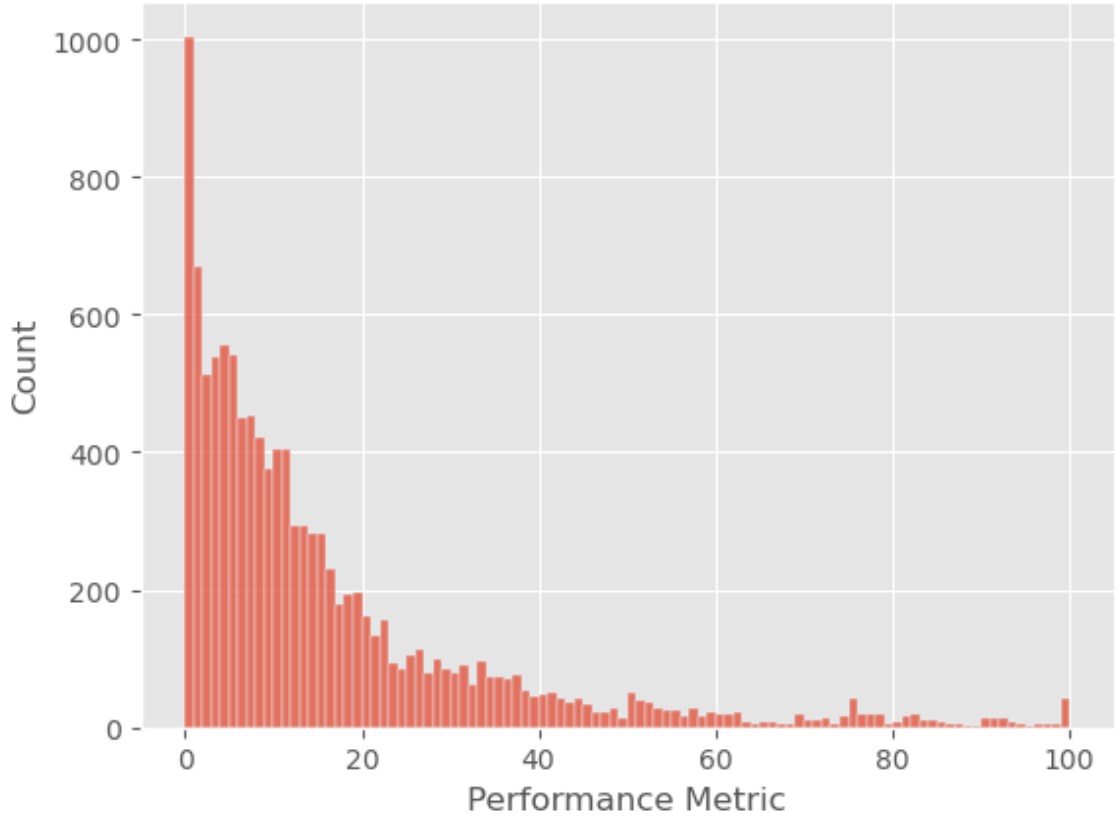
11208 rows × 10 columns

After deleting rows containing NA values, the number of data is reduced to 11208 from 11214.

In [9]:

```
sns.histplot(data["Performance Metric"], bins=100)
plt.show()
```

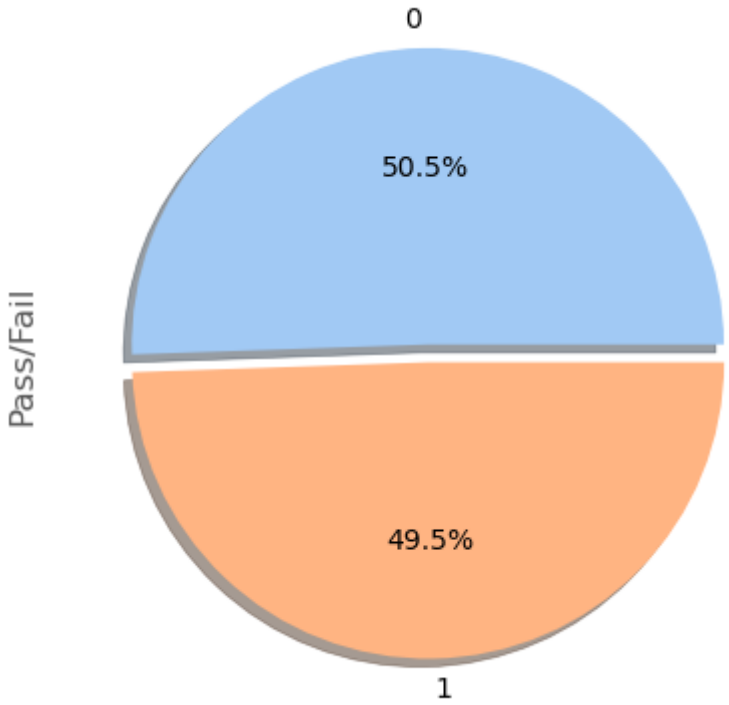
executed in 291ms, finished 03:25:51 2023-08-11



In [10]:

```
#draw a pie plot of the pass rate
colors = sns.color_palette('pastel')
data["Pass/Fail"].value_counts().plot.pie(colors = colors, explode = [0.03,0.03],autopct='%1.1f%
plt.show()
```

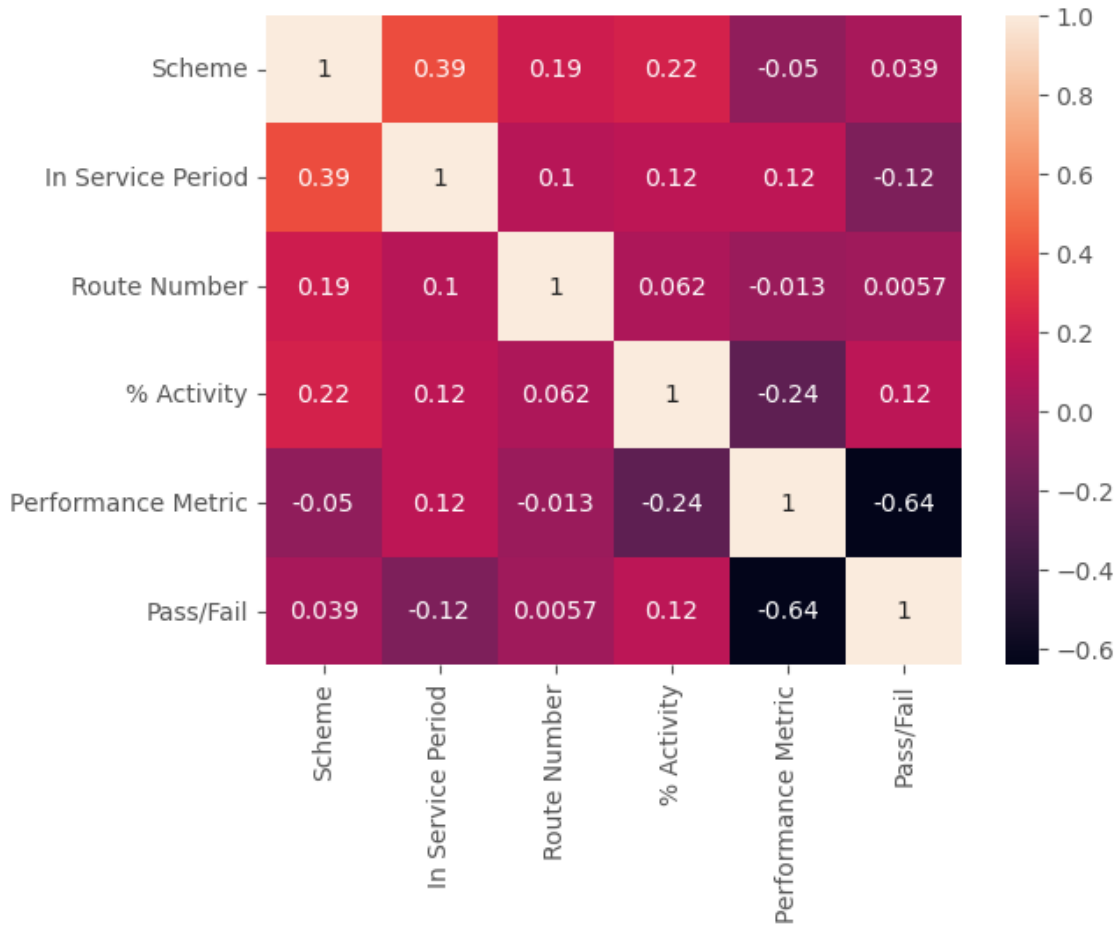
executed in 94ms, finished 03:25:51 2023-08-11



In [11]:

```
sns.heatmap(data.corr(), annot=True)
plt.show()
```

executed in 272ms, finished 03:25:51 2023-08-11



In [12]:

```
##only consider those data belonging to "Schemem Group": 37-60%
data1 = data[data["Scheme Group"]=="37-60"]

#data = data[data["In Service Period"]==60]
```

executed in 9ms, finished 03:25:51 2023-08-11

In [13]:

```
data1.isna().any()
```

executed in 14ms, finished 03:25:51 2023-08-11

Out[13]:

```
Vessel Group          False
Scheme                False
Scheme Group          False
In Service Period     False
Route Number          False
% Activity            False
Activity Group        False
Performance Metric    False
Pass/Fail             False
Product Code          False
dtype: bool
```

