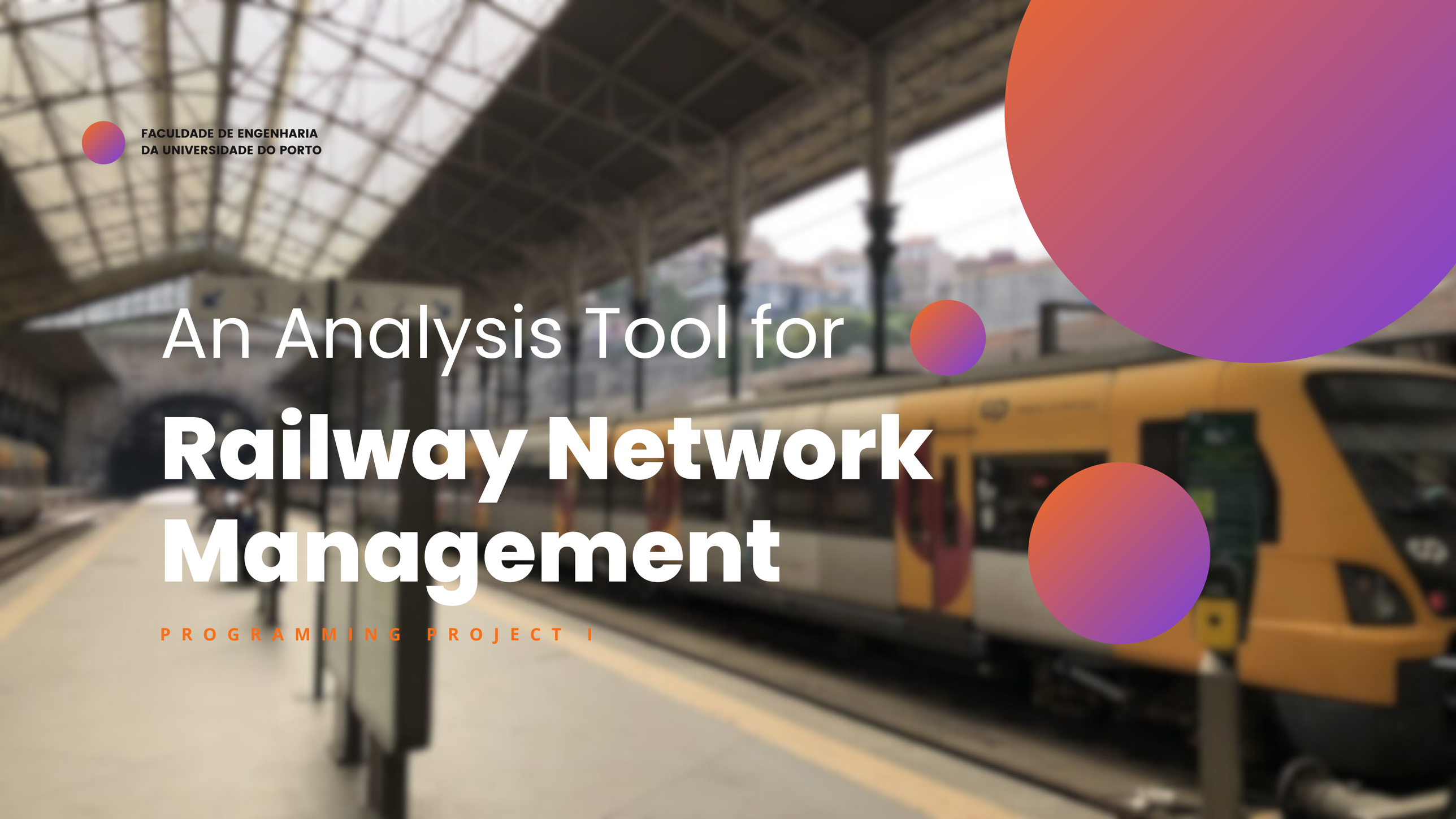

FACULDADE DE ENGENHARIA
DA UNIVERSIDADE DO PORTO

An Analysis Tool for **Railway Network Management**

PROGRAMMING PROJECT I

Our Project

We were tasked with implementing an analysis tool that can support the management team of a railway network to make informed decisions about how to best allocate its resources, both financial and physical (e.g., trains).

Once you run the program, it will read the data files and, then, display a menu with the tasks.
Choosing option 2 and then option 1 means you want to execute the resolution of task 2.1.

When reading the data files, the program will generate a graph representing the Portuguese railway system.
This graph's nodes represent the stations and the edges represent the connections between them.

Basic Service Metrics

2.1 Maximum flow

We were asked to find the maximum flow between two stations.

We've implemented Edmonds-Karp algorithm to solve this problem.

The program will ask for the source and sink stations and will display the maximum flow between them.

```
ID: 514 | Canas Felgueira | VISEU | NELAS | Canas de Senhorim | Linha da Beira Alt

Maximum number of trains that can simultaneously travel between Povoa and Canas Felgueira is 2
--------- Menu ---------
1 - Exit
2 - Basic Service Metrics
3 - Operation Cost Optimization
4 - Reliability and Sensitivity to Line Failures
5 - Reset Graph
Option:
```

2.2 Maximum flow in the entire railway system

```
Calculating ...
The connection that requires the most amount of trains is
Lisboa Oriente - Entroncamento
Lisboa Oriente - Santarem
Entroncamento - Santarem
With a maximum of 22 trains
```

In topic 2.2, we are asked to find the two stations of the entire network with the maximum flow between them.
First, we compute the combination of all source and sink stations.
It's important to note that, since the graph is undirected, the flow between stations A and B is the same as the flow between stations B and A.

So, the computed combination set does not include pair (A,B) and (B,A).
Then, for each pair, we calculate the maximum flow between them using Edmonds-Karp algorithm.
Finally, we display the pair with the maximum flow.

2.3 Larger budgets

Find the top-k municipalities and districts that should spend more money in the railway system

The user first chooses **k**, an integer.
We chose to distinguish the municipalities and districts by their maximum internal flow.
When data files are read, we also organize the data in a way that we can easily know each district's municipalities and each municipality's stations.

```
How many municipalities do you want to see?4
 These are the 4 municipalities which should spend more money on maintenance
and purchasing of trains:
1 - LISBOA      (total flow: 678)
2 - POMBAL      (total flow: 156)
3 - AVEIRO      (total flow: 134)
4 - COIMBRA     (total flow: 126)
```

```
How many districts do you want to see?3
 These are the 3 districts which should spend more money on maintenance and purcha
sing of trains:
1 - LISBOA      (total flow: 5414)
2 - AVEIRO      (total flow: 4866)
3 - LEIRIA      (total flow: 1674)
```

If we want to know the maximum flow of a municipality, we sum the maximum flow of all its pair of stations.
Then we sort the municipalities by their maximum internal flow and display the top-k.
A similar process is done for the districts.

2.4 Maximum number of trains

Arriving at a given station, considering the entire network

01

First, we create a new node which will connect to all the stations which have only 1 connection (meaning that they're the beginning of a line).
These connections have infinite capacity.

02

Then, we calculate the maximum flow between this new node and the given station using Edmonds-Karp algorithm.
This is the maximum number of trains that can arrive at the given station, considering the entire network.

```
ID: 16 | Valongo-Vouga | AVEIRO | AGUEDA | Valongo do Vouga | Linha do Voug

Maximum number of trains that can simultaneously arrive at Valongo-Vouga is 4
--------- Menu ---------
1 - Exit
2 - Basic Service Metrics
3 - Operation Cost Optimization
4 - Reliability and Sensitivity to Line Failures
5 - Reset Graph
```

Operation Cost Optimization

3.1 Minimum Cost

01

Each **STANDARD** line has a cost of 2 euros per train and each **ALFA STANDARD** line has a cost of 4 euros per train.
We've decided that the maximum cost of a line is its capacity multiplied by its cost per train.

02

We've implemented Dijkstra algorithm to find the minimum cost path between two stations, considering the maximum cost of each line.

03

We find the maximum number of trains that can go through this path - it's the minimum capacity of all the connections in the path.

04

Then we calculate the path's cost, which corresponds to the sum of each connection's cost per train multiplied by the maximum number of trains that can go through the path.
Finally, we display the calculated path and its cost.

```
The maximum number of trains that can go from Eixo to Estarreja with minimum cost is 2
Path: Eixo -> Azurva -> Esgueira -> Aveiro - Vouga -> Cacia -> Canelas -> Salreu -> Estarreja
The cost of this path is 28
```

4 Reliability and Sensitivity to Line Failures

This topic involves studying the impact of failures (like accidents, construction works, etc) in the railway system.

What we do, in this option, is change the capacity of some connections.
The user indicates how many connections he wants to change and then, for each connection, he indicates the connection's new capacity.
Then he can do see the results of all exercises again, but using the new values.

```
Select a path:
1 - Aveiro - Vouga  ->  Quintans  (STANDARD)
2 - Aveiro - Vouga  ->  Cacia  (STANDARD)
3 - Aveiro - Vouga  ->  Esgueira  (STANDARD)
4 - Aveiro - Vouga  ->  Espinho  (ALFA PENDULAR)
5 - Aveiro - Vouga  ->  Coimbra B  (ALFA PENDULAR)
Option: 4

What's this path's capacity? 0
```

```
Affected stations:
Porto Campanha: -18 trains
Espinho: -18 trains
Vila Nova de Gaia-Devesas: -12 trains
Trofa: -10 trains
Aveiro - Vouga: -10 trains
Chao de Macas-Fatima: -2 trains
Coimbra B: -2 trains
```

To remove the changes, the user must choose option 5 of the menu, which will reset the graph.

Before changing the capacities, the user is asked if he wants to see a report of the most affected stations.
We've defined that the most affected stations are the ones whose flow to the entire network is the most affected.
If the user chooses to see the report, the program will display the top-5 most affected stations.

First, we calculate the maximum flow between each station and the entire network, using the algorithm of the topic 2.4.
Then, after the changes, we recalculate these values and compare them with the previous ones.
The stations with the highest difference between the previous and the new values are the most affected ones.