**1, Introduction**

**1,1 Intro**

The Hungarian capital, Budapest's growing, nearly 2 million population require an extensive public transport network. This paper aim to analyse the operation of Budapest public transport by exploring the openly accessible GTFS data format. The analysis will further investigate the public bus routes as a key part of the urban transportation mix. Discovering key similarities among bus routes will help identify clusters of bus services with different characteristics across the city. Better understanding of the bus network will lead to more sufficient, data-led city planning such as reduce congestions, create more efficient schedule, discover bus lane need, or improve air quality.

Budapest and most cities transportation need significantly differ based on whether it’s a weekday or weekend. Therefore, paper will differentiate between a regular weekday’s and weekend’s transportation schedule to provide comparison between the two contrasting operation mode.

**1,2 Technical requirements**

For the analysis, the following Python libraries will be used. The aim was to use standard libraries to showcase how regular Pandas and Geopandas can be sufficient to work with GTFS format. For the clustering, Sklearn machine learning library is imported. To create the data visualisations Seaborn, Contextily and Folium packages are utilised.

**Literature Review**

Public transportation is a key component of urban development and planning. In most major cities, significant public spending is allocated towards enhancing transportation networks, as they impact the socio-economic development of areas, through providing (or limiting) access to education, employment, healthcare and leisure (Deka, D., 2004). Access to various forms of transportation has long been seen as a source of economic inequality – owning a horse in the middle ages meant you could get further than simply on foot. Today, numerous studies suggest that lower income households are drawn towards the more impoverished, inner-city areas due to cheaper access to transportation than in the suburbs (LeRoy and Sonstelie, 1983; Glaeser et al., 2008).

In addition, transportation networks can have substantial environmental impacts. As the global rate of automobiles per capita continues to rise, countries and particularly large cities can expect a continued rise in traffic congestions and related pollution (via emissions) unless significant action is taken (May, 2013). As such, enhancements opportunities in urban transportation planning are highly sought-after, particularly in the developed world, where countries have means for funding such projects.

There are various modes of transport that define a particular cities urban transportation structure. In most cities cars and public busses tend to be the primary form of transportation, however many cities have popular alternatives, such as the underground in London (Guo and Wilson, 2011), or cycling network in Amsterdam (Buehler and Pucher, 2009). For Budapest in particular, the public transportation mix is fairly complex, with numerous metro lines, buses, trams, trolleybuses, and overground systems collectively operating to sustain the population’s transportation needs. The following essay will focus on the 229 bus services with 710 routes across Budapest and their characteristics.

This analysis will only use GTFS feed data. GTFS is becoming more and more accessible across the world. The larges data store can be found on transitfeeds.com, with currently 677 location’s GTFS feed provided by 1327 provider. Analysing and understanding these feeds lead to better understand the transit of cities and can provide improvement opportunities

**Research Question:**

R1: What are the key components of Budapest’s public transportation mix?

R2: How can we categories Budapest public bus route system based on key variables?

**3. Methodology**

The accessed GTFS data contains an entire month (November 2020) of public transport schedule. This dataset was selected for the purpose of excluding Covid-19 related anomalies in the transportation schedule. According to the operator company the schedule is defined monthly, therefore generally the same day of the weeks has essentially the same routes and timetable planned for. For memory efficiency reasons, the busiest weekend (Saturday or Sunday) and the busiest weekday (Monday, Tuesday, Wednesday, Thursday, Friday) in the month will be selected as samples for the analysis and clustering.