In [14]:

```
#number of all types of vessels
data1.value_counts("Vessel Group")
```

executed in 21ms, finished 03:25:52 2023-08-11

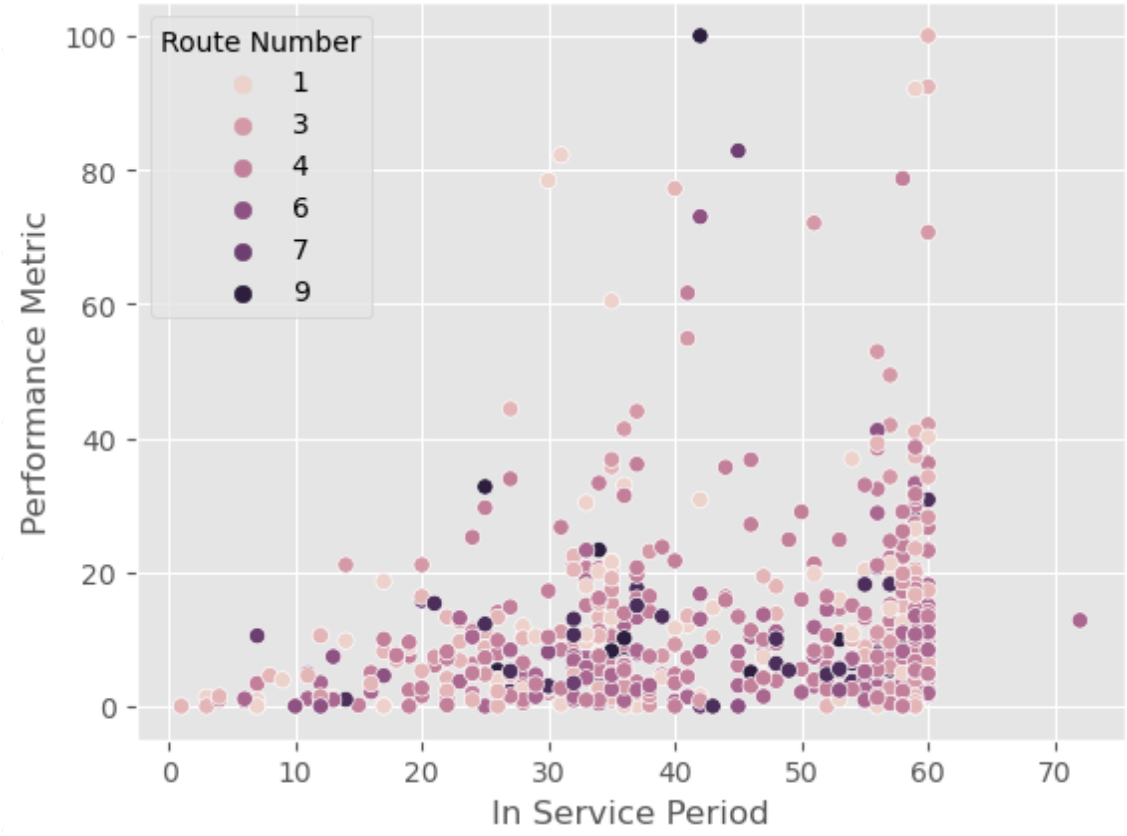
Out[14]:

Vessel Group	
Container	408
Bulker	296
Offshore Vessel	217
Tanker	201
Chemical Tanker	174
General Cargo	130
Tug	122
LNG Carrier	118
Bulk Carrier	107

In [15]:

```
sns.scatterplot(x="In Service Period", y="Performance Metric", data=data1[data1["Product Code"]=
plt.show()
```

executed in 2.15ms, finished 03:25:53 2023-08-11



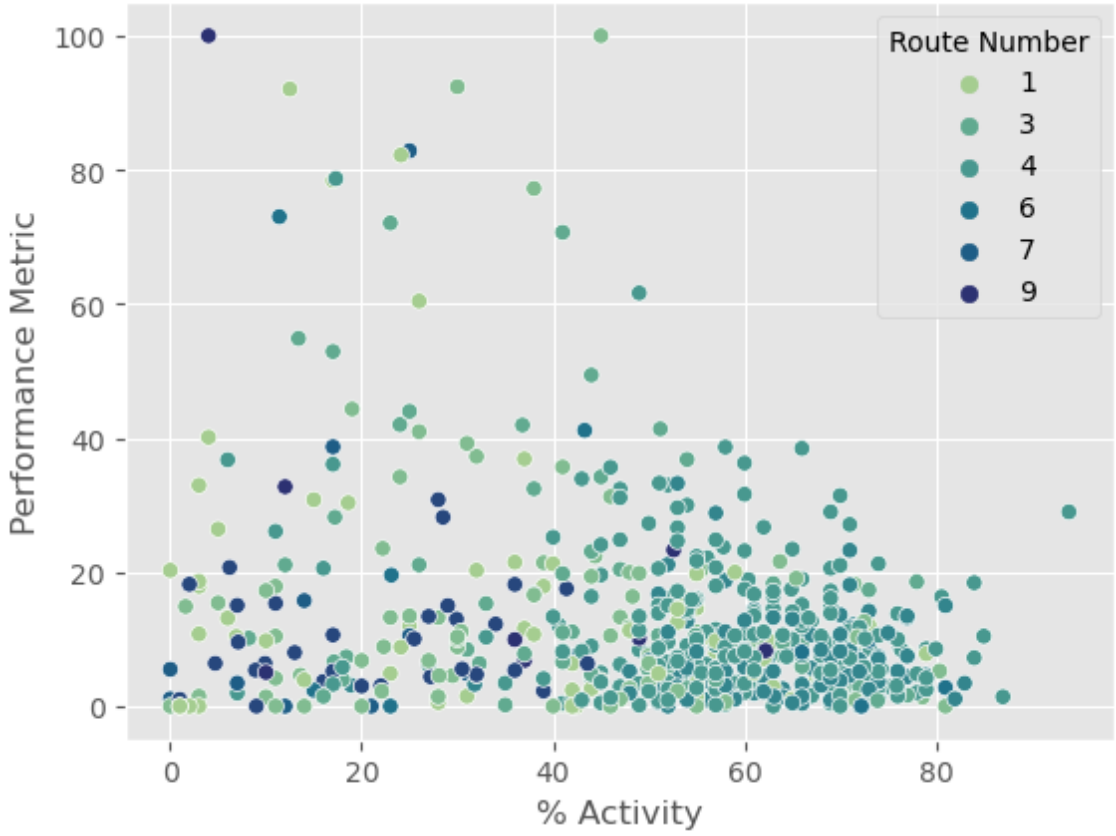
Crude/Oil Products Tanker	5
Navy	4
Gas Processing Vessel	4
Patrol Vessel	3
Offshore Tug/Supply Ship	3
Shuttle Tanker	3
Well Stimulation Vessel	2
Barge	2
Pollution Control Vessel	2
Heavy Load Carrier, semi submersible	2
Deck Cargo Ship	2
Unknown Function, Naval/Naval Auxiliary	1
Wood Chips Carrier	1
Livestock Carrier	1
Production Floating	1
Pipe Layer Crane Vessel	1
Pipe Layer	1
Ore Carrier	1
Anchor Handling Vessel	1
Fishing Vessel	1
Diving Support Vessel	1
Crew Boat	1
Bunkering Tanker	1
Bulk Carrier, Self-discharging	1
Asphalt/Bitumen Tanker	1

```
Work/Maintenance Pontoon, non propelled      1
dtype: int64
```

In [16]:

```
sns.scatterplot(x="% Activity", y="Performance Metric", data=data1[data1["Product Code"]=="a"],
                palette="crest")
plt.show()
```

executed in 215ms, finished 03:25:53 2023-08-11



In [17]:

```
#classify the (scheme group-37-60) data into 3 subsets by the activity group
act0_30 = data1[data1["Activity Group"]=="0-30%"]
act31_60 = data1[data1["Activity Group"]=="31-60%"]
act61_100 = data1[data1["Activity Group"]=="61-100%"]
```

executed in 7ms, finished 03:25:53 2023-08-11

In [18]:

```
act0_30
```

executed in 29ms, finished 03:25:54 2023-08-11

Out[18]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric	Pass/Fa
108	Products Tanker	59.0	37-60	56.0	1	14.5	0-30%	45.11	
138	Bulk Carrier	59.0	37-60	31.0	2	4.1	0-30%	53.98	
154	Offshore Vessel	60.0	37-60	39.0	1	15.0	0-30%	72.18	
176	Anchor Handling Tug Supply	60.0	37-60	28.0	1	28.5	0-30%	1.20	
200	Tug	60.0	37-60	58.0	8	3.0	0-30%	11.82	
...	...	...	...	...	...	...	...	...	
11142	Offshore Vessel	60.0	37-60	25.0	4	20.0	0-30%	17.56	
11173	Anchor Handling Tug Supply	48.0	37-60	1.0	7	5.0	0-30%	2.73	
11206	Anchor Handling Tug Supply	60.0	37-60	52.0	4	23.8	0-30%	5.93	
11211	Bulk Carrier	60.0	37-60	35.0	1	25.2	0-30%	0.01	
11214	Ro-Ro	60.0	37-60	32.0	7	12.0	0-30%	14.33	

584 rows × 10 columns

In [19]:

```
act31_60
```

executed in 28ms, finished 03:25:54 2023-08-11

Out[19]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric	Pass/F
16	Bulk Carrier	60.0	37-60	41.0	4	52.3	31-60%	9.07	
42	Products Tanker	47.0	37-60	29.0	2	49.6	31-60%	15.23	
70	Bulk Carrier	60.0	37-60	19.0	6	35.7	31-60%	0.15	
90	Container Ship (Fully Cellular)	59.0	37-60	59.0	2	51.1	31-60%	31.35	
99	Bulk Carrier	59.0	37-60	37.0	4	50.5	31-60%	7.91	
...	...	...	...	...	...	...	...	...	
11179	Platform Supply Ship	60.0	37-60	57.0	3	36.8	31-60%	41.93	
11185	General Cargo	60.0	37-60	24.0	4	40.0	31-60%	0.33	
11188	Bulker	40.0	37-60	38.0	1	43.0	31-60%	5.08	
11208	Bulker	60.0	37-60	59.0	2	36.0	31-60%	26.59	
11215	General Cargo	60.0	37-60	36.0	1	36.0	31-60%	10.77	

