MULTIMODAL FREIGHT PATH OPTIMIZATION

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VOC

- From consolidation to chartering, Bolloré Logistics delivers efficient solutions that meet the strictest time, cost and sustainability constraints. We ensure the dynamic traceability of flows and the management of alerts to allow them to switch to alternative solutions and backup plans whenever necessary.
- Our performance relies on centralized freight procurement, value added logistics services, consolidation platforms at the crossroads of international trade, in-house NVOCC (TSL) for maritime groupage.
- Against the backdrop of volatility and the digitization of freight markets, we are re-inventing our transport management systems. Indeed, IoT technologies enhance our performance level in areas such as visibility and piloting. Data analytics is generating optimized transport solutions by modelling a very large number of operational factors. Our goal is to always meet our customers' needs in terms of stability and competitive rates.

VOC

- INTERNATIONAL FREIGHT FORWARDING IS OUR CORE BUSINESS FROM GROUP'S ORIGIN
- **HIGH-PERFORMANCE TRANSPORT IS A DRIVER OF COMPETITIVENESS**
- In a complex and volatile world, a lean and agile supply chain is essential for the creation of value. Cost efficiency, time to market constraints, lower carbon footprint are key-performance objectives of all our customers. They select partners with proven capabilities for providing top quality service and for ensuring the visibility of international flows.

- Dedicated team of logistics analysts and project managers in charge from project kick-off to go-live and support handover.
- Strong emphasis on design phase to understand customer requirements and meet its objectives with the best tailored solution.
- Training phase to ensure smooth project start.

PROJECT OVERVIEW

- A client from European retail industry addressed our consultancy firm the following topic their logistics department faced with. They send merchandises from a big regional warehouse in Europe to another one close to cities where stores are located.
- They want to optimize their freight delivery between those warehouses to find best transport modes between air cargo, container ships, railway, trucks or tractor trailers. A trip can be done with one or several transport types.
- They want to find the best trade-off considering tuneable objective : whether cost, duration or CO2 emissions as well as a mixed objective of those. Best path and 3 sub optimal alternatives should be provided to their logistics department.
- A dataset of available airports, railway stations, truck stations and ports is provided to find best trade-off between all these transport types. They want to assess our tool based on their dataset.

DISCLAIMER

- This project is a proof-of-concept of NetworkX (Python framework for graphs) use.
- The dataset has been built by my own : the Jupyter notebook explains the different steps.
- In order to stay simple and interesting enough, the problem is based on several simplifications :
  - This simple Dijkstra path finder model is not suitable for large dataset.
  - The model does not include costs like those while changing between two transport carriers or insurance cost…
  - A change lasts the same time between two carriers no matter which type it is.
  - As the package is considered able to be put in a 30 tons container, we assume that every freight carrier (aircraft, ship, truck, railway) is able to carry it in a single trip, wheter by carrying the whole container or by splitting it in smaller boxes.
  - Each mode of transportation is considered able to begin the trip as soon as the package arrives : it does not take into account waiting time in case of groups of merchandises to carry on.

DATASET : TRANSPORT TYPE AVAILABLE

- Merchandises can be carried out by : aircraft (air cargo), containers (sea cargo), train (railway cargo) or trucks/trailers (road cargo).
  - Certain types of transport modes are available with another of same type : airport -> aiport, port -> port, train -> train and truck station -> truck station. Connections between them are done by trailers (arrival airport -> port of departure). However they are considered slower and more expensive comparing to trucks.
- Different hubs are available depending the type of transport : airports for air cargo, ports for sea cargo, railway stations for railway cargo or highway stations for road cargo.
- GPS coordinates (continent, country, latitude/longitude WGS84) are provided for each hub as well as their transport mode.
- A graph is created with a complete of hubs in this dataset.

ROADMAP

- A directional graph NetworkX (Python) is built considering hubs as nodes and objective value as edge.
- The full trip is made of a single connection or several steps.
- A mixed objective is built on cost, duration, CO2 emissions for each part of the trip. Specific coefficient weight value : one for cost, another for duration and the last for CO2 emissions. For instance, if cost one is equal to 1 and the others to zero, mixed objective is equivalent to consider cost only. Otherwise it is a mix of all depending on how the client want to weight each parameter.
- The total mixed objective at the end of the trip is the sum of all mixed objective for each step of the trip. It has to be minimized to find the optimal path. Best solution as well as 3 next alternatives are provided at the end including :
  - Evolution of cost, duration, CO2 emissions and mixed objective along the trip.
  - Continents, countries, hubs and transport types along the trip.
  - Comparison of all parameters between best solution and next 3 suboptimal paths.

ANALYZING DATASET AND DEFINING OBJECTIVE

- Data available : all connections between hubs with transport type, country, continent and GPS coordinates.
- For this proof-of-concept tool, let us take for instance :
  - Point of departure : Paris highway station (truck or trailer)
  - Point of arrival : Milano highway station (truck or trailer)
  - Mixed objective : 50% weight on duration, 40% on cost and 10% on CO2 emissions
  - Payload : 40 ft – 30.4 tons container
- Goal :
  - Find best path minimizing mixed objective at the end of the trip
  - Find next 3 alternatives

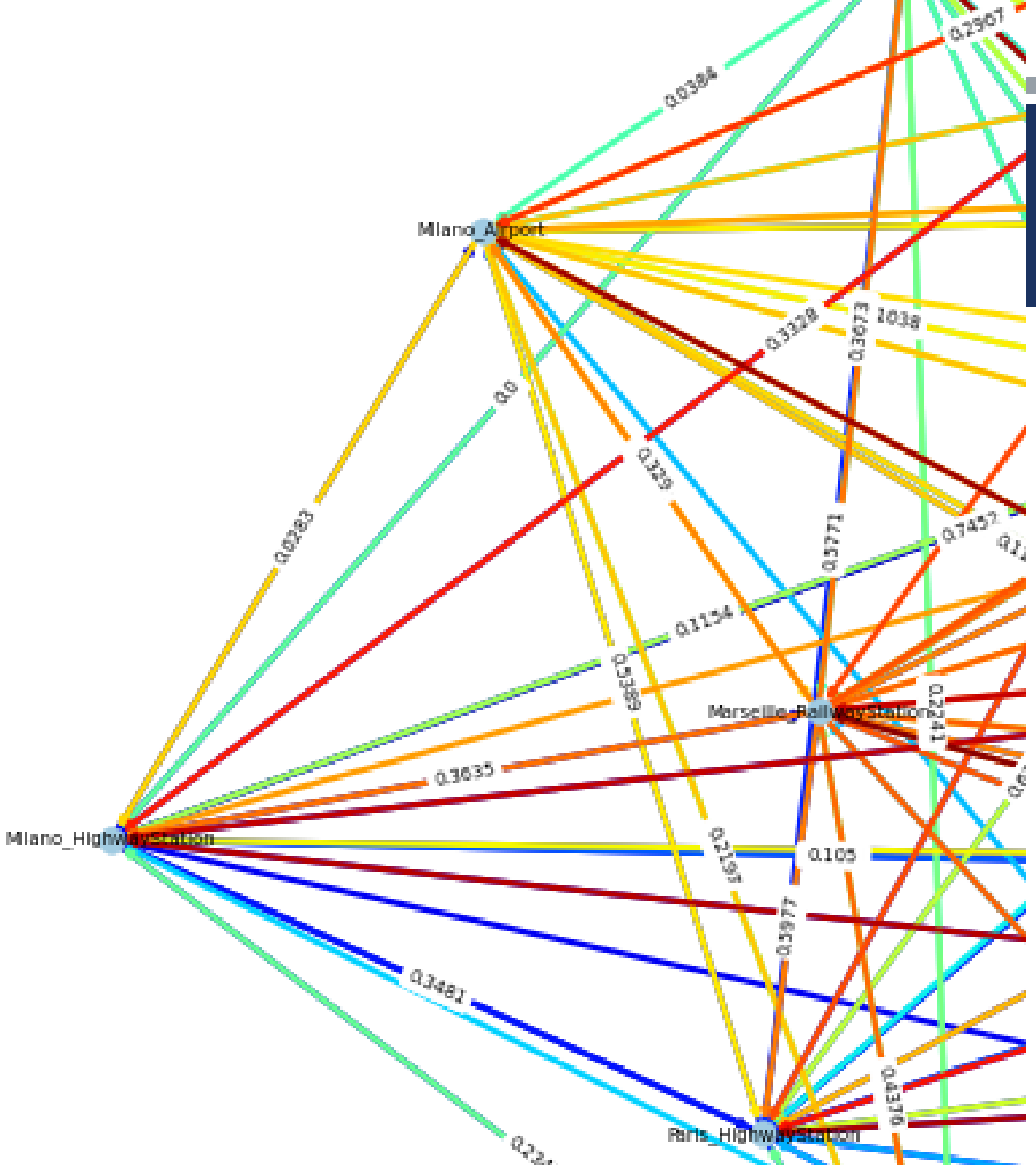
BUILDING THE NETWORK

- Connections between all hubs are built after available data and figures taken from a European report focused on transportation statistics « Cost figures for freight transport » released by the Netherlands Institute for Transport Policy Analysis.

Per km and per ton (*)	Air cargo	Sea cargo	Railway	Tractor trailer	Truck trailer
Cost (€)	0.1800	0.0013	0.0170	0.1150	0.2280
Speed (km/h)	900	45	35	100	80
CO2 emissions (g)	437	3	27	80	85

- (*) : distance of the trip (in km) and payload weight (in tons)

- Following parameters are computed for each connection between two hubs : distance, cost, duration, CO2 emissions and mixed objective after previous ratios.
- For the mixed objective, features are Min-Max standardised with a dedicated scaler. Even mixed objective is standardised in that way to ensure values between 0 and 1. Total mixed objective can exceed the 1 value beacause of cumulative edges in the network. It is not possible to get and final value between 0 and 1.
- The network is drawn as a directional graph whose nodes correspond to hubs and edges to mixed objective values. Connections are colored from blue to red considering their value.


Milano_Airport
Milano_HighwayStation
Marseille_RailwayStation
Paris_HighwayStation
0.0384
0.2367
0.3328
0.3673
1038
0.0
0.0283
0.329
0.7452
0.3771
0.1154
0.5369
0.3635
0.2241
0.2197
0.105
0.3977
0.3481
0.4376

PATH OPTIMIZATION

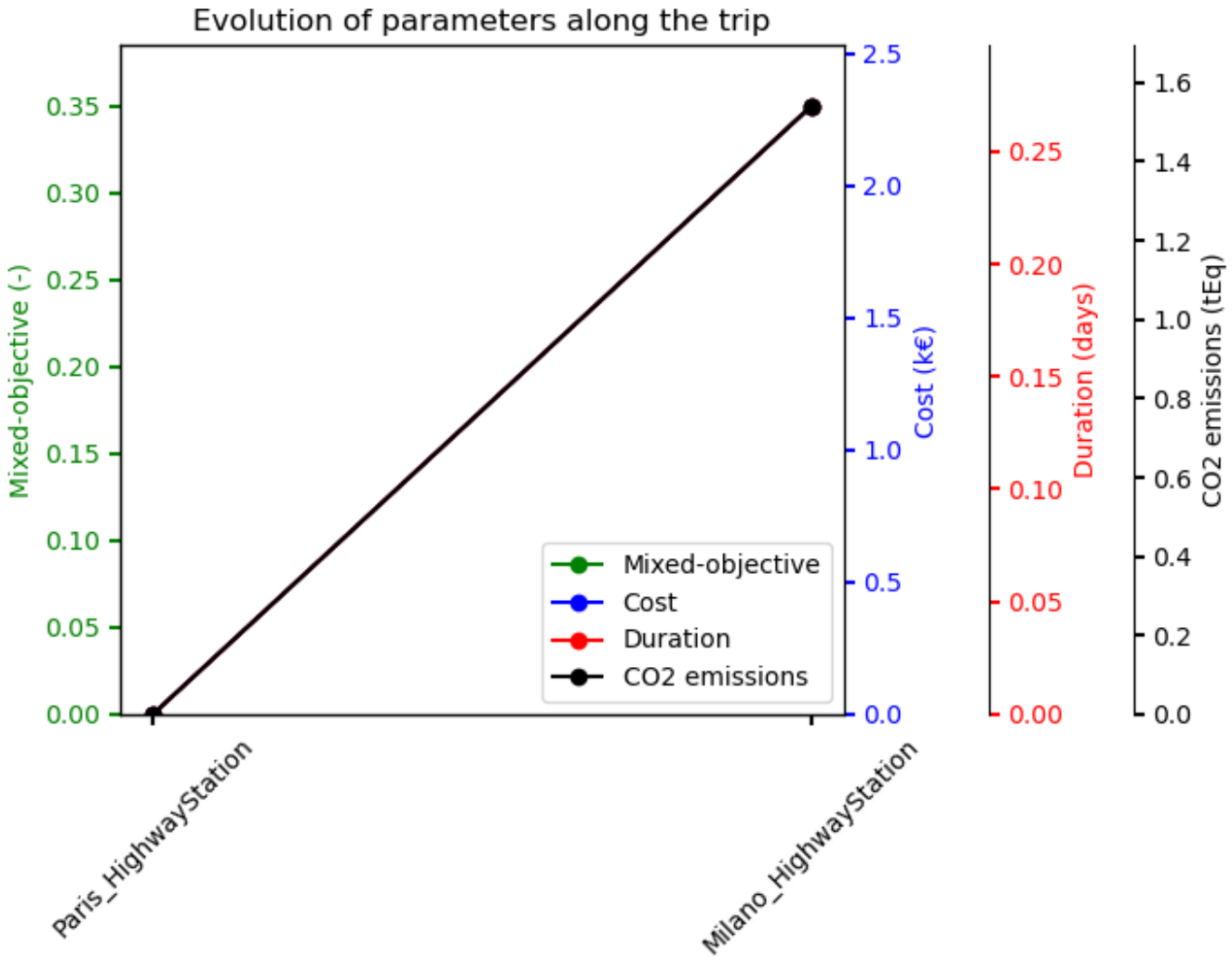
- A greedy algorithm, Dijkstra model, computes all paths available in the network. It is though expensive but convenient for this simple dataset.
- A dictionary saves all features along the trip.

BEST PATH

- The straight trip from Paris to Milano highway station is found to be the one which minimizes mixed objective as defined previously. This trip is done in 6 hours, costs 2300 € and generates 1.54 tons of CO2 using a tractor trailer.

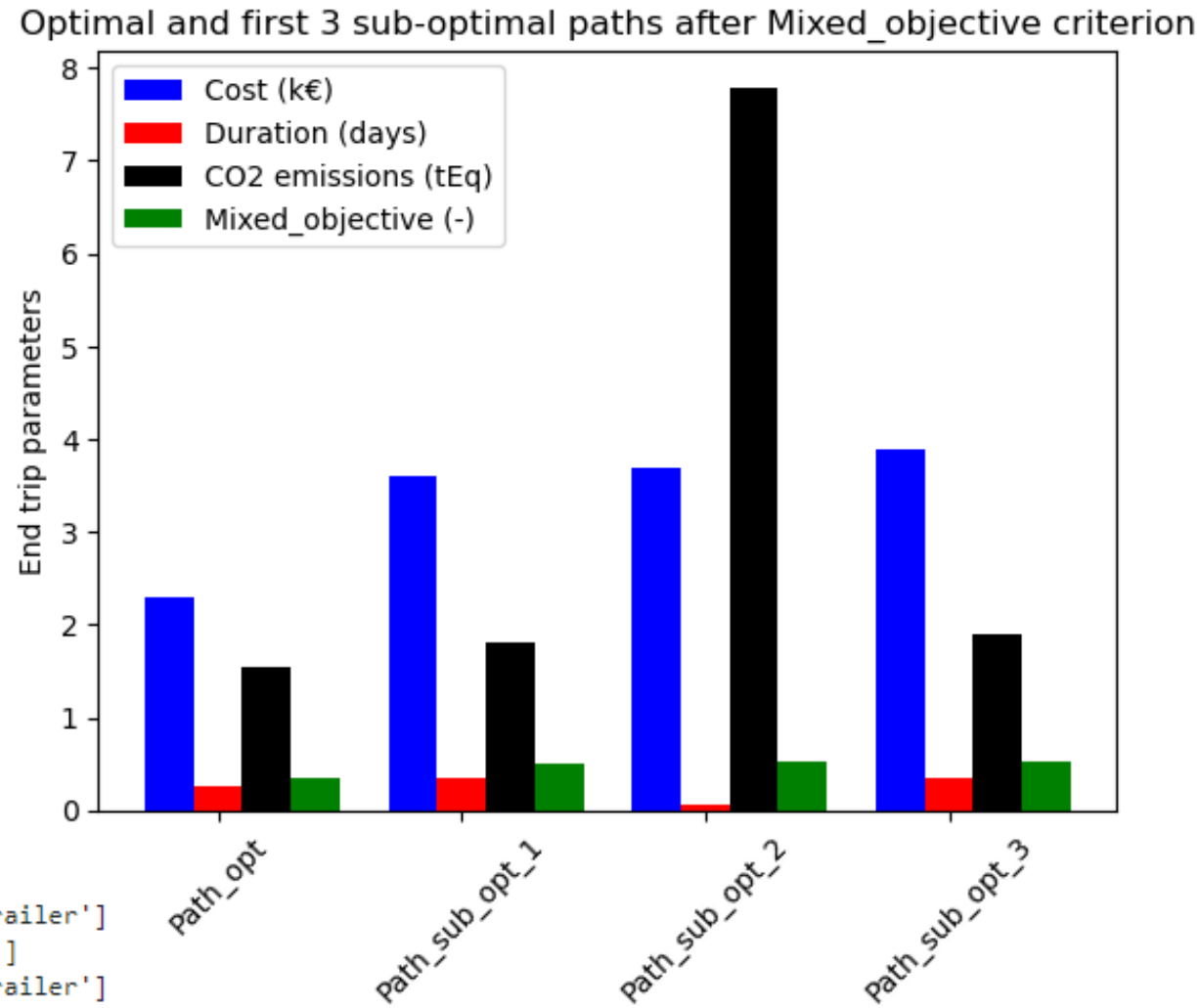

```
################## Network optimal path results ##################
Point of departure : Paris_HighwayStation
Point of arrival : Milano_HighwayStation
Payload weight (t) : 30.4
Criterion to find optimal path : Mixed_objective
    with coefficient applied on cost : 4
    with coefficient applied on duration : 5
    with coefficient applied on CO2 emissions : 1
Optimal path from departure to arrival : ['Paris_HighwayStation', 'Milano_HighwayStation']
Countries along the trip : ['France', 'Italy']
Transport type along the trip : ['Tractor_trailer']
Total trip cost (k€) : 2.3
Total trip duration : 0 day(s) 6 hours
Total trip CO2 emissions (tEq) : 1.54
Total trip mixed objective (-) : 0.35
##################################################################
```

- This graph showing evolution of different parameters is useful when facing trip with different steps in order to detect sensitive connections which enhance huge increasing in terms of duration, cost…
- In that case, it is less relevant.