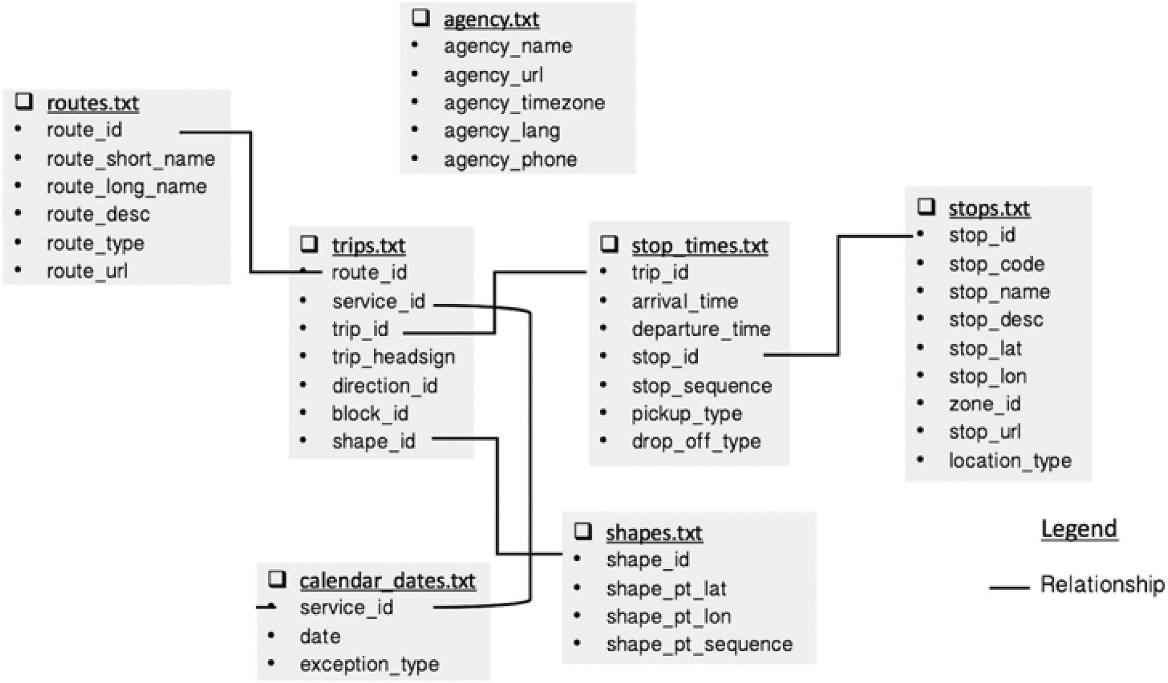
This workpaper will provided step-by-step instructions from reading the raw data, cleaning and preparing it to the explanatory analysis and bus route clustering. The explanatory analysis will be aimed to showcase the information that can be gathered from the rich GTFS file format. Apart from highlight the general usefulness of the GTFS public transport data, we wish to gain more understanding of Budapest public transportation system. The workpaper also written with the aim of reusability whether using another month of Budapest GTFS data or use a different cities GTFS dataset.

This analysis will be using GTFS (General Transit Feed Specification) Static and not the real-time extensions of GTFS. GTFS contains multiple txt files which has complex relational relationships. In the case of BKK it contains the following files:

* **agency.txt** – It contains information about the service agency (BKK) of the feed, and time zone of the city where the transit operates and contact information.
* **stops.txt** –It contains the transit station/stop names, stop ID, and geo-locations (latitude, longitude).
* **trips.txt** –It contains the directions headed of each vehicle movement. Each trip has a service ID which specifies the days it operates on.
* **route.txt** –It contains the information on how trips are grouped into single services. Vehicle type of transportation, name/number of the route,
* **stop\_times.txt** –It contains the information on the arrival and departure time of each transit station/stop, as well as station sequence and corresponding trip IDs. This is the largest file in the folder
* **calendar\_dates.txt** –It contains the service id and their related dates
* **shapes.txt** –It contains geographical polylines representing the routes that a transit vehicle takes.

(Kunama et al., 2017)

The relationship among the tables is illustrated below.



(Modified from source: Prommaharaj et al., 2020)

In order to execute the clustering of bus routes, K-means classification method will be utilised. K-means is an unsupervised machine learning algorithm, therefore by definition it seeks to uncover hidden characteristics of the data feed into it. (Allahyari et al., 2017). No training dataset required, and the algorithm can be used on numerical and categorical data attributes. The following numerical attribute will be calculated in order to create the clusters:

1. Average speed of the route/shape – defined in km/h
2. Stop Density of route/shape - stops per kilometre across the route
3. Trip activity level - number of trips have been taken on the route in a day

For defining the K – number of clusters for our classifications, we’ll be using the Elbow Method. Elbow Method is a popular test to conduct to identify the appropriate number of clusters that the data requires.

4, Data Processing

4,1 Data Gathering

4,2 Data Cleaning, Preparation

5, Analysis

5,1 Descriptive Stats

5,1,1 Vehicle types

5,1,2 Traffic of stops

5,1,3 Visualise a daily changes of the public transport traffic

Weekday:

The following couple of figures will explore the four identified clusters in the bus routes.

* **Cluster 0:** the group of routes with the lowest average speed and the highest stop density represents the bus routes for reaching/connecting more habitants of the city rather than providing quick commuting solutions. The map below shows that this cluster covering most of the city with a high density in Inner Budapest and certain north suburb area.
* **Cluster 1:** the category the contains the most frequent bus schedules (count\_trips) with 95.7 average trips per day. It transits slightly faster and has fewer stops on average than Cluster 0. Cluster 1 consist the essential bus routes for the city’s population crossing the Danube bridges regularly connecting the two part of the city Buda and Pest.
* **Cluster 2:** this group has the higher speed, occasional buses with only 9.7 trips per day. A lot of these routes are the nigh bus routes, they cover most of the main squares and streets of the city with low stop density and higher speed with the lack of traffic at night.
* **Cluster 3:** This is the cluster of fast buses with the aim of take long distance with higher speed which requires low stop density. These routes are helping commuters to get to the city centre from the suburbs and also contains the bus 200E which connects the city with the international airport.

Weekend clusters resulted similar outcome

6. Discussion and Conclusion

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