951 rows × 10 columns

In [20]:

```
act61_100
```

executed in 20ms, finished 03:25:55 2023-08-11

Out[20]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric
7	General Cargo Ship	60.0	37-60	29.0	4	60.1	61-100%	3.22
8	Container	60.0	37-60	10.0	1	69.0	61-100%	6.30
30	Container Ship (Fully Cellular)	60.0	37-60	58.0	5	75.3	61-100%	13.16
56	Container Ship (Fully Cellular)	60.0	37-60	12.0	4	71.5	61-100%	0.84
59	Deck Cargo Ship	38.0	37-60	35.0	1	78.9	61-100%	5.23
...	...	...	...	...	...	...	...	...
11016	Container Ship (Fully Cellular)	60.0	37-60	36.0	1	61.0	61-100%	10.07
11100	Bulk Carrier	60.0	37-60	53.0	4	68.3	61-100%	3.14
11141	Bulk Carrier	60.0	37-60	52.0	5	60.7	61-100%	37.56
11154	Chemical/Products Tanker	60.0	37-60	34.0	4	63.3	61-100%	7.36
11202	Bulker	60.0	37-60	58.0	5	62.0	61-100%	0.59

935 rows × 10 columns

In [21]:

```
target_products = ["a", "f", "g", "i", "k", "m", "n", "o", "q", "r", "s"] #target products
```

executed in 17ms, finished 03:25:55 2023-08-11

In [22]:

```
data1[data1["Product Code"].isin(target_products)]
```

executed in 28ms, finished 03:25:56 2023-08-11

Out[22]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric	Pass/F
7	General Cargo Ship	60.0	37-60	29.0	4	60.1	61-100%	3.22	
8	Container	60.0	37-60	10.0	1	69.0	61-100%	6.30	
16	Bulk Carrier	60.0	37-60	41.0	4	52.3	31-60%	9.07	
30	Container Ship (Fully Cellular)	60.0	37-60	58.0	5	75.3	61-100%	13.16	
42	Products Tanker	47.0	37-60	29.0	2	49.6	31-60%	15.23	
...	...	...	...	...	...	...	...	...	
11206	Anchor Handling Tug Supply	60.0	37-60	52.0	4	23.8	0-30%	5.93	
11208	Bulker	60.0	37-60	59.0	2	36.0	31-60%	26.59	
11211	Bulk Carrier	60.0	37-60	35.0	1	25.2	0-30%	0.01	
11214	Ro-Ro	60.0	37-60	32.0	7	12.0	0-30%	14.33	
11215	General Cargo	60.0	37-60	36.0	1	36.0	31-60%	10.77	

1652 rows × 10 columns

In [23]:

```
products = data1["Product Code"].unique()
```

executed in 5ms, finished 03:25:57 2023-08-11

In [24]:

```
#highlight those numbers < 10 with different colours
def highlight(cell):
    '''
    This function takes as input all entry in a dataframe and changes the colour of the number
    if it's less than 10.
    '''
    if type(cell) != str and cell == 0:
        return "color: red" #if it's 0, mark it as bright red
    elif type(cell) != str and cell < 10:
        return "color: darkred" #if it's below 10, mark it as dark red
    else:
        return "color: black"
```

executed in 10ms, finished 03:25:57 2023-08-11

In [25]:

```
def get_table(df):
    '''
    This function helps derive a table of the numbers of vessels for different products and diffe
    It takes as input a data frame.
    '''
    products = ["a", "f", "g", "i", "k", "m", "n", "o", "q", "r", "s"] #target products
    #build a matrix consisting of zeros; rows=products; columns=routes
    table_product_route = np.zeros((len(products), 9))

    #fix product type
    for i, product in enumerate(products):
        df_product = df[df["Product Code"]==product]
        #fix route number
        for j in range(9):
            table_product_route[i, j] = len(df_product[df_product["Route Number"]==j+1])

    #make it a data frame
    table = pd.DataFrame(data=table_product_route, columns=range(1,10,1), index=products)
    table.index.name = "Products"
    table.columns.name = "Routes"

    return table.astype(int).style.applymap(highlight)
```

executed in 16ms, finished 03:25:58 2023-08-11

In [26]:

```
#table of the numbers of vessels from group "Activity Group": 0-30%
table1 = get_table(df=act0_30)
display(table1)

#table of the numbers of vessels from group "Activity Group": 31-60%
table2 = get_table(df=act31_60)
display(table2)

#table of the numbers of vessels from group "Activity Group": 61-100%
table3 = get_table(df=act61_100)
display(table3)
```

executed in 150ms, finished 03:25:59 2023-08-11

Routes	1	2	3	4	5	6	7	8	9
Products									
a	31	36	13	9	1	4	9	23	3
f	32	13	2	6	1	4	13	3	2
g	52	31	12	22	0	4	5	12	5
i	0	0	0	0	0	0	1	0	0
k	8	3	3	8	0	0	5	0	0
m	2	1	1	0	0	0	1	0	0
n	0	0	1	0	0	0	5	0	0
o	6	2	0	0	0	0	0	1	0
q	2	0	0	0	0	0	0	0	0
r	5	7	0	0	0	1	7	0	1
s	1	0	0	0	0	0	0	0	0

Routes	1	2	3	4	5	6	7	8	9
Products									
a	30	37	30	118	39	4	1	11	5
f	29	27	12	38	10	1	2	6	0
g	4	4	7	8	6	1	0	1	0
i	0	2	0	0	0	0	0	0	0
k	7	21	11	10	2	1	1	1	1
m	2	4	6	17	3	1	0	0	0
n	3	0	1	3	1	3	3	1	0
o	7	8	0	19	2	1	0	0	0
q	1	1	0	2	0	1	1	1	0
r	9	12	5	10	2	2	2	0	2
s	1	0	0	0	0	0	0	0	0

Routes	1	2	3	4	5	6	7	8	9
Products									
a	13	13	12	120	78	6	0	0	1
f	9	4	2	28	11	0	0	0	0
g	1	0	3	4	8	6	0	0	0
i	4	1	0	9	0	4	0	0	0
k	10	19	4	49	19	20	0	4	1
m	0	0	1	40	5	2	0	0	0
n	0	0	0	15	10	0	0	0	0
o	2	1	0	14	5	0	0	0	0
q	7	0	1	12	4	0	0	0	0
r	6	1	2	6	4	1	0	0	0
v	0	0	0	4	0	0	0	0	0

activity rule

In [27]:

```
##extrapolate by activity

for product in products:
    product0_30 = act0_30[act0_30["Product Code"]==product]
    product31_60 = act31_60[act31_60["Product Code"]==product]
    product61_100 = act61_100[act61_100["Product Code"]==product]

    #fix route number
    for j in range(9):
        route0_30 = product0_30[product0_30["Route Number"]==j+1]
        route31_60 = product31_60[product31_60["Route Number"]==j+1]
        route61_100 = product61_100[product61_100["Route Number"]==j+1]

        #consider those metric <=10 as good results
        good0_30 = route0_30[route0_30["Performance Metric"]<=10]
        good31_60 = route31_60[route31_60["Performance Metric"]<=10]

        if len(route61_100)==0:
            act61_100 = pd.concat([good31_60, act61_100])
        if len(route31_60)==0:
            act31_60 = pd.concat([good0_30, act31_60])
```

executed in 346ms, finished 03:26:10 2023-08-11

In [28]:

```
a = pd.concat([act0_30, act31_60, act61_100])
a
```

executed in 14ms, finished 03:26:11 2023-08-11

Out[28]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric
108	Products Tanker	59.0	37-60	56.0	1	14.5	0-30%	45.11
138	Bulk Carrier	59.0	37-60	31.0	2	4.1	0-30%	53.98
154	Offshore Vessel	60.0	37-60	39.0	1	15.0	0-30%	72.18
176	Anchor Handling Tug Supply	60.0	37-60	28.0	1	28.5	0-30%	1.20
200	Tug	60.0	37-60	58.0	8	3.0	0-30%	11.82
...	...	...	...	...	...	...	...	...
11016	Container Ship (Fully Cellular)	60.0	37-60	36.0	1	61.0	61-100%	10.07
11100	Bulk Carrier	60.0	37-60	53.0	4	68.3	61-100%	3.14
11141	Bulk Carrier	60.0	37-60	52.0	5	60.7	61-100%	37.56
11154	Chemical/Products Tanker	60.0	37-60	34.0	4	63.3	61-100%	7.36
11202	Bulker	60.0	37-60	58.0	5	62.0	61-100%	0.59

2536 rows × 10 columns

In [29]:

```
a[a["Product Code"].isin(target_products)]
```

executed in 27ms, finished 03:26:11 2023-08-11

Out[29]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric
108	Products Tanker	59.0	37-60	56.0	1	14.5	0-30%	45.11
138	Bulk Carrier	59.0	37-60	31.0	2	4.1	0-30%	53.98
154	Offshore Vessel	60.0	37-60	39.0	1	15.0	0-30%	72.18
176	Anchor Handling Tug Supply	60.0	37-60	28.0	1	28.5	0-30%	1.20
200	Tug	60.0	37-60	58.0	8	3.0	0-30%	11.82
...	...	...	...	...	...	...	...	...
11016	Container Ship (Fully Cellular)	60.0	37-60	36.0	1	61.0	61-100%	10.07
11100	Bulk Carrier	60.0	37-60	53.0	4	68.3	61-100%	3.14
11141	Bulk Carrier	60.0	37-60	52.0	5	60.7	61-100%	37.56
11154	Chemical/Products Tanker	60.0	37-60	34.0	4	63.3	61-100%	7.36
11202	Bulker	60.0	37-60	58.0	5	62.0	61-100%	0.59

1684 rows × 10 columns

Show the three tables after extrapolation by activity group.

In [30]:

```
act_group = [act0_30, act31_60, act61_100]

#
groups = ["Activity Group 0-30%", "Activity Group 31-60%", "Activity Group 61-100%"]

#dervie the table of numbers after extrapolation by activity
for i, group in enumerate(act_group):
    print(groups[i])
    display(get_table(df=group))
    print("\n\n\n")
```

executed in 113ms, finished 03:26:12 2023-08-11

Activity Group 0-30%

Routes	1	2	3	4	5	6	7	8	9
Products									
a	31	36	13	9	1	4	9	23	3
f	32	13	2	6	1	4	13	3	2
g	52	31	12	22	0	4	5	12	5
i	0	0	0	0	0	0	1	0	0
k	8	3	3	8	0	0	5	0	0
m	2	1	1	0	0	0	1	0	0
n	0	0	1	0	0	0	5	0	0
o	6	2	0	0	0	0	0	1	0
q	2	0	0	0	0	0	0	0	0
r	5	7	0	0	0	1	7	0	1
s	1	0	0	0	0	0	0	0	0

Activity Group 31-60%

Routes	1	2	3	4	5	6	7	8	9
Products									
a	30	37	30	118	39	4	1	11	5
f	29	27	12	38	10	1	2	6	2
g	4	4	7	8	6	1	2	1	2
i	0	2	0	0	0	0	0	0	0
k	7	21	11	10	2	1	1	1	1
m	2	4	6	17	3	1	0	0	0
n	3	0	1	3	1	3	3	1	0
o	7	8	0	19	2	1	0	0	0
q	1	1	0	2	0	1	1	1	0
r	9	12	5	10	2	2	2	0	2
s	1	0	0	0	0	0	0	0	0

Activity Group 61-100%

Routes	1	2	3	4	5	6	7	8	9
Products									
a	13	13	12	120	78	6	1	8	1
f	9	4	2	28	11	1	0	4	0
g	1	1	3	4	8	6	0	0	0
i	4	1	0	9	0	4	0	0	0
k	10	19	4	49	19	20	0	4	1
m	1	1	1	40	5	2	0	0	0
n	3	0	1	15	10	3	1	0	0
o	2	1	0	14	5	1	0	0	0
q	7	0	1	12	4	0	0	0	0
r	6	1	2	6	4	1	0	0	0
s	0	0	1	4	0	0	0	0	0

By time

For those target data missing in Scheme Group 37-60, we are using the existing data in Scheme Group 0-36 for extrapolation.

In [31]:

```
#the data we will use after is from "Scheme Group" = 0-36
data2 = data[data["Scheme Group"]=="0-36"]
act0_30_2 = data2[data2["Activity Group"]=="0-30%"]
act31_60_2 = data2[data2["Activity Group"]=="31-60%"]
act61_100_2 = data2[data2["Activity Group"]=="61-100%"]
act_group2 = [act0_30_2, act31_60_2, act61_100_2]

#by time
for route in range(1, 10): #and for each route
    for product in products: #and for each product
        #for the target product in each route and in each activity group
        target0_30 = act0_30[(act0_30["Route Number"]==route)&(act0_30["Product Code"]==product)
        target31_60 = act31_60[(act31_60["Route Number"]==route)&(act31_60["Product Code"]==prod
        target61_100 = act61_100[(act61_100["Route Number"]==route)&(act61_100["Product Code"]==

        if len(target0_30) < 10: #if there's not enough data
            #extract the data we need and concatenate it with our data group
            data_need = act0_30_2[(act0_30_2["Route Number"]==route)&(act0_30_2["Product Code"]=
            act0_30 = pd.concat([act0_30, data_need])

        if len(target31_60) < 10: #if there's not enough data
            data_need = act31_60_2[(act31_60_2["Route Number"]==route)&(act31_60_2["Product Code
            act31_60 = pd.concat([act31_60, data_need])

        if len(target61_100) < 10: #if there's not enough data
            data_need = act61_100_2[(act61_100_2["Route Number"]==route)&(act61_100_2["Product C
            act61_100 = pd.concat([act61_100, data_need])
```

executed in 980ms, finished 03:27:40 2023-08-11

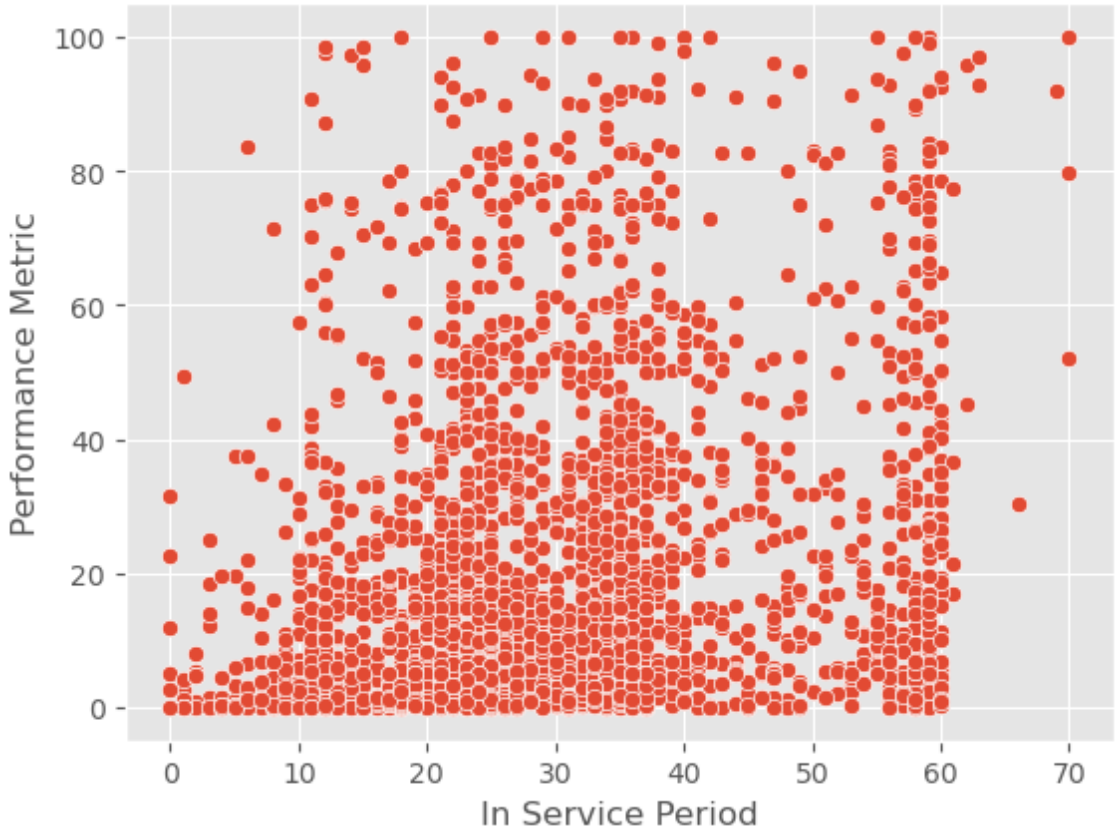
In [32]:

```
sns.scatterplot(data=act0_30, x="In Service Period", y="Performance Metric")
```

executed in 140ms, finished 03:27:40 2023-08-11

Out[32]:

<AxesSubplot:xlabel='In Service Period', ylabel='Performance Metric'>



In [33]:

```
#get the tables
display(get_table(df=act0_30))
display(get_table(df=act31_60))
display(get_table(df=act61_100))
```

executed in 103ms, finished 03:27:45 2023-08-11

Routes	1	2	3	4	5	6	7	8	9
Products									
a	31	36	13	21	3	12	26	23	36
f	32	13	22	47	5	11	13	40	34
g	52	31	12	22	2	13	41	12	36
i	0	1	0	0	0	2	1	0	0
k	19	22	12	9	0	1	12	3	6
m	5	9	3	2	0	0	4	2	1
n	4	1	1	1	0	0	14	0	1
o	37	3	1	3	1	5	2	1	1
q	4	0	0	0	0	0	0	0	0
r	83	89	3	9	3	5	25	3	5
s	5	0	0	0	0	0	3	0	0

Routes	1	2	3	4	5	6	7	8	9
Products									
a	30	37	30	118	39	20	3	11	10
f	29	27	12	38	10	23	7	10	9
g	46	29	35	20	19	6	4	9	5
i	0	5	2	1	0	0	0	0	0
k	26	21	11	10	2	4	2	1	7
m	5	15	18	17	8	3	0	2	0
n	17	2	3	23	5	5	6	2	0
o	107	44	9	19	13	17	3	1	0
q	11	3	0	12	4	5	2	3	1
r	214	12	24	10	29	29	4	4	3
s	10	0	0	0	1	0	0	0	0

Routes	1	2	3	4	5	6	7	8	9
Products									
a	13	13	12	120	78	17	1	9	3
f	39	33	28	28	11	10	1	5	3
g	3	4	4	10	20	23	0	1	1
i	6	2	0	11	0	6	0	0	0
k	10	19	9	49	19	20	0	8	2
m	3	2	3	40	12	5	1	1	0
n	4	1	2	15	10	7	2	0	0
o	24	1	1	14	10	13	0	1	0
q	13	0	2	12	13	2	1	0	0
r	54	9	3	35	14	8	0	1	0
s	3	0	1	5	2	2	0	0	0

In [34]:
```
b = pd.concat([act0_30, act31_60, act61_100])
b
```

executed in 23ms, finished 03:27:59 2023-08-11

Out[34]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric
108	Products Tanker	59.0	37-60	56.0	1	14.5	0-30%	45.11
138	Bulk Carrier	59.0	37-60	31.0	2	4.1	0-30%	53.98
154	Offshore Vessel	60.0	37-60	39.0	1	15.0	0-30%	72.18
176	Anchor Handling Tug Supply	60.0	37-60	28.0	1	28.5	0-30%	1.20
200	Tug	60.0	37-60	58.0	8	3.0	0-30%	11.82
...	...	...	...	...	...	...	...	...
7765	Fishing Vessel	23.0	0-36	25.0	9	80.4	61-100%	8.20
7801	Fishing Vessel	24.0	0-36	25.0	9	65.6	61-100%	14.65
9316	Product Tanker	24.0	0-36	24.0	9	80.0	61-100%	5.30
9352	Passenger/Cruise	36.0	0-36	18.0	9	70.4	61-100%	9.22
9906	Crude Oil Tanker	24.0	0-36	25.0	9	65.3	61-100%	5.39

7582 rows × 10 columns

In [35]:

```
b[b["Product Code"].isin(target_products)]
```

executed in 24ms, finished 03:27:59 2023-08-11

Out[35]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric
108	Products Tanker	59.0	37-60	56.0	1	14.5	0-30%	45.11
138	Bulk Carrier	59.0	37-60	31.0	2	4.1	0-30%	53.98
154	Offshore Vessel	60.0	37-60	39.0	1	15.0	0-30%	72.18
176	Anchor Handling Tug Supply	60.0	37-60	28.0	1	28.5	0-30%	1.20
200	Tug	60.0	37-60	58.0	8	3.0	0-30%	11.82
...	...	...	...	...	...	...	...	...
3615	Fishing Vessel	24.0	0-36	51.0	9	78.8	61-100%	5.55
4713	Fishing Vessel	24.0	0-36	22.0	9	68.0	61-100%	5.39
9316	Product Tanker	24.0	0-36	24.0	9	80.0	61-100%	5.30
9352	Passenger/Cruise	36.0	0-36	18.0	9	70.4	61-100%	9.22
9906	Crude Oil Tanker	24.0	0-36	25.0	9	65.3	61-100%	5.39

3521 rows × 10 columns

product rule

a = m < n; q < n
f = 0 > h = c > l
g < s; s > p
i = d (if no d, i = b) < k

At last, for those data still missing, we use the Product Rule to extrapolate.

In [37]:

```
###examine if data follow the product rule
def rule_test(df, product1, product2):

    for route in range(1,10):
        mean1 = np.mean(df[(df["Product Code"]==product1)&(df["Route Number"]==route)]["Performa
        mean2 = np.mean(df[(df["Product Code"]==product2)&(df["Route Number"]==route)]["Performa
        if mean1>mean2:
            print(f"The rule between {product1} and {product2} in route {route} is violated. {pro
                +"\n")
```

executed in 11ms, finished 04:08:47 2023-08-11

In [38]:

```
#all possible target product relationships
pairs = [["a","n"],
         ["q","n"],
         ["m","n"],
         ["c","f"],
         ["h","f"],
         ["l","f"],
         ["g","s"],
         ["p","s"],
         ["i","k"]]
len(pairs)
```

executed in 8ms, finished 04:08:48 2023-08-11

Out[38]:

9

In [39]:

```
#test in activity group 0-30%
for i in range(9):
    rule_test(act0_30, product1=pairs[i][0], product2=pairs[i][1])
```

executed in 96ms, finished 04:08:49 2023-08-11

The rule between a and n in route 3 is violated. a should have outperformed n.

The rule between a and n in route 4 is violated. a should have outperformed n.

The rule between a and n in route 7 is violated. a should have outperformed n.

The rule between a and n in route 9 is violated. a should have outperformed n.

The rule between m and n in route 2 is violated. m should have outperformed n.

The rule between m and n in route 3 is violated. m should have outperformed n.

The rule between m and n in route 4 is violated. m should have outperformed n.

The rule between m and n in route 7 is violated. m should have outperformed n.

The rule between m and n in route 9 is violated. m should have outperformed n.

The rule between h and f in route 4 is violated. h should have outperformed f.

The rule between h and f in route 5 is violated. h should have outperformed f.

The rule between h and f in route 6 is violated. h should have outperformed f.

The rule between h and f in route 7 is violated. h should have outperformed f.

The rule between h and f in route 8 is violated. h should have outperformed f.

The rule between h and f in route 9 is violated. h should have outperformed f.

The rule between l and f in route 2 is violated. l should have outperformed f.

The rule between l and f in route 4 is violated. l should have outperformed f.

The rule between l and f in route 6 is violated. l should have outperformed f.

The rule between l and f in route 7 is violated. l should have outperformed f.

The rule between g and s in route 1 is violated. g should have outperformed s.

The rule between p and s in route 1 is violated. p should have outperformed s.

The rule between p and s in route 7 is violated. p should have outperformed s.

The rule between i and k in route 2 is violated. i should have outperformed k.

The rule between i and k in route 6 is violated. i should have outperformed k.

The rule between i and k in route 7 is violated. i should have outperformed k.

In [40]:

```
#test in activity group 31-60%
for i in range(9):
    rule_test(act31_60, product1=pairs[i][0], product2=pairs[i][1])
```

executed in 94ms, finished 04:08:51 2023-08-11

The rule between a and n in route 1 is violated. a should have outperformed n.

The rule between a and n in route 3 is violated. a should have outperformed n.

The rule between a and n in route 5 is violated. a should have outperformed n.

The rule between a and n in route 6 is violated. a should have outperformed n.

The rule between a and n in route 7 is violated. a should have outperformed n.

The rule between q and n in route 1 is violated. q should have outperformed n.

The rule between q and n in route 4 is violated. q should have outperformed n.

The rule between q and n in route 5 is violated. q should have outperformed n.

The rule between q and n in route 6 is violated. q should have outperformed n.

The rule between q and n in route 7 is violated. q should have outperformed n.

The rule between m and n in route 1 is violated. m should have outperformed n.

The rule between m and n in route 3 is violated. m should have outperformed n.

The rule between m and n in route 4 is violated. m should have outperformed n.

The rule between m and n in route 5 is violated. m should have outperformed n.

The rule between m and n in route 6 is violated. m should have outperformed n.

The rule between c and f in route 8 is violated. c should have outperformed f.

The rule between h and f in route 1 is violated. h should have outperformed f.

The rule between h and f in route 2 is violated. h should have outperformed f.

The rule between h and f in route 6 is violated. h should have outperformed f.

The rule between l and f in route 1 is violated. l should have outperformed f.

The rule between l and f in route 2 is violated. l should have outperformed f.

The rule between l and f in route 3 is violated. l should have outperformed f.

The rule between l and f in route 4 is violated. l should have outperformed f.

The rule between l and f in route 5 is violated. l should have outperformed f.

The rule between l and f in route 6 is violated. l should have outperformed f.

The rule between g and s in route 5 is violated. g should have outperformed s.

The rule between i and k in route 2 is violated. i should have outperformed k.

The rule between i and k in route 3 is violated. i should have outperformed k.

In [41]:

```
#test in activity group 61-100%
for i in range(9):
    rule_test(act61_100, product1=pairs[i][0], product2=pairs[i][1])
```

executed in 93ms, finished 04:08:53 2023-08-11

The rule between a and n in route 1 is violated. a should have outperformed n.

The rule between a and n in route 3 is violated. a should have outperformed n.

The rule between a and n in route 4 is violated. a should have outperformed n.

The rule between q and n in route 1 is violated. q should have outperformed n.

The rule between q and n in route 3 is violated. q should have outperformed n.

The rule between q and n in route 4 is violated. q should have outperformed n.

The rule between q and n in route 5 is violated. q should have outperformed n.

The rule between q and n in route 7 is violated. q should have outperformed n.

The rule between m and n in route 1 is violated. m should have outperformed n.

The rule between m and n in route 3 is violated. m should have outperformed n.

The rule between m and n in route 4 is violated. m should have outperformed n.

The rule between m and n in route 5 is violated. m should have outperformed n.

The rule between m and n in route 7 is violated. m should have outperformed n.

The rule between c and f in route 3 is violated. c should have outperformed f.

The rule between c and f in route 4 is violated. c should have outperformed f.

The rule between c and f in route 8 is violated. c should have outperformed f.

The rule between h and f in route 1 is violated. h should have outperformed f.

The rule between h and f in route 3 is violated. h should have outperformed f.

The rule between h and f in route 4 is violated. h should have outperformed f.

The rule between h and f in route 5 is violated. h should have outperformed f.

The rule between h and f in route 8 is violated. h should have outperformed f.

The rule between h and f in route 9 is violated. h should have outperformed f.

The rule between l and f in route 1 is violated. l should have outperformed f.

The rule between l and f in route 2 is violated. l should have outperformed f.

The rule between l and f in route 4 is violated. l should have outperformed f.

The rule between l and f in route 5 is violated. l should have outperformed f.

The rule between l and f in route 6 is violated. l should have outperformed f.

The rule between g and s in route 1 is violated. g should have outperformed s.

The rule between g and s in route 3 is violated. g should have outperformed s.

The rule between g and s in route 4 is violated. g should have outperformed s.

The rule between g and s in route 5 is violated. g should have outperformed s.

The rule between p and s in route 3 is violated. p should have outperformed s.

The rule between i and k in route 1 is violated. i should have outperformed k.

The rule between i and k in route 2 is violated. i should have outperformed k.

The rule between i and k in route 4 is violated. i should have outperformed k.

In [42]:

```
#extrapolate by product

def extrap_by_product(df1, df2):
    '''
    This function take as input a dataframe and returns the extrapolated dataframe by product rul
    Note the dataframe belongs to a specific activity group!
    '''
    #products needed
    products = ["a", "b", "c", "d", "f", "g", "h", "i", "k", "l", "m", "n", "o", "p", "q", "r", '
    df_extrap = pd.DataFrame()
    #each route, each product split out
    for i in range(1,10):
        route_fix1 = df1[df1["Route Number"]==i] #scheme group 37-60 waiting for extrapolation
        route_fix2 = df2[df2["Route Number"]==i] #scheme group 0-36 used to extrapolate
        for j in products:
            globals()[f'product_{j}_route_1'] = route_fix1[route_fix1["Product Code"]==j]
            globals()[f'product_{j}_route_2'] = route_fix2[route_fix2["Product Code"]==j]

        #extrapolate a
        a = product_a_route_1.copy()
        m = product_m_route_1.copy()
        n = product_n_route_1.copy()
        if len(a) < 10: #if it needs extrapolation
            m["Product Code"] = "a" #a=m
            a_extrap = pd.concat([a, m])
            if len(a_extrap) < 10: #if it still needs extrapolation
                n["Product Code"] = "a" #a<n
                a_mean = np.mean(product_a_route_2["Performance Metric"])
                n_mean = np.mean(product_n_route_2["Performance Metric"])
                mean_dif = a_mean - n_mean
                if pd.isna(mean_dif)==False: #if mean difference exists
                    n["Performance Metric"] += mean_dif
                    a_extrap = pd.concat([a_extrap, n])
        else:
            a_extrap = pd.DataFrame()

        #extrapolate f
        c = product_c_route_1.copy()
        f = product_f_route_1.copy()
        h = product_h_route_1.copy()
        l = product_l_route_1.copy()
        o = product_o_route_1.copy()
        if len(f) < 10:
            o["Product Code"] = "f" #f=o
            f_extrap = pd.concat([f, o])
            if len(f_extrap) < 10:
                #f>c
                c["Product Code"] = "f"
                c_mean = np.mean(product_c_route_2["Performance Metric"])
                f_mean = np.mean(product_f_route_2["Performance Metric"])
                mean_dif = f_mean - c_mean
                if pd.isna(mean_dif)==False:
                    c["Performance Metric"] += mean_dif
                    f_extrap = pd.concat([f_extrap, c])
                    if len(f_extrap) < 10:
                        #f>h
                        h["Product Code"] = "f"
                        h_mean = np.mean(product_h_route_2["Performance Metric"])
                        f_mean = np.mean(product_f_route_2["Performance Metric"])
```

```
                mean_dif = f_mean - h_mean
                if pd.isna(mean_dif)==False:
                    h["Performance Metric"] += mean_dif
                    f_extrap = pd.concat([f_extrap, h])
                    if len(f_extrap) < 10:
                        #f>l
                        l["Product Code"] = "f"
                        l_mean = np.mean(product_l_route_2["Performance Metric"])
                        f_mean = np.mean(product_f_route_2["Performance Metric"])
                        mean_dif = f_mean - l_mean
                        if pd.isna(mean_dif)==False:
                            l["Performance Metric"] += mean_dif
                            f_extrap = pd.concat([f_extrap, l])
else:
    f_extrap = pd.DataFrame()

#extrapolate g
g = product_g_route_1.copy()
s = product_s_route_1.copy()
if len(g) < 10:
    #g<s
    s["Product Code"] = "g"
    s_mean = np.mean(product_s_route_2["Performance Metric"])
    g_mean = np.mean(product_g_route_2["Performance Metric"])
    mean_dif = g_mean - s_mean
    g_extrap = pd.DataFrame()
    if pd.isna(mean_dif)==False:
        s["Performance Metric"] += mean_dif
        g_extrap = pd.concat([g, s])
else:
    g_extrap = pd.DataFrame()

#extrapolate i
b = product_b_route_1.copy()
d = product_d_route_1.copy()
i = product_i_route_1.copy()
k = product_k_route_1.copy()
if len(i) < 10:
    if len(d) > 0:
        d["Product Code"] = "i"  #i=d
        i_extrap = pd.concat([i, d])
        if len(i_extrap) < 10:
            k["Product Code"] = "i" #i<k
            k_mean = np.mean(product_k_route_2["Performance Metric"])
            i_mean = np.mean(product_i_route_2["Performance Metric"])
            mean_dif = i_mean - k_mean
            if pd.isna(mean_dif)==False:
                k["Performance Metric"] += mean_dif
                i_extrap = pd.concat([i_extrap, k])
    else: #if there's no data for product D
        b["Product Code"] = "i"  #i=b other way
        i_extrap = pd.concat([i, b])
        if len(i_extrap) < 10:
            k["Product Code"] = "i" #i<k
            k_mean = np.mean(product_k_route_2["Performance Metric"])
            i_mean = np.mean(product_i_route_2["Performance Metric"])
            mean_dif = i_mean - k_mean
            if pd.isna(mean_dif)==False:
                k["Performance Metric"] += mean_dif
                i_extrap = pd.concat([i_extrap, k])
else:
```

```
    i_extrap = pd.DataFrame()

#extrapolate k
i = product_i_route_1.copy()
k = product_k_route_1.copy()
if len(k) < 10:
    i["Product Code"] = "k" #k>i
    i_mean = np.mean(product_i_route_2["Performance Metric"])
    k_mean = np.mean(product_k_route_2["Performance Metric"])
    mean_dif = k_mean - i_mean
    k_extrap = pd.DataFrame()
    if pd.isna(mean_dif)==False:
        i["Performance Metric"] += mean_dif
        k_extrap = pd.concat([k, i])
        if len(k_extrap) <10:
            d["Product Code"] = "k" #k>d
            d_mean = np.mean(product_d_route_2["Performance Metric"])
            k_mean = np.mean(product_k_route_2["Performance Metric"])
            mean_dif = k_mean - d_mean
            if pd.isna(mean_dif)==False:
                d["Performance Metric"] += mean_dif
                k_extrap = pd.concat([k_extrap, d])
else:
    k_extrap = pd.DataFrame()

#extrapolate m
a = product_a_route_1.copy()
m = product_m_route_1.copy()
n = product_n_route_1.copy()
if len(m) < 10:
    a["Product Code"] = "m" #m=a
    m_extrap = pd.concat([m, a])
    if len(m_extrap) < 10:
        n["Product Code"] = "m" #m<n
        n_mean = np.mean(product_n_route_2["Performance Metric"])
        m_mean = np.mean(product_m_route_2["Performance Metric"])
        mean_dif = m_mean - n_mean
        if pd.isna(mean_dif)==False:
            n["Performance Metric"] += mean_dif
            m_extrap = pd.concat([m_extrap, n])
else:
    m_extrap = pd.DataFrame()

#extrapolate n
a = product_a_route_1.copy()
m = product_m_route_1.copy()
n = product_n_route_1.copy()
if len(n) < 10:
    a["Product Code"] = "n" #n>a
    a_mean = np.mean(product_a_route_2["Performance Metric"])
    n_mean = np.mean(product_n_route_2["Performance Metric"])
    mean_dif = n_mean - a_mean
    n_extrap = pd.DataFrame()
    if pd.isna(mean_dif)==False:
        a["Performance Metric"] += mean_dif
        n_extrap = pd.concat([n, a])
        if len(n_extrap) < 10:
            m["Product Code"] = "n" #n>m
            m_mean = np.mean(product_m_route_2["Performance Metric"])
            n_mean = np.mean(product_n_route_2["Performance Metric"])
            mean_dif = n_mean - m_mean
```

```
            if pd.isna(mean_dif)==False:
                m["Performance Metric"] += mean_dif
                n_extrap = pd.concat([n_extrap, m])
                if len(n_extrap) <10:
                    q["Product Code"] = "n" #n>q
                    q_mean = np.mean(product_q_route_2["Performance Metric"])
                    n_mean = np.mean(product_n_route_2["Performance Metric"])
                    mean_dif = n_mean - q_mean
                    if pd.isna(mean_dif)==False:
                        q["Performance Metric"] += mean_dif
                        n_extrap = pd.concat([n_extrap, q])
else:
    n_extrap = pd.DataFrame()

#extrapolate o
c = product_c_route_1.copy()
f = product_f_route_1.copy()
h = product_h_route_1.copy()
l = product_l_route_1.copy()
o = product_o_route_1.copy()
if len(o) < 10:
    f["Product Code"] = "o" #o=f
    o_extrap = pd.concat([o, f])
    if len(o_extrap) < 10:
        c["Product Code"] = "o"#o>c
        c_mean = np.mean(product_c_route_2["Performance Metric"])
        o_mean = np.mean(product_o_route_2["Performance Metric"])
        mean_dif = o_mean - c_mean
        if pd.isna(mean_dif)==False:
            c["Performance Metric"] += mean_dif
            o_extrap = pd.concat([o_extrap, c])
            if len(f_extrap) < 10:
                h["Product Code"] = "o" #o>h
                h_mean = np.mean(product_h_route_2["Performance Metric"])
                o_mean = np.mean(product_o_route_2["Performance Metric"])
                mean_dif = o_mean - h_mean
                if pd.isna(mean_dif)==False:
                    h["Performance Metric"] += mean_dif
                    o_extrap = pd.concat([o_extrap, h])
                    if len(f_extrap) < 10:
                        l["Product Code"] = "o" #o>l
                        l_mean = np.mean(product_l_route_2["Performance Metric"])
                        o_mean = np.mean(product_o_route_2["Performance Metric"])
                        mean_dif = o_mean - l_mean
                        if pd.isna(mean_dif)==False:
                            l["Performance Metric"] += mean_dif
                            o_extrap = pd.concat([o_extrap, l])
else:
    o_extrap = pd.DataFrame()

#extrapolate q
n = product_n_route_1.copy()
q = product_q_route_1.copy()
if len(q) < 10:
    n["Product Code"] = "q" #q<n
    n_mean = np.mean(product_n_route_2["Performance Metric"])
    q_mean = np.mean(product_q_route_2["Performance Metric"])
    mean_dif = q_mean - n_mean
    q_extrap = pd.DataFrame()
    if pd.isna(mean_dif)==False:
        n["Performance Metric"] += mean_dif
```

```
            q_extrap = pd.concat([q, n])
        else:
            q_extrap = pd.DataFrame()

        #extrapolate s
        g = product_g_route_1.copy()
        p = product_p_route_1.copy()
        s = product_s_route_1.copy()
        if len(s) < 10:
            g["Product Code"] = "s" #s>g
            g_mean = np.mean(product_g_route_2["Performance Metric"])
            s_mean = np.mean(product_s_route_2["Performance Metric"])
            mean_dif = s_mean - g_mean
            s_extrap = pd.DataFrame()
            if pd.isna(mean_dif)==False:
                g["Performance Metric"] += mean_dif
                s_extrap = pd.concat([s, g])
                if len(s_extrap) < 10:
                    p["Product Code"] = "q" #s>p
                    p_mean = np.mean(product_l_route_2["Performance Metric"])
                    s_mean = np.mean(product_o_route_2["Performance Metric"])
                    mean_dif = s_mean - p_mean
                    if pd.isna(mean_dif)==False:
                        p["Performance Metric"] += mean_dif
                        s_extrap = pd.concat([s_extrap, p])
        else:
            s_extrap = pd.DataFrame()

        df_product = pd.concat([a_extrap, f_extrap, g_extrap, i_extrap, k_extrap,
                                m_extrap, n_extrap, o_extrap, q_extrap, s_extrap])
        df_extrap = pd.concat([df_extrap, df_product])

    #some data's performance metric beyond the range0-100, we need to fix it manually
    df_extrap.loc[df_extrap["Performance Metric"]<0, ["Performance Metric"]] = 0
    df_extrap.loc[df_extrap["Performance Metric"]>100, ["Performance Metric"]] = 100
    return df_extrap
```

executed in 46ms, finished 04:08:56 2023-08-11

Notice: We cannot extrapolate any data for product "R" by the rules since there's no rule for that product.

In [43]:

```
act0_30_extrap = pd.concat([act0_30, extrap_by_product(df1=act0_30, df2=act0_30_2)])
act0_30_extrap
```

executed in 159ms, finished 04:09:02 2023-08-11

Out[43]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric	Pass
108	Products Tanker	59.0	37-60	56.0	1	14.5	0-30%	45.11	
138	Bulk Carrier	59.0	37-60	31.0	2	4.1	0-30%	53.98	
154	Offshore Vessel	60.0	37-60	39.0	1	15.0	0-30%	72.18	
176	Anchor Handling Tug Supply	60.0	37-60	28.0	1	28.5	0-30%	1.20	
200	Tug	60.0	37-60	58.0	8	3.0	0-30%	11.82	
...	...	...	...	...	...	...	...	...	
10986	Offshore Vessel	24.0	0-36	23.0	9	9.0	0-30%	4.16	
11111	Offshore Vessel	36.0	0-36	22.0	9	2.0	0-30%	3.39	
11157	Offshore Tug/Supply Ship	24.0	0-36	59.0	9	9.0	0-30%	46.36	
11171	Offshore Vessel	36.0	0-36	57.0	9	14.0	0-30%	28.86	
11180	Offshore Vessel	36.0	0-36	44.0	9	14.0	0-30%	5.00	

3497 rows × 10 columns

In [44]:

```
act31_60_extrap = pd.concat([act31_60, extrap_by_product(df1=act31_60, df2=act31_60_2)])
act31_60_extrap
```

executed in 162ms, finished 04:09:03 2023-08-11

Out[44]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric	Pas
9242	Offshore Vessel	60.0	37-60	59.0	9	8.0	0-30%	2.25	
10824	Offshore Vessel	60.0	37-60	23.0	9	15.0	0-30%	8.43	
6073	General Cargo Ship	41.0	37-60	36.0	1	29.0	0-30%	3.75	
5599	Container	60.0	37-60	13.0	7	23.0	0-30%	7.50	
5596	Container	60.0	37-60	13.0	7	23.0	0-30%	6.30	
...	...	...	...	...	...	...	...	...	
10207	Product Tanker	36.0	0-36	36.0	9	33.0	31-60%	41.55	
10350	Crew/Supply Vessel	36.0	0-36	18.0	9	31.4	31-60%	1.00	
10723	Product Tanker	24.0	0-36	35.0	9	46.0	31-60%	2.97	
11110	Anchor Handling Tug Supply	36.0	0-36	36.0	9	35.6	31-60%	3.39	
11144	Product Tanker	24.0	0-36	29.0	9	40.0	31-60%	2.86	

3796 rows × 10 columns

In [45]:

```
act61_100_extrap = pd.concat([act61_100, extrap_by_product(df1=act61_100, df2=act61_100_2)])
act61_100_extrap
```

executed in 158ms, finished 04:09:04 2023-08-11

Out[45]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric
10280	Bulk Carrier	60.0	37-60	49.0	8	38.8	31-60%	4.85
10289	Container	60.0	37-60	59.0	8	48.0	31-60%	2.03
10758	Product Tanker	60.0	37-60	52.0	8	52.0	31-60%	5.85
10888	Bulk Carrier	60.0	37-60	51.0	8	37.2	31-60%	4.30
11091	Chemical Tanker	60.0	37-60	17.0	6	52.0	31-60%	1.70
...	...	...	...	...	...	...	...	...
3615	Fishing Vessel	24.0	0-36	51.0	9	78.8	61-100%	5.55
4713	Fishing Vessel	24.0	0-36	22.0	9	68.0	61-100%	5.39
9316	Product Tanker	24.0	0-36	24.0	9	80.0	61-100%	5.30
9352	Passenger/Cruise	36.0	0-36	18.0	9	70.4	61-100%	9.22
9906	Crude Oil Tanker	24.0	0-36	25.0	9	65.3	61-100%	5.39

2071 rows × 10 columns

In [46]:

```
##total population for scheme group 37-60
scheme37_60_extrap = pd.concat([act0_30_extrap, act31_60_extrap, act61_100_extrap])
scheme37_60_extrap
```

executed in 19ms, finished 04:09:07 2023-08-11

Out[46]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric
108	Products Tanker	59.0	37-60	56.0	1	14.5	0-30%	45.11
138	Bulk Carrier	59.0	37-60	31.0	2	4.1	0-30%	53.98
154	Offshore Vessel	60.0	37-60	39.0	1	15.0	0-30%	72.18
176	Anchor Handling Tug Supply	60.0	37-60	28.0	1	28.5	0-30%	1.20
200	Tug	60.0	37-60	58.0	8	3.0	0-30%	11.82
...	...	...	...	...	...	...	...	...
3615	Fishing Vessel	24.0	0-36	51.0	9	78.8	61-100%	5.55
4713	Fishing Vessel	24.0	0-36	22.0	9	68.0	61-100%	5.39
9316	Product Tanker	24.0	0-36	24.0	9	80.0	61-100%	5.30
9352	Passenger/Cruise	36.0	0-36	18.0	9	70.4	61-100%	9.22
9906	Crude Oil Tanker	24.0	0-36	25.0	9	65.3	61-100%	5.39

9364 rows × 10 columns

In [49]:

```
## how many observations for target products in total
final_target = scheme37_60_extrap[scheme37_60_extrap["Product Code"].isin(target_products)]
final_target
```

executed in 28ms, finished 04:58:38 2023-08-11

Out[49]:

	Vessel Group	Scheme	Scheme Group	In Service Period	Route Number	% Activity	Activity Group	Performance Metric
108	Products Tanker	59.0	37-60	56.0	1	14.5	0-30%	45.11
138	Bulk Carrier	59.0	37-60	31.0	2	4.1	0-30%	53.98
154	Offshore Vessel	60.0	37-60	39.0	1	15.0	0-30%	72.18
176	Anchor Handling Tug Supply	60.0	37-60	28.0	1	28.5	0-30%	1.20
200	Tug	60.0	37-60	58.0	8	3.0	0-30%	11.82
...	...	...	...	...	...	...	...	...
3615	Fishing Vessel	24.0	0-36	51.0	9	78.8	61-100%	5.55
4713	Fishing Vessel	24.0	0-36	22.0	9	68.0	61-100%	5.39
9316	Product Tanker	24.0	0-36	24.0	9	80.0	61-100%	5.30
9352	Passenger/Cruise	36.0	0-36	18.0	9	70.4	61-100%	9.22
9906	Crude Oil Tanker	24.0	0-36	25.0	9	65.3	61-100%	5.39

5303 rows × 10 columns

In [48]:

```
act_group = [act0_30_extrap, act31_60_extrap, act61_100_extrap]
#dervie the table of numbers after extrapolation by product
for i, group in enumerate(act_group):
    print(groups[i], "after extrapolation by the product rule")
    display(get_table(df=group))
    print("\n\n\n")
```

executed in 110ms, finished 04:10:58 2023-08-11

Activity Group 0-30% after extrapolation by the product rule

Routes	1	2	3	4	5	6	7	8	9
Products									
a	31	36	13	21	6	12	26	23	36
f	32	13	22	47	19	11	13	40	34
g	52	31	12	22	2	13	41	12	36
i	11	13	17	9	2	6	8	9	38
k	19	22	12	9	0	4	12	3	6
m	41	54	19	25	3	12	34	27	38
n	39	38	1	23	0	0	14	0	38
o	37	19	24	53	8	21	17	42	36
q	12	0	0	0	0	0	0	0	0
r	83	89	3	9	3	5	25	3	5
s	62	0	0	0	0	0	47	0	0

Activity Group 31-60% after extrapolation by the product rule

Routes	1	2	3	4	5	6	7	8	9
Products									
a	30	37	30	118	39	20	12	11	10
f	29	27	12	38	10	23	17	10	18
g	46	29	35	20	19	6	4	9	5
i	13	25	17	21	10	2	1	8	5
k	26	21	11	10	2	4	2	1	7
m	40	15	18	17	55	26	3	15	10
n	17	41	36	23	49	30	15	15	0
o	107	44	30	19	13	17	13	12	9
q	11	8	0	12	13	15	10	8	1
r	214	12	24	10	29	29	4	4	3
s	10	0	0	0	21	0	0	0	0

Activity Group 61-100% after extrapolation by the product rule

Routes	1	2	3	4	5	6	7	8	9
Products									
a	13	13	12	120	78	17	3	19	6
f	39	33	28	28	11	10	2	16	6
g	9	4	4	10	20	23	0	1	1
i	28	17	22	11	33	17	1	6	2
k	10	19	9	49	19	20	0	8	2
m	19	17	18	40	12	27	5	11	3
n	21	15	16	15	10	31	2	0	0
o	24	35	30	14	10	13	1	5	3
q	14	0	6	12	13	11	4	0	0
r	54	9	3	35	14	8	0	1	0
s	9	0	1	20	24	27	0	0	0

In [106]:

```
# aggregate the data for each product, on each route, for activity range 0-30.
# give the pass rate overall
pr0_30 = pd.DataFrame(np.zeros((len(target_products),1)), index=target_products, columns=["Pass
for i, product in enumerate(target_products):
    num_pass = len(act0_30_extrap[(act0_30_extrap["Performance Metric"] <= 10)&(act0_30_extrap["
    num_fail = len(act0_30_extrap[(act0_30_extrap["Performance Metric"] > 10)&(act0_30_extrap["P
    pr0_30.iloc[i, ] = round(100*num_pass/(num_pass+num_fail),2)

pr0_30.sort_values(by="Pass rate (%)", ascending=False)
```

executed in 24ms, finished 06:08:20 2023-08-11

Out[106]:

	Pass rate (%)
n	58.82
i	52.21
q	50.00
a	49.02
m	44.66
k	42.53
g	39.37
r	34.22
f	33.77
o	30.74
s	12.84

In [101]:

```
# aggregate the data for each product, on each route, for activity range 31-60.
# give the pass rate overall
pr31_60 = pd.DataFrame(np.zeros((len(target_products),1)), index=target_products, columns=["Pass
for i, product in enumerate(target_products):
    num_pass = len(act31_60_extrap[(act31_60_extrap["Performance Metric"] <= 10)&(act31_60_extra
    num_fail = len(act31_60_extrap[(act31_60_extrap["Performance Metric"] > 10)&(act31_60_extrap
    pr31_60.iloc[i, ] = round(100*num_pass/(num_pass+num_fail),2)

pr31_60.sort_values(by="Pass rate (%)", ascending=False)
```

executed in 22ms, finished 06:07:14 2023-08-11

Out[101]:

	Pass rate (%)
s	77.42
k	67.86
i	62.75
m	56.78
a	55.70
n	53.98
g	51.45
f	48.37
r	40.12
o	35.61
q	29.49

In [100]:

```
# aggregate the data for each product, on each route, for activity range 61-100.
# give the pass rate overall
pr61_100 = pd.DataFrame(np.zeros((len(target_products),1)), index=target_products, columns=["Pas
for i, product in enumerate(target_products):
    num_pass = len(act61_100_extrap[(act61_100_extrap["Performance Metric"] <= 10)&(act61_100_ex
    num_fail = len(act61_100_extrap[(act61_100_extrap["Performance Metric"] > 10)&(act61_100_ext
    pr61_100.iloc[i, ] = round(100*num_pass/(num_pass+num_fail),2)

pr61_100.sort_values(by="Pass rate (%)", ascending=False)
```

executed in 22ms, finished 06:07:14 2023-08-11

Out[100]:

	Pass rate (%)
a	71.89
m	68.42
k	64.71
n	62.73
f	61.27
q	60.00
o	54.81
i	54.74
s	51.85
g	37.50
r	31.45

In [72]:

```
#Confidence Interval

def deg_conf(df, product, alpha=0.05):
    '''
    The function takes as input a dataframe, a type of product and a route and a confidence level
    Return the confidence interval of the mean for that specific type of product aggregated on al
    '''


    N = len(scheme37_60_extrap[scheme37_60_extrap["Product Code"]==product]) #number of populati
    subdata = df[df["Product Code"]==product] #target dataset
    pm = subdata["Performance Metric"] #performance metric
    mu = np.mean(pm) #mean
    sigma = np.std(pm) #sigma
    z = norm.ppf(1 - alpha/2) # 1-alpha/2 critical value
    n = len(subdata) #number of subset
    if n==0:
        return None
    else:
        B = np.sqrt((N-n)/n/(N-1)) * z * sigma #bound
        CI = "["+str(round(mu-B,2))+", "+str(round(mu+B,2))+"]" #Confidence Interval
        return CI
```

executed in 20ms, finished 05:52:33 2023-08-11

In [112]:

```
#get the confidence interval along with the pass rate for activity group 0-30
ci_table0_30 = pd.DataFrame(columns=["Pass rate (%)", "CI"], index=target_products)
ci_table0_30["Pass rate (%)"] = pr0_30["Pass rate (%)"]
for i, product in enumerate(target_products):

    ci_table0_30.CI[i] = deg_conf(df=act0_30_extrap, product=product)


ci_table0_30.sort_values(by="Pass rate (%)", ascending=False)
```

executed in 34ms, finished 06:30:29 2023-08-11

Out[112]:

	Pass rate (%)	CI
n	58.82	[12.32, 17.82]
i	52.21	[13.54, 19.46]
q	50.00	[11.71, 33.15]
a	49.02	[16.71, 22.13]
m	44.66	[19.15, 23.74]
k	42.53	[16.38, 24.57]
g	39.37	[22.25, 27.12]
r	34.22	[21.6, 26.79]
f	33.77	[22.53, 27.16]
o	30.74	[24.2, 28.57]
s	12.84	[31.3, 38.02]

In [127]:

```
#those pr >= 75
display(ci_table0_30[ci_table0_30["Pass rate (%)"]>=75])
#those pr 60-74
display(ci_table0_30[(ci_table0_30["Pass rate (%)"]<75)&(ci_table0_30["Pass rate (%)"]>=60)])
#those pr50-59
display(ci_table0_30[(ci_table0_30["Pass rate (%)"]<59)&(ci_table0_30["Pass rate (%)"]>=50)])
#those pr<50
display(ci_table0_30[ci_table0_30["Pass rate (%)"]<50])
```

executed in 24ms, finished 12:51:11 2023-08-11

	Pass rate (%)	CI

	Pass rate (%)	CI

	Pass rate (%)	CI
i	52.21	[13.54, 19.46]
n	58.82	[12.32, 17.82]
q	50.00	[11.71, 33.15]

	Pass rate (%)	CI
a	49.02	[16.71, 22.13]
f	33.77	[22.53, 27.16]
g	39.37	[22.25, 27.12]
k	42.53	[16.38, 24.57]
m	44.66	[19.15, 23.74]
o	30.74	[24.2, 28.57]
r	34.22	[21.6, 26.79]
s	12.84	[31.3, 38.02]

In [115]:

```
#for activity group 31-60
ci_table31_60 = pd.DataFrame(columns=["Pass rate (%)", "CI"], index=target_products)
ci_table31_60["Pass rate (%)"] = pr31_60["Pass rate (%)"]
for i, product in enumerate(target_products):

    ci_table31_60.CI[i] = deg_conf(df=act31_60_extrap, product=product)


ci_table31_60.sort_values(by="Pass rate (%)", ascending=False)
```

executed in 34ms, finished 06:30:29 2023-08-11

Out[115]:

	Pass rate (%)	CI
s	77.42	[3.45, 10.81]
k	67.86	[7.67, 10.22]
i	62.75	[8.82, 12.8]
m	56.78	[11.87, 15.32]
a	55.70	[11.42, 13.7]
n	53.98	[11.84, 15.04]
g	51.45	[12.12, 15.53]
f	48.37	[12.55, 16.04]
r	40.12	[17.68, 20.45]
o	35.61	[17.81, 21.15]
q	29.49	[15.42, 19.57]

In [128]:

```
#those pr >= 75
display(ci_table31_60[ci_table31_60["Pass rate (%)"]>=75])
#those pr 60-74
display(ci_table31_60[(ci_table31_60["Pass rate (%)"]<75)&(ci_table31_60["Pass rate (%)"]>=60)])
#those pr50-59
display(ci_table31_60[(ci_table31_60["Pass rate (%)"]<59)&(ci_table31_60["Pass rate (%)"]>=50)])
#those pr<50
display(ci_table31_60[ci_table31_60["Pass rate (%)"]<50])
```

executed in 24ms, finished 12:53:57 2023-08-11

	Pass rate (%)	CI
s	77.42	[3.45, 10.81]

	Pass rate (%)	CI
i	62.75	[8.82, 12.8]
k	67.86	[7.67, 10.22]

	Pass rate (%)	CI
a	55.70	[11.42, 13.7]
g	51.45	[12.12, 15.53]
m	56.78	[11.87, 15.32]
n	53.98	[11.84, 15.04]

	Pass rate (%)	CI
f	48.37	[12.55, 16.04]
o	35.61	[17.81, 21.15]
q	29.49	[15.42, 19.57]
r	40.12	[17.68, 20.45]

In [116]:

```
#for activity group 61-100
ci_table61_100 = pd.DataFrame(columns=["Pass rate (%)", "CI"], index=target_products)
ci_table61_100["Pass rate (%)"] = pr61_100["Pass rate (%)"]
for i, product in enumerate(target_products):

    ci_table61_100.CI[i] = deg_conf(df=act61_100_extrap, product=product)


ci_table61_100.sort_values(by="Pass rate (%)", ascending=False)
```

executed in 40ms, finished 06:30:31 2023-08-11

Out[116]:

	Pass rate (%)	CI
a	71.89	[7.25, 8.46]
m	68.42	[8.01, 10.23]
k	64.71	[8.52, 10.83]
n	62.73	[7.8, 10.82]
f	61.27	[9.46, 11.69]
q	60.00	[8.64, 11.93]
o	54.81	[10.89, 14.61]
i	54.74	[9.26, 11.43]
s	51.85	[8.94, 11.78]
g	37.50	[11.56, 15.32]
r	31.45	[16.77, 22.8]

In [129]:

```
#those pr >= 75
display(ci_table61_100[ci_table61_100["Pass rate (%)"]>=75])
#those pr 60-74
display(ci_table61_100[(ci_table61_100["Pass rate (%)"]<75)&(ci_table61_100["Pass rate (%)"]>=60
#those pr50-59
display(ci_table61_100[(ci_table61_100["Pass rate (%)"]<59)&(ci_table61_100["Pass rate (%)"]>=50
#those pr<50
display(ci_table61_100[ci_table61_100["Pass rate (%)"]<50])
```

executed in 17ms, finished 12:53:59 2023-08-11

	Pass rate (%)	CI

	Pass rate (%)	CI
a	71.89	[7.25, 8.46]
f	61.27	[9.46, 11.69]
k	64.71	[8.52, 10.83]
m	68.42	[8.01, 10.23]
n	62.73	[7.8, 10.82]
q	60.00	[8.64, 11.93]

	Pass rate (%)	CI
i	54.74	[9.26, 11.43]
o	54.81	[10.89, 14.61]
s	51.85	[8.94, 11.78]

	Pass rate (%)	CI
g	37.50	[11.56, 15.32]
r	31.45	[16.77, 22.8]

In [ ]: