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Background

Wales Transportation system has a wide range of modes of transport. The Bus services are managed by the local authorities and there are several development plans in progress by Welsh Government. Although the Government is sincerely making attempts, this report will provide additional inputs on the data captured and analyse and provide views to support the Government in its improvement plans.
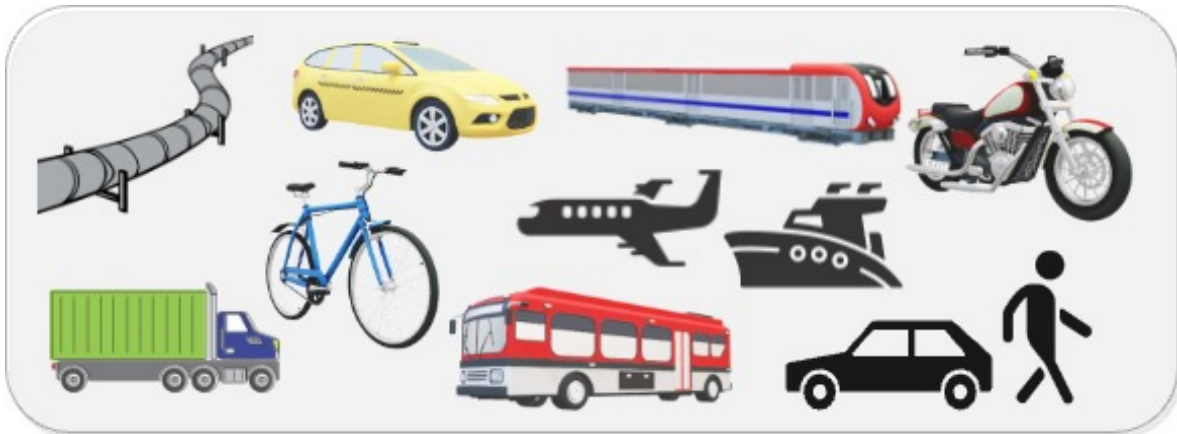
The University of Essex attempted to produce a report (Murugan, 2024) on the data (GOV, 2024) published by Wales. In addition, this report focuses on Bus transportation in particular, identifies the challenges and data exploration using data science tools, and provides solutions to overcome the challenges along with the limitations and risks.

Challenges

Recently published report titled "Making the Connection", the major issues identified are related to the unreliability of services, and unaffordability is the highest challenge (Sustrans, 2022).

Unreliable services

Reduction in bus services leads to unreliable services directly impacting employment and education.
- Buses have experienced a reduction of 17.8%, affecting approximately 12% of the population who now lack access to public transport (Sustrans, 2022).
- No wheelchair facilities
- Disruptions in operations
- Public transport is not well-connected
- Local commutation is very limited
- Driving cars is also difficult due to congestion

Unaffordable Services

If someone owns a car, expenses to run a car are very high and it is impacting their daily life.
- Bus ticket prices have increased, impacting about 23% of the public, who rely on public transport (Sustrans, 2022), which also impacts the Education
- Car expenses are also increased as the road infrastructure does not support car driving safely leading to high maintenance cost

- Employment is impacted by 40% of job seekers due to the non-availability and non-affordability of having a car for better employment
- Ill-health, senior citizens unable to go to GP or hospitals about 48% of disabled have raised concerns about their travel to GP Surgery and Hospitals (MacDonald, 2023)

Data Exploration

The section of the report will explain how the data has been collected, what data is available, how the data analysis has been conducted step by step, and presenting the data to understand the issues

Data Acquisition

The data gathering has been completed by the Welsh Government who provided the data in Excel (GOV, 2024) covering various areas of the survey. The accuracy of data is still an open question when dealing with large population. The estimates from the National Survey are subject to a margin of uncertainty as data collected is at a specific point in time.

Data Pre-processing

Data has been classified into multiple components including overall satisfaction with the transport system. Each group has several tables with different views to help further analysis.
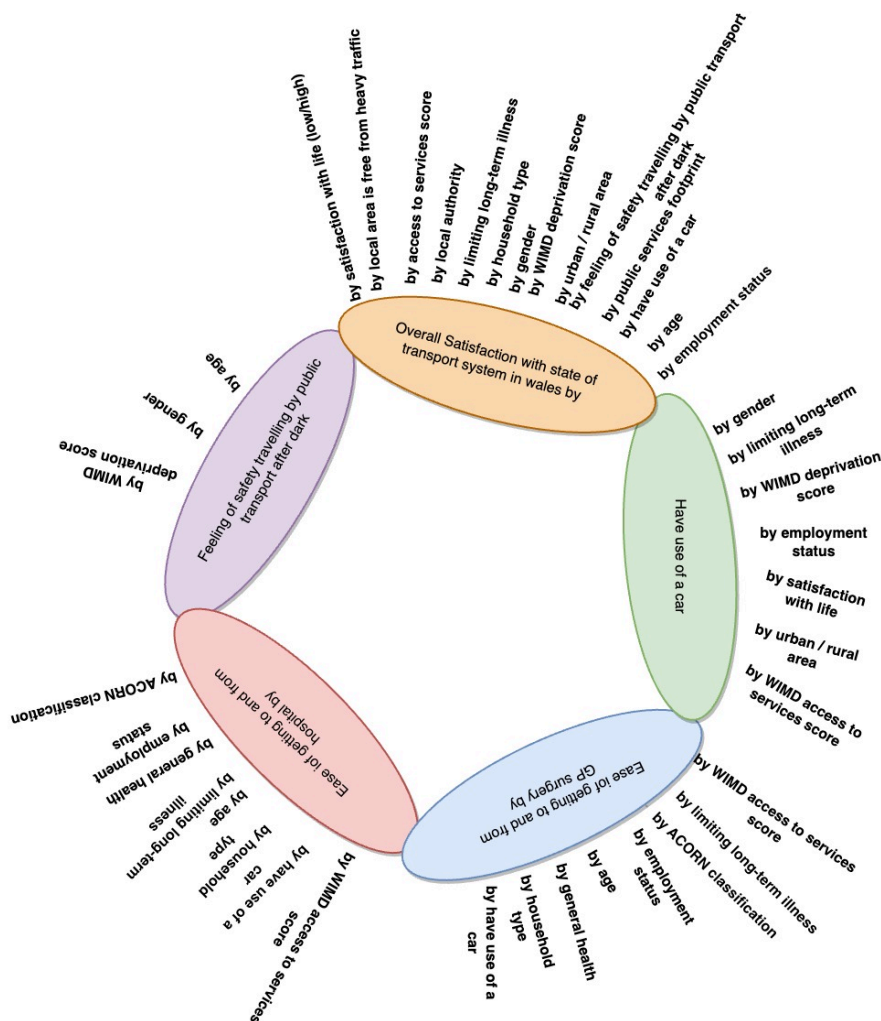
Data Analysis

Data analysis was conducted on 42 tables and slices and dice of the information for further analysis. The analysis includes categorization of data, identifying recurring patterns, and identifying key events as part of qualitative analysis.
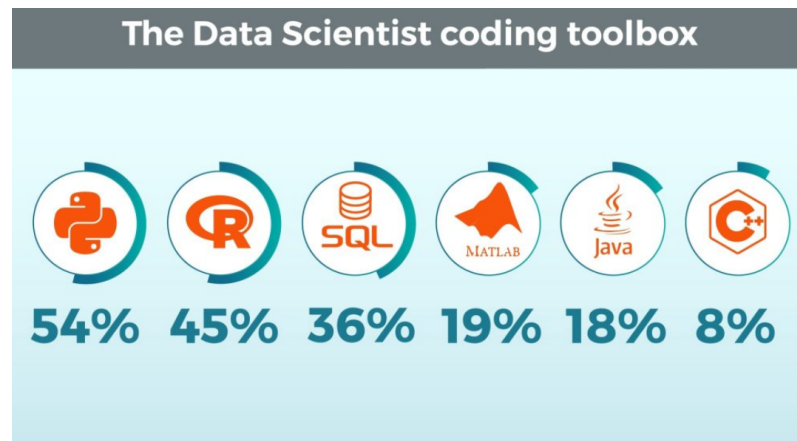
Data Analysis Coding Tools

Python which is about 54% proven to be used in Data Science, this report will use Python coding for creating graphs and charts (365 Team, 2023).

The below image shows the common libraries and references to the Excel document used as part of this Python implementation.

Loading Libraries

```
''' These libraries are used for data visualisation as graph is this Assignment '''

# Load Libraries

import pandas as p
import matplotlib.pyplot as m
import numpy as n
```

Data Transformed

```
'''
This file contains 9 sheets, each sheet contains data that are analysed
and transformed from National Survey for Wales – Transport dataset
'''

# Reading Data from Excel file

file = 'Data_Transformed.xlsx'
```

Deviation

There is a deviation from the original report (Murugan, 2024). The below studies are conducted in addition to get a better understanding of the issues

- It has been identified Table 5 and Table 6 provide the information related to areas where transportation has footprint and by satisfaction level by Local Authority

- Understand the social impact related to safety scores Table 40 and Table 41 provide information about traveling safely after dark by Gender and Age

Transport footprint and Satisfaction level by Local Authority

It has been identified in Table 5: Overall satisfaction with Wales transport system, by local authority and Table 6: the actual footprint exists in Wales can additional information for a better design. This provides information related to areas where transportation services are low or high.

Data Transformation

- Table 6 related to the satisfaction level based on footprint is being converted to percentage to show it displays better on the pie chart. Below is the code used the produce the graph.

Data Extraction / Analysis - Sheet 5

```
# Loading data from Sheet 5
data_sheet5 = p.read_excel(file, sheet_name='Graph 5').round(2)
data_sheet5
```

	Category	Value
0	North Wales	6.17
1	Mid and West	5.40
2	Swansea Bay	5.66
3	Cwm Taf	5.78
4	Cardiff and Vale	5.96
5	Gwent	6.14

Data Visualization - Sheet 5

```
# Retrieving data from Sheet 5, and calculating as percentage
category = data_sheet5['Category']
values = data_sheet5['Value']
total = sum(values)
percent = [(val / total) * 100 for val in values]
width = {'linewidth': 2, 'edgecolor': 'white'}

# Plotting Pie Graph
m.figure(figsize=(5, 5))
m.pie(values, labels=['{} {:.0f}%'.format(cat, perc) for cat, perc in zip(category, percent)], startangle=140,
      wedgeprops=width)
m.title('Public Transport by Footprint', fontweight='bold')
m.show()
```

Public Transport by Footprint
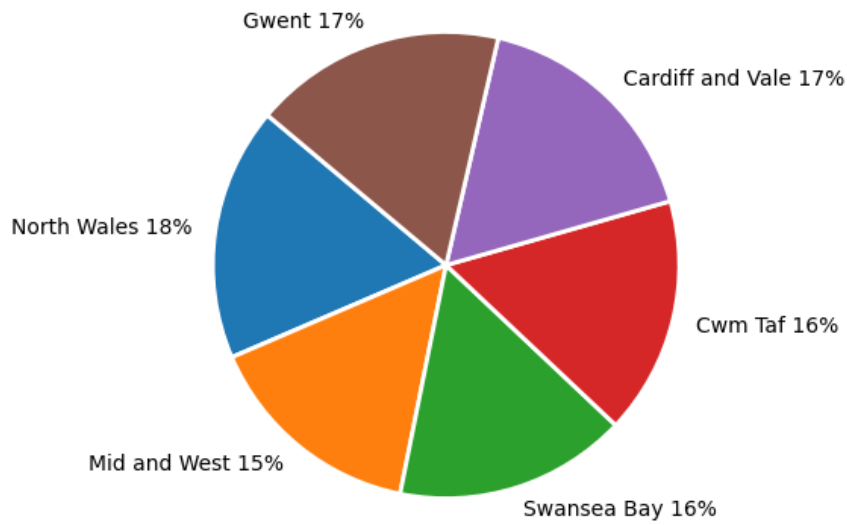
Interpretation

Satisfaction level across all parts of the country seems to be similar, which means that whether or not footprint exists, the satisfaction level seems to be the same. So, either the footprint does not exist or even if the footprint exists, still the services are not up to the mark.

On further analysis of that table and categorising the satisfaction level, plotting that data in the Wales map using the below levels.

	LOW	Upper	
Not Satisfied	5.2	5.4	●
Satisfied	5.5	5.9	●
Very Satisfied	6	6.5	●
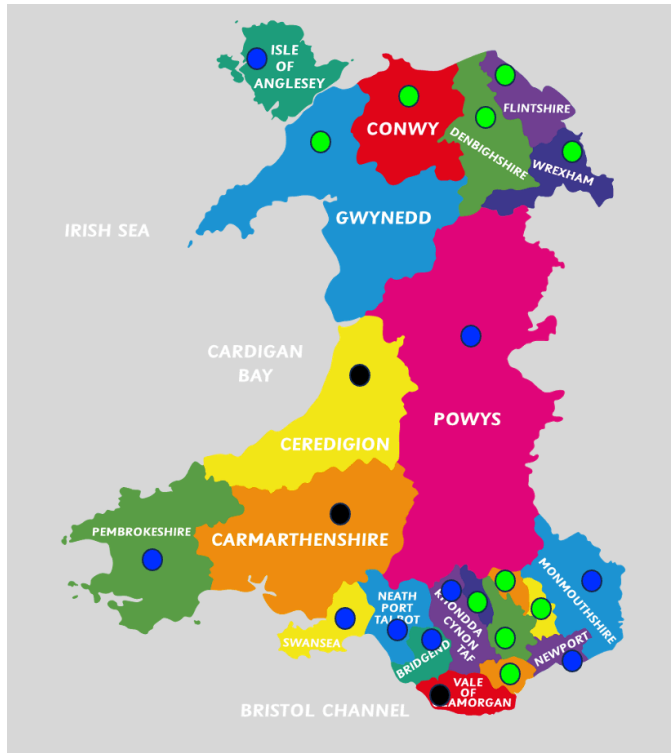
Mapping of Table 5 on the location in the map, spotted the dots as per the table provides a clear understanding of where the satisfaction levels are high, medium, and low (Fun Play, 2024).

Data Extraction / Analysis - Sheet 4

```python
# Loading data from Sheet 4
data_sheet4 = p.read_excel(file, sheet_name='Graph 4').round(2)
data_sheet4 = data_sheet4.drop(22)
data_sheet4
```

	Local Authority	Satisfaction Score
0	Ceredigion	5.24
1	Carmarthenshire	5.34
2	Vale of Glamorgan	5.44
3	Isle of Anglesey	5.45
4	Neath Port Talbot	5.47
5	Powys	5.48
6	Bridgend	5.48
7	Pembrokeshire	5.49
8	Rhondda Cynon Taf	5.70
9	Swansea	5.85
10	Newport	5.89
11	Monmouthshire	5.94
12	Gwynedd	5.99
13	Merthyr Tydfil	6.08
14	Denbighshire	6.08
15	Cardiff	6.13
16	Blaenau Gwent	6.22
17	Conwy	6.22
18	Caerphilly	6.23
19	Wrexham	6.36
20	Torfaen	6.48
21	Flintshire	6.50

Data Visualization - Sheet 4

```python
# Retrieving data from Sheet 4
authority = data_sheet4['Local Authority']
score = data_sheet4['Satisfaction Score']

# Plotting Radar Graph
length = len(authority)
angle = n.linspace(0, 2 * n.pi, length, endpoint=False).tolist()
score = n.concatenate((score, [score[0]]))
angle += angle[:1]
fig, ax = m.subplots(figsize=(6, 6), subplot_kw=dict(polar=True))
ax.plot(angle, score, color='red')

# Setting value-range, labels and title
starting = 5
ending = 6.6
ax.set_ylim(starting, ending)
ax.set_rlabel_position(90)
ax.set_xticks(angle[:-1])
ax.set_xticklabels(authority)
ax.xaxis.set_tick_params(pad=15)
m.title('Satisfaction score based on Local Authorities', fontweight='bold')
m.show()
```


Satisfaction score based on Local Authorities
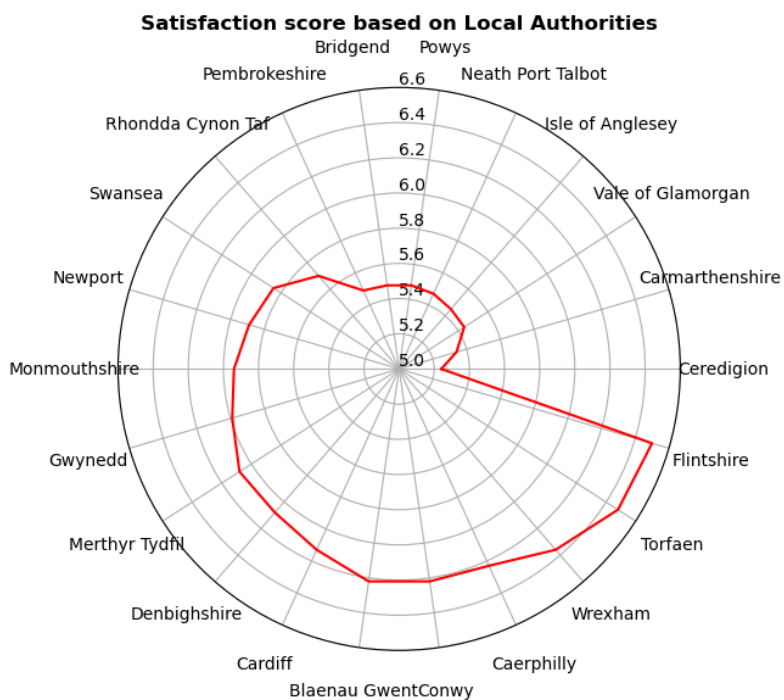
Interpretation

Wales people's satisfaction level on the transportation services seems to be dense in both corners. The satisfaction level is very low in most of the areas of Wales. This analysis creates a need for designing an approach that helps to connect different places in Wales and also connections within the cities to make it more efficient.

Feeling Safe traveling by Wales transport system after dark

Table 40 and Table 41 – these two tables provide information related to feeling safe in traveling by public service after dark by age and gender.

Data Extraction / Analysis - Sheet 9

```
# Loading data from Sheet 9
data_sheet9 = p.read_excel(file, sheet_name='Graph 9').round()
data_sheet9
```

|	Feeling Safety after dark	Safe	Unsafe
0	Male	45	5
1	Female	35	15
2	Age < 65	41	9
3	Age > 65	35	15

Data Visualization - Sheet 9

```
# Retrieving data from Sheet 9
categories = data_sheet9['Feeling Safety after dark']
value1 = data_sheet9['Safe']
value2 = data_sheet9['Unsafe']
width = 0.35

# Plotting Vertical Bar Graph
m.figure(figsize=(9, 5))
m.bar(categories, value1, width=width, label='Safe')
m.bar(categories, value2, width=width, label='Unsafe', bottom=value1)

# Setting title and legend
m.title('Feeling Safety to travel by Public Transport after dark', fontweight='bold')
m.legend(loc='upper left', bbox_to_anchor=(1, 1))
m.show()
```
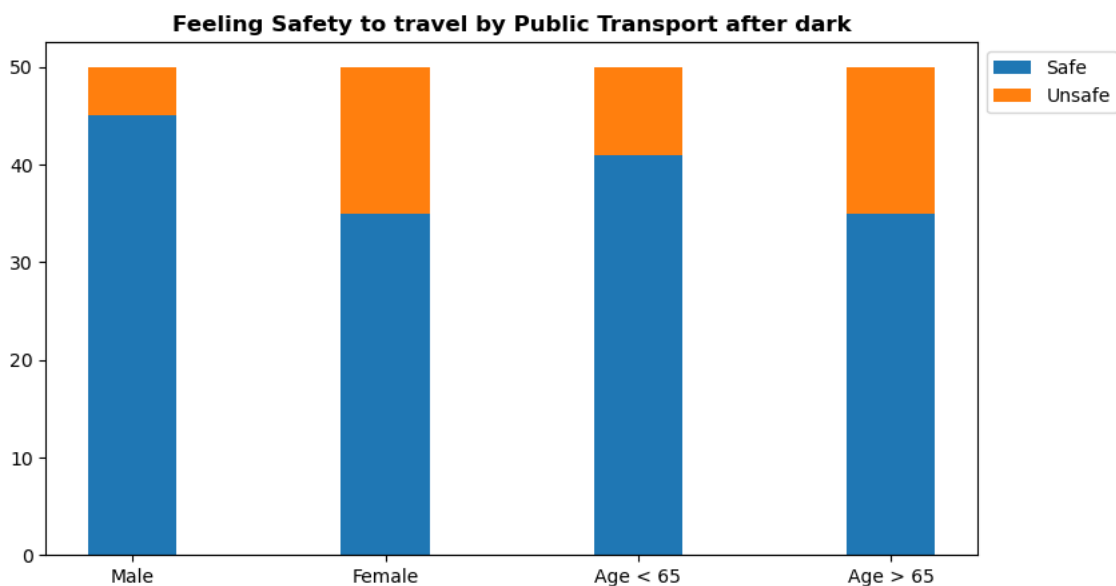

Data Transformation

Very Safe and Fairly Safe considered as safe and fairly unsafe and very unsafe have been considered as unsafe in both tables

- Table 40 related to age has been combined as < 65 and > 65
- Table 41 related to gender

Overall Satisfaction with Access to Services by Groups

The overall satisfaction has about 14 tables, however, about 9 tables provide general information about the category of people living in Wales and their satisfaction level with the Welsh Transportation system.

Data Extraction / Analysis - Sheet 1

```python
# Loading data from Sheet 1
data_sheet1 = p.read_excel(file, sheet_name = 'Graph 1')
p.set_option('display.max_colwidth', None)
data_sheet1
```

|	Tables	Categories	Favourable	Not Favourable
0	Table 9	Satisfied with life/Low Satisfied	5.30	6.00
1	Table 4	Urban / Rural	6.00	5.50
2	Table 3	Male /Female	6.00	5.80
3	Table 13	Free from heavy traffic	5.85	5.75
4	Table 11	Employed / Unemployed	5.70	6.10
5	Table 12	Long term illness / No illness	5.70	5.90
6	Table 10	Age	5.90	6.20
7	Table 2	Have a car / No Car	5.80	6.40
8	Table 14	Feeling safe after dark	6.10	5.60

Data Visualization - Sheet 1

```python
# Retrieving data from Sheet 1
categories = data_sheet1['Categories']
favourable = data_sheet1['Favourable']
not_favourable = data_sheet1['Not Favourable']
width = 0.35

# Plotting Bar Graph
favour_bar = n.arange(len(categories))
not_favour_bar = [x + width for x in favour_bar]
m.figure(figsize = (12, 6))
m.bar(favour_bar, favourable, color='lightblue', width=width, edgecolor='grey', label='Favourable')
m.bar(not_favour_bar, not_favourable, color='orange', width=width, edgecolor='grey', label='Not Favourable')

# Setting labels, title and legend
m.title('Satisfaction with Wales Transport System by different Categories', fontweight='bold')
m.xticks(favour_bar + width/2, categories, rotation=45, ha='right')
m.ylim(5.10, 6.50)
m.yticks(n.arange(5.10, 6.50, 0.20))
m.legend(loc='upper left', bbox_to_anchor=(1, 1))
m.show()
```
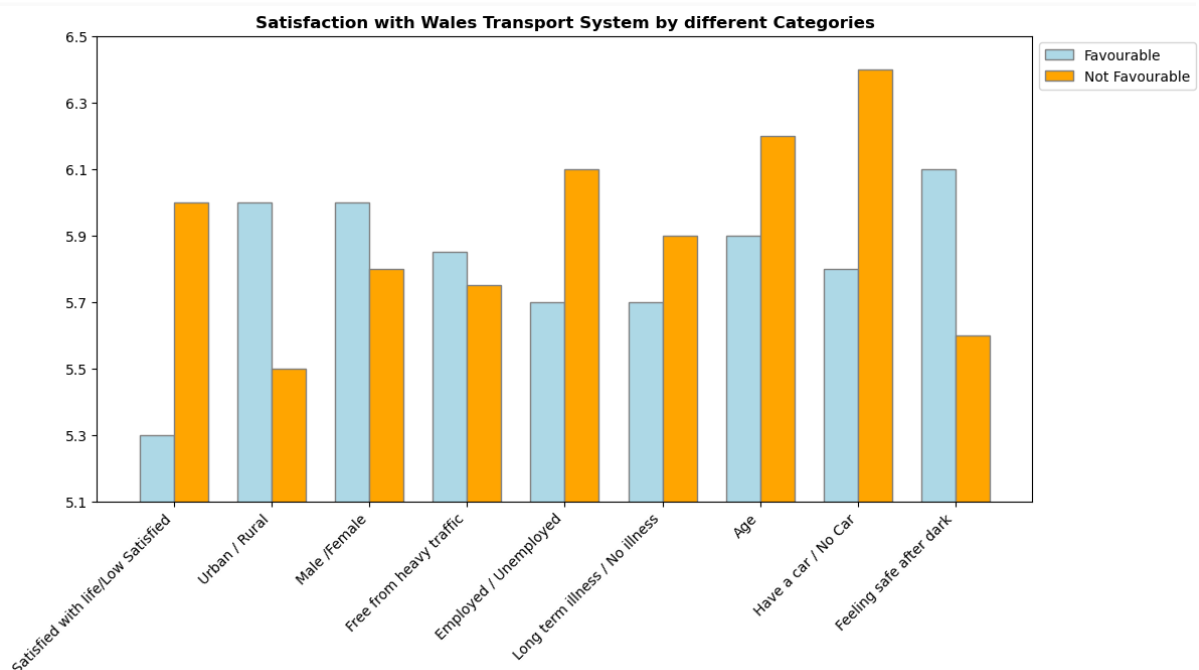

There are a few data transformed to generate this graph:

- Table 13 –An average of agree and neither agree nor disagree is considered as agree, and an average of disagree and neither agree nor disagree is considered to be disagree

- Table 10 – Age group 16-64 classified as one group and 65 and over classified as the senior group

Interpretation

The overall satisfaction is evenly distributed among both groups in each category, but those without a car express the highest dissatisfaction.

Overall Satisfaction to Services by Household

Further classification satisfaction by Household type Table 1 provides information on the satisfaction with Wales transport system.

Data Extraction / Analysis - Sheet 2

```python
# Loading data from Sheet 2
data_sheet2 = p.read_excel(file, sheet_name='Graph 2').round(2)
p.set_option('display.max_colwidth', None)
data_sheet2
```

	Category	Value
0	Single pensioner (No Children)	6.23
1	Married couple pensioner (No Children)	6.02
2	Single person, not a pensioner (No Children)	5.98
3	Two adult household with children	5.78
4	Two adult household (up to one pensioner) without children	5.57
5	Single parent household	5.93
6	Other households	6.14

Data Visualization - Sheet 2

```python
# Retrieving data from Sheet 2, and calculating as percentage
category = data_sheet2['Category']
values = data_sheet2['Value']
total = sum(values)
percent = [(val / total) * 100 for val in values]
width = {'linewidth': 2, 'edgecolor': 'white'}

# Plotting Pie Graph
m.figure(figsize=(6, 6))
m.pie(values, labels=['{} {:.0f}%'.format(cat, perc) for cat, perc in zip(category, percent)],
      startangle=140, wedgeprops=width)
m.title('Satisfaction with Wales Transport System by House Type', fontweight='bold')
m.show()
```


Satisfaction with Wales Transport System by House Type
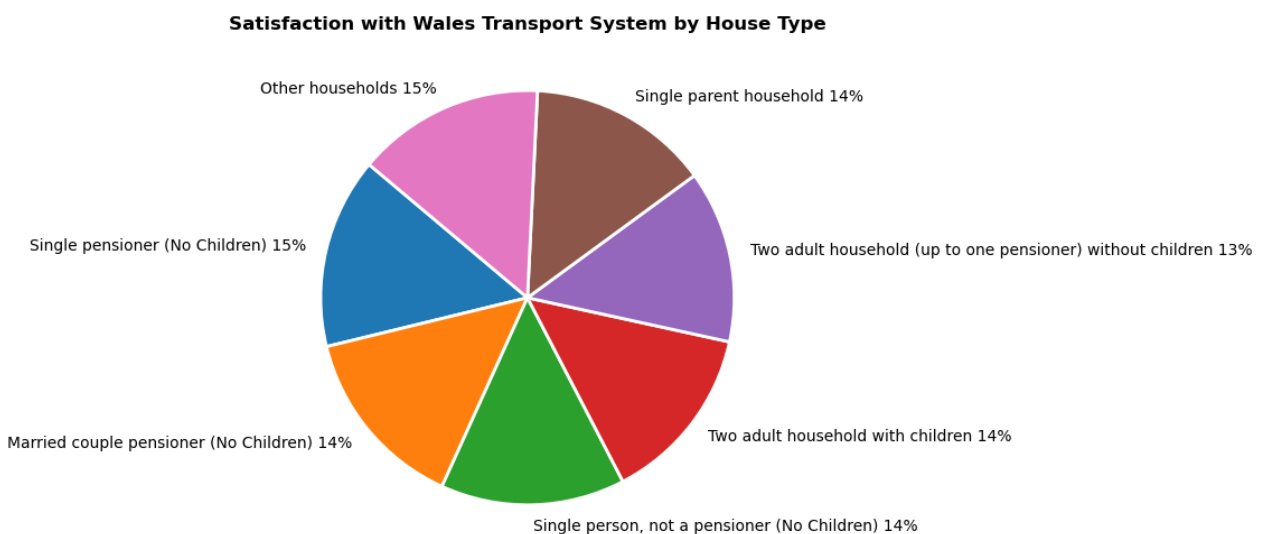
Interpretation

This graph interprets that all of the household types are impacted as the percentages are almost the same.

Deprived Score against Access to Services in the Area

The tables related to 7 and 8 are considered which provides data related to access to services in the deprived area.

Data Extraction / Analysis - Sheet 3

```
# Loading data from Sheet 3
data_sheet3 = p.read_excel(file, sheet_name='Graph 3').round(2)
data_sheet3
```

	Overall satisfaction	Deprived score	Access to Services
0	20% most deprived	6.06	5.44
1	20% - 40% most deprived	6.01	5.78
2	40% - 60% most deprived	5.81	6.04
3	20% - 40% least deprived	5.73	6.02
4	20% least deprived	5.79	6.14

Data Visualization - Sheet 3

```
# Retrieving data from Sheet 3
category = data_sheet3['Overall satisfaction']
value1 = data_sheet3['Deprived  score']
value2 = data_sheet3['Access to Services']
width = 0.35

# Plotting Bar-Line graph
m.figure(figsize=(9, 5))
m.plot(category, value2, color='orange', label='Access to Services')
m.bar(category, value1, width=width, color='lightblue', label='Deprived Score')

# Setting labels, value-range, title and legend
m.title('Comparison of Deprived Score and Access to Services', fontweight='bold')
m.xticks(rotation=45, ha='right')
m.ylim(5.00, 6.20)
m.yticks(n.arange(5.00, 6.20, 0.20))
m.legend(loc='upper left', bbox_to_anchor=(1, 1))
m.show()
```

Comparison of Deprived Score and Access to Services
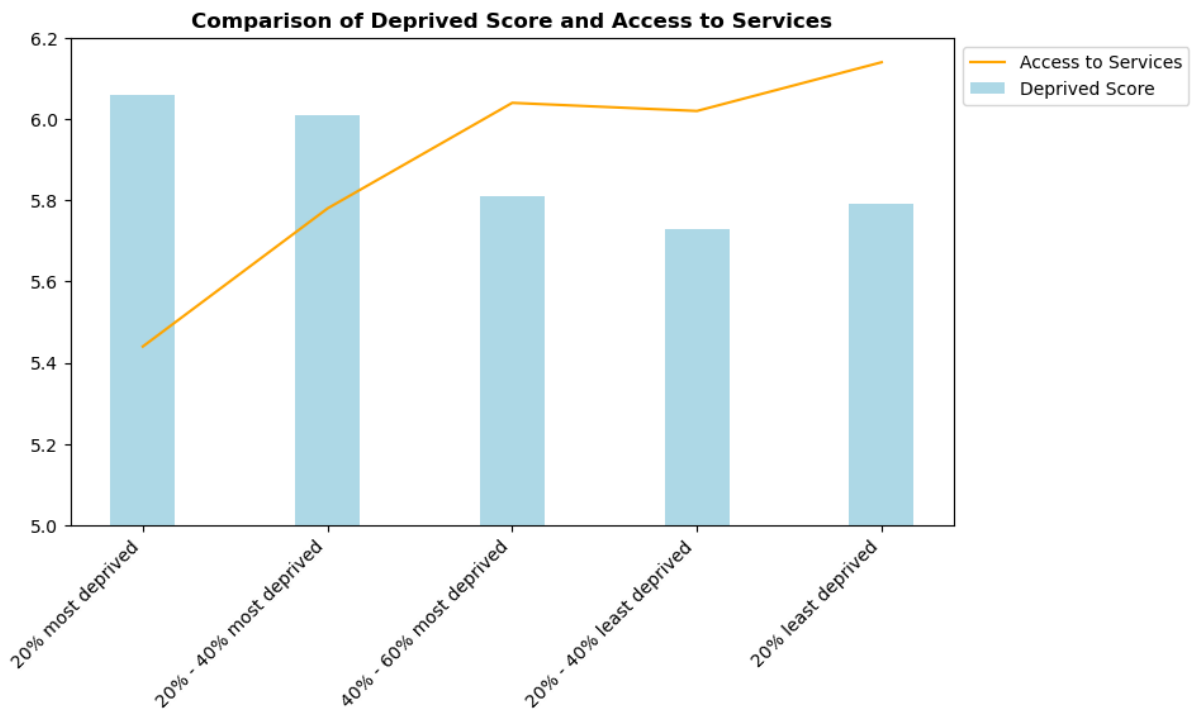
Interpretation

The public belonging to the most deprived area has a very low satisfaction level with the Wales Transport system. This could be because, in the least deprived area, the category of people having a car could be a possible reason or the public transport is efficient enough.

Satisfaction level from a group of the public has use of car

Data provided in Tables 15 to 18 and Tables 20 to 22, provide information related to the public have use of cars with different categories.

Data Extraction / Analysis - Sheet 6

```
# Loading data from Sheet 6
data_sheet6 = p.read_excel(file, sheet_name='Graph 6')
data_sheet6
```

	Have use of a Car	Satisfied	Not Satisfied
0	Have a Car	79	21
1	Satisfaction with life	78	72
2	Male/Female	82	76
3	Urban/Rural	77	86
4	Employed/Not Employed	90	66
5	Long term illness	69	82
6	Most Deprived - Access to Service	84	16
7	Least Deprived - Access to Service	71	29

Data Visualization - Sheet 6

```
# Retrieving data from Sheet 6
categories = data_sheet6['Have use of a Car']
satisfied = data_sheet6['Satisfied']
not_satisfied = data_sheet6['Not Satisfied']

# Plotting Horizontal Bar Graph
height = 0.35
width = 0.35
bar_satisfied = n.arange(len(categories))
bar_not_satisfied = bar_satisfied + width
m.figure(figsize=(10, 6))
m.barh(bar_satisfied, satisfied, height=height, label='Satisfied')
m.barh(bar_not_satisfied, not_satisfied, height=height, label='Not Satisfied')

# Setting labels, value-range, title and legend
m.yticks(bar_satisfied + width / 2, categories)
m.xlim(0, 100)
m.xticks(n.arange(0, 100, 10))
m.title('Satisfaction with Use of Car', fontweight='bold')
m.legend(loc='upper left', bbox_to_anchor=(1, 1))
m.show()
```


Satisfaction with Use of Car
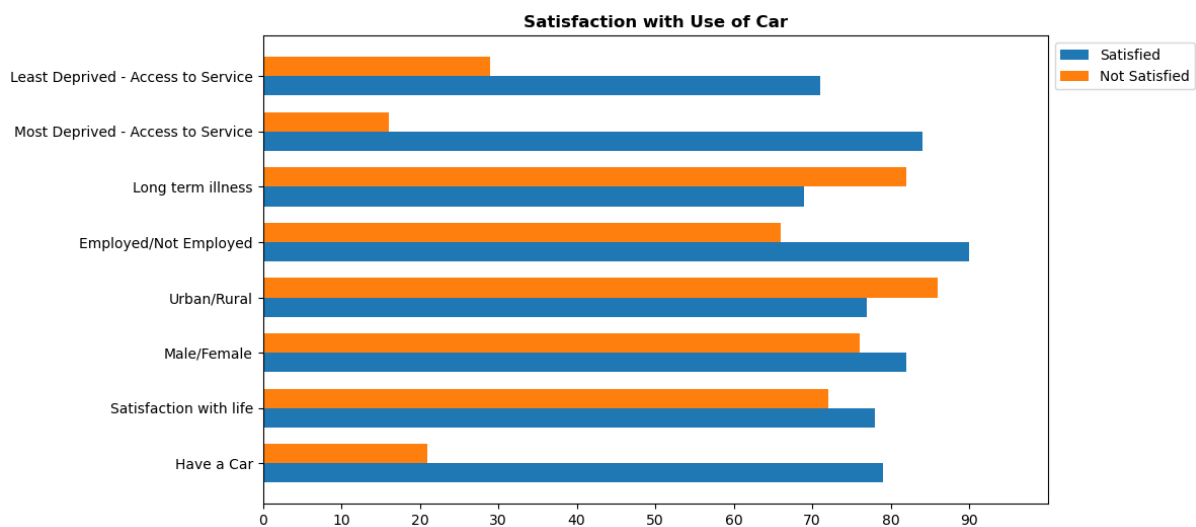
Data Transformation

- Table 20 clubbed data together for the least and most deprived
- Table 16 – Satisfaction score converted to %

Interpretation

Urban areas are most unsatisfied and satisfaction with life without a car is high indicating that not having a car in general is not satisfied with life overall.

Service Access with and without a car against Deprivation Score without a car

Tables 19 and 20 are chosen to identify the access to services when someone owns a car and does not own a car with a deprivation score.

Data Extraction / Analysis - Sheet 7

```
# Loading data from Sheet 7
data_sheet7 = p.read_excel(file, sheet_name='Graph 7').round()
data_sheet7
```

|	Access to Service having a CAR	CAR	No CAR	Deprivation score of No CAR
0	20% most deprived	65.0	35.0	11.0
1	20% - 40% most deprived	75.0	25.0	17.0
2	40% - 60% most deprived	81.0	19.0	21.0
3	20% - 40% least deprived	86.0	14.0	26.0
4	20% least deprived	89.0	11.0	31.0

Data Visualization - Sheet 7

```
# Retrieving data from Sheet 7
category = data_sheet7['Access to Service having a CAR']
value1 = data_sheet7['CAR']
value2 = data_sheet7['No CAR']
value3 = data_sheet7['Deprivation score of No CAR']

# Plotting Bar-Line Graph
width = 0.35
m.figure(figsize=(9, 5))
m.plot(category, value3, color='red', label='Deprivation score of No CAR')
m.bar(n.arange(len(category)) - width/2, value1, width=width, color='lightblue', label='CAR')
m.bar(n.arange(len(category)) + width/2, value2, width=width, color='pink', label='No CAR')

# Setting labels, value-range, title and legend
m.title('Access to Services when having and not having a car vs the deprevation score of people with no car',
        fontweight='bold')
m.xticks(rotation=45, ha='right', fontsize=10)
m.ylim(5.00, 6.20)
m.yticks(n.arange(0, 110, 10))
m.legend(loc='upper left', bbox_to_anchor=(1, 1))
m.show()
```


Access to Services when having and not having a car vs the deprevation score of people with no car
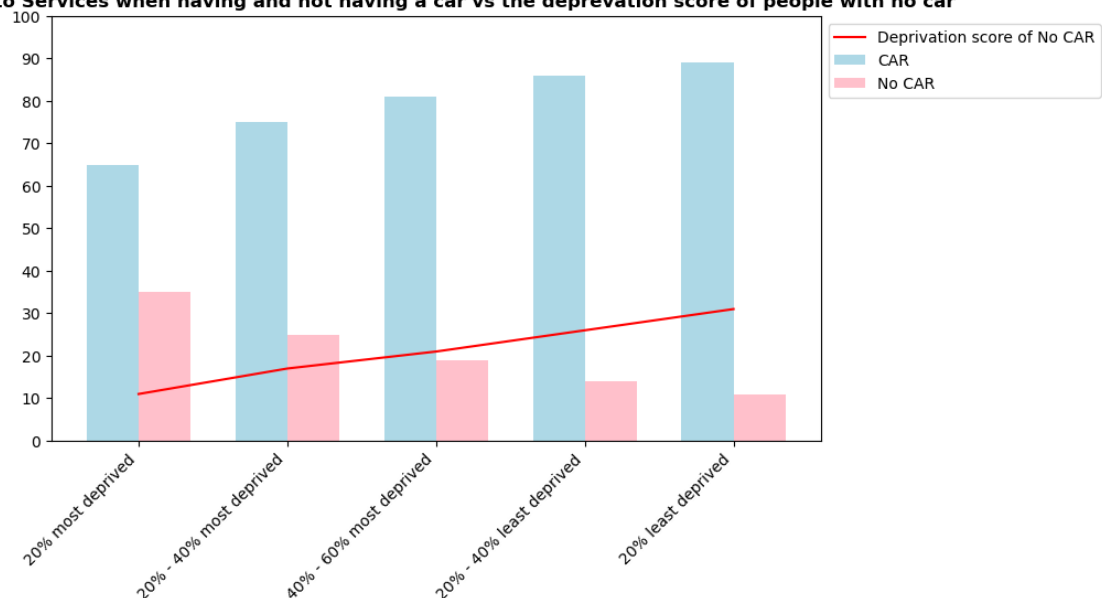
Interpretation

In the most deprived areas, a high number of residents lack cars, and service access is significantly lower

compared to the least deprived areas.

Ease of Access to Hospital and GP

Table 23 and Table 31 Ease of getting to and from GP and Hospital, after analysis of having a car and not having a car, how people get to the hospital by access to services.

Data Extraction / Analysis - Sheet 8

```
# Loading data from Sheet 8
data_sheet8 = p.read_excel(file, sheet_name='Graph 8').round()
data_sheet8
```

	Getting to hospital with poor health	Easy to go to Hospital	Difficult to go hospital	Difficult to go to GP
0	20% most deprived	81	19	6.0
1	20% - 40% most deprived	82	17	6.0
2	40% - 60% most deprived	83	18	5.0
3	20% - 40% least deprived	83	17	8.0
4	20% least deprived	82	18	7.0

Data Visualization - Sheet 8

```
# Retrieving data from Sheet 8
category = data_sheet8['Getting to hospital with poor health']
value1 = data_sheet8['Easy to go to Hospital']
value2 = data_sheet8['Difficult to go hospital']
value3 = data_sheet8['Difficult to go to GP']

# Plotting Bar-Line Graph
width = 0.35
m.figure(figsize=(9, 5))
m.plot(category, value3, color='blue', label='Difficult to go to GP')
m.bar(n.arange(len(category)) - width/2, value1, width=width, color='pink', label='Easy to go to Hospital')
m.bar(n.arange(len(category)) + width/2, value2, width=width, color='orange', label='Difficult to go hospital')

# Setting labels, value-range, title and legend
m.title('Ease access to Hospital and GP in the deprivated areas', fontweight='bold')
m.xticks(rotation=45, ha='right', fontsize=10)
m.ylim(5.00, 6.20)
m.yticks(n.arange(0, 100, 10))
m.legend(loc='upper left', bbox_to_anchor=(1, 1))
m.show()
```


Ease access to Hospital and GP in the deprivated areas
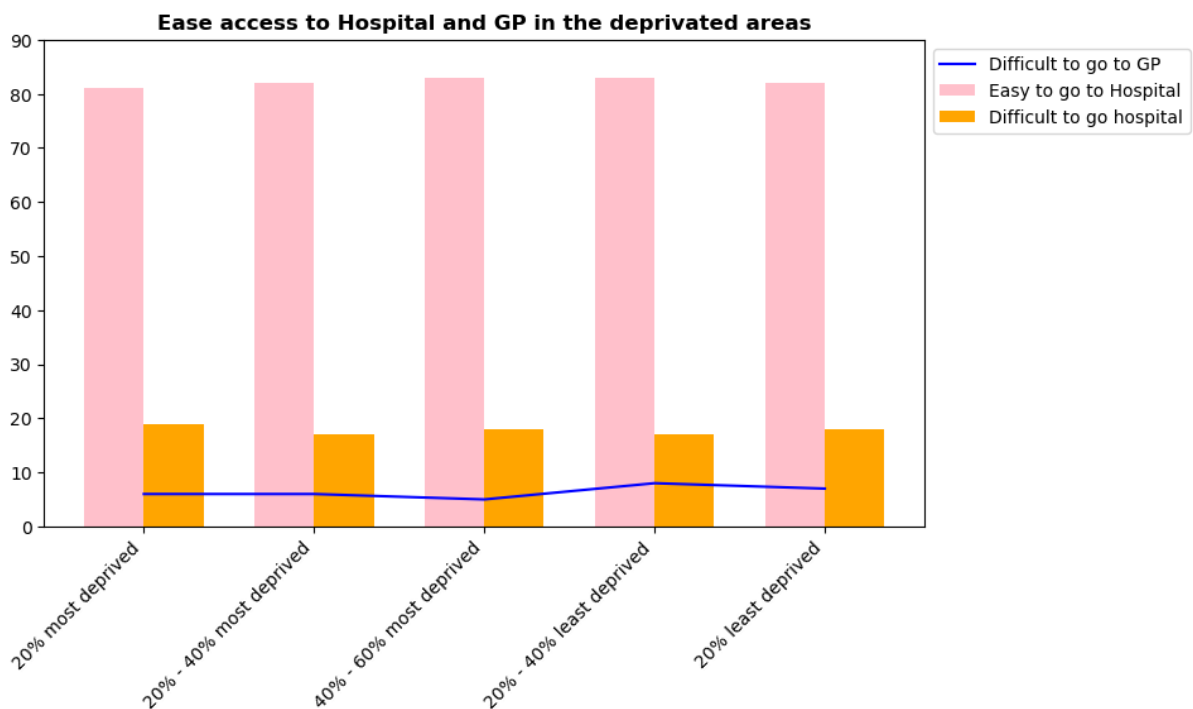
Interpretation

The ease of accessing hospitals seems easier than accessing GPs. Typically, individuals are advised to consult a GP first, and then, based on the GP's recommendation, proceed to a hospital.

Missing data

If the below information available, it may help in focusing on the right decisions.

- The data related to safety when traveling by car and walking in the local area in comparison with traveling by public transport may show the results not skewed as the statistics provide 58% of offenses related to public order, violence, and theft (Llwybr, 2023).

- Some analysis shows that 70% of working people travel by car and about 10% go to work by walking and 10% work from home, so it is only 10% of people use public transport (Experian, 2006).

- In addition to employed category and have use of a car, additionally, if data available to cover by walk and work from home will be useful to prioritize the solution.

Data Science Algorithm

Here are a few highly recommended Data Science algorithms.
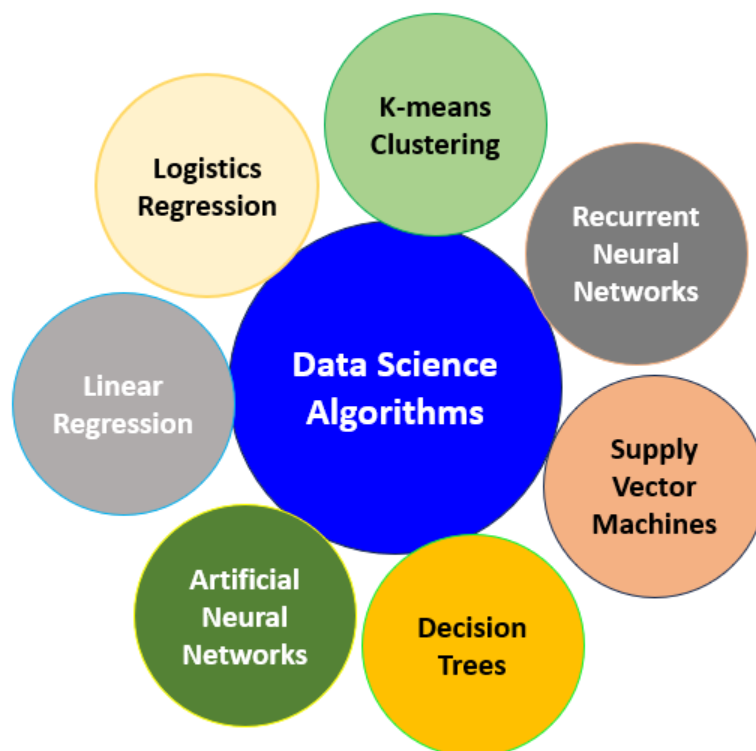
Reason for Choosing Decision Tree Algorithm

Decision Tree has been chosen as it best fits for discrete data fitting challenges and easy-to-build comparison. The Data Science Algorithm lays out the problems and possible outcomes in a simple manner and provides an effective method for decision-making (Coursera, 2023).

Decision Tree

The decision tree will have branches that provide steps that will lead to a decision (Taylor, 2022).
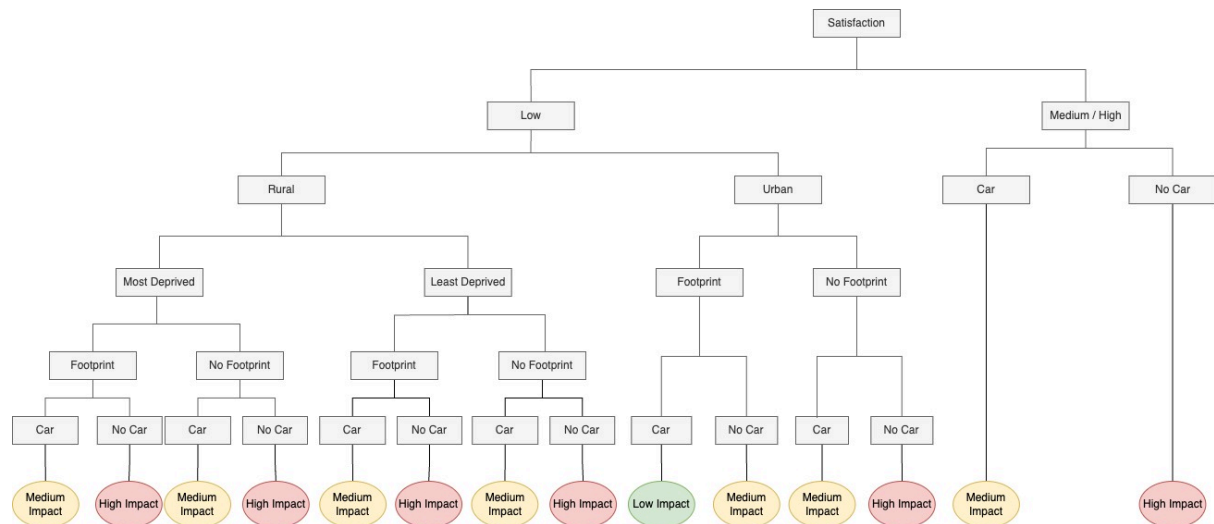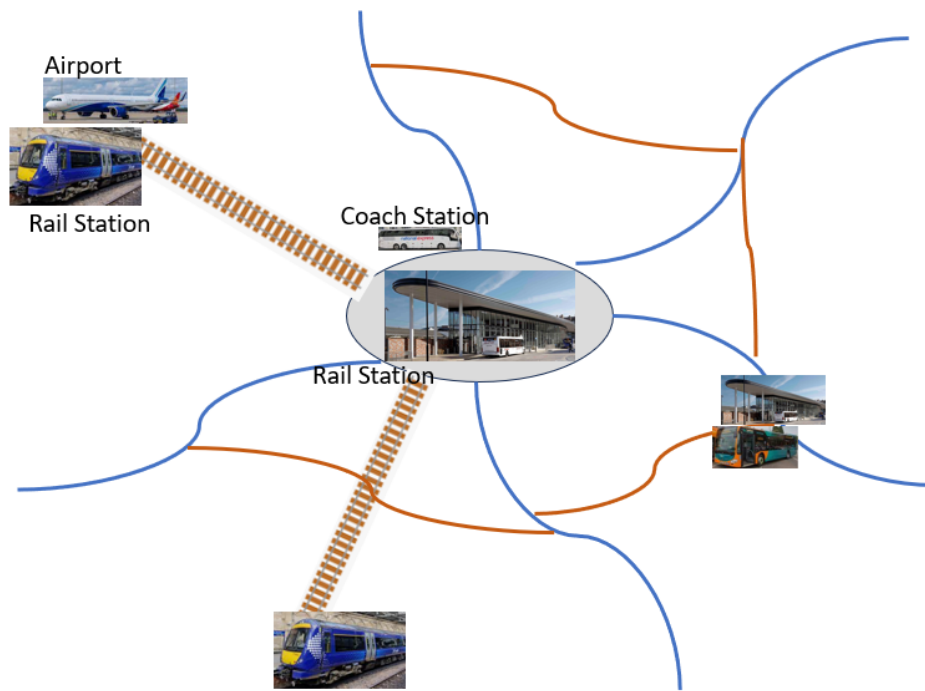

Solution

Two solutions will improve the state of public transportation.

Integrated Public Transport System

Based on data analysis, the proposed Unified Network diagram illustrates the integrated public transportation system (Roberts and Jones, 2019).

This level of integrated system connects with rural and urban areas and identifies an intersection point connecting all routes Airport, bus, coach, and rail services. Implementation of such integrated systems is proven already. This solution will address the issues for people to travel within all parts of Wales, implementing the "joined up way" (Peskett, 2023).

Limitation

The solution may fail if the below-listed dependencies and risks are not mitigated.

- Each of the interchange bus stops should support low-floor bus users and wheelchair users (TFL, 2006).
- Such bus stops require a good passenger waiting area. Regarding safety (Table 40, 41) enforcement of CCTV is essential.
- Building such interchanges will be expensive and approval on funding requied.
- The bus fare increase is not encouraging the public to make use of public transport (Shaw, 2023).

A new bus stop in Barry an interchange planned to be delivered in Sep 2023 which will provide an improvement in the reliability of bus services once implemented (Peskett, 2023). The project is delayed, however, got its first bus in Nov 2023 (Peskett, 2023). The full implementation of the project has been delayed and moved to Q1 2024 (VOG, 2023).

Franchise System

Wales government after a detailed analysis, tries to introduce a new operating model with bus franchising (Mosalski, 2023). Implementation of this solution can overcome the problem of setting up municipal bus companies by Local Authorities thus improving passenger experience(Deakin, 2022).

Limitation

There are a few areas of limitations in progressing with the Franchise solution.

- Bus re-regulation and franchising contracts in Wales are bespoke cost regimes and funding is always been a challenge. There is no plan for clear revenue support (Deakin, 2022).
- There is a risk in the cost involved in the tendering process for the franchising system. This in turn can become an affordability issue for the public (Debus, 2021)

- Availability of appropriate infrastructure and local road network
- Carbon Emission plans from the franchise and the contract need additional Governance from Local Authorities

The policy template provided by Wales Transport clearly articulates the Strategic Road network division responsible for highways has not been implemented many of their schemes which can become a blocker to get any efficiency of this solution implementation (TOW, 2022).

Conclusion

The analysis results emphasize the importance of the implementing the solution with proper consideration to limitations and risks. Careful consideration is required in terms of data collection as there is a lot of variation for different groups. There has to be data governance in place to include the audit process and ensure the data collected is reviewed for quality assurance. Though there are graphs and charts in the report, it is recommended to use other analytical BI tools to get consistent outcome. The data analysis also proves that people in rural areas are likely to be more rural and live in the countryside (Experian, 2006). The public should be encouraged to use public transport rather than cars to avoid traffic congestion.

It requires a deep data analysis to review their situation in specific areas rather than generalizing the data across Wales. So, there is a need for additional data requirements and analysis to provide appropriate solutions for specific areas in Wales. Funding and investment are some of the major challenges for any of these improvement activities to progress. This requires an intervention and support from the Welsh Government (Rodrigues and Matthew, 2023).

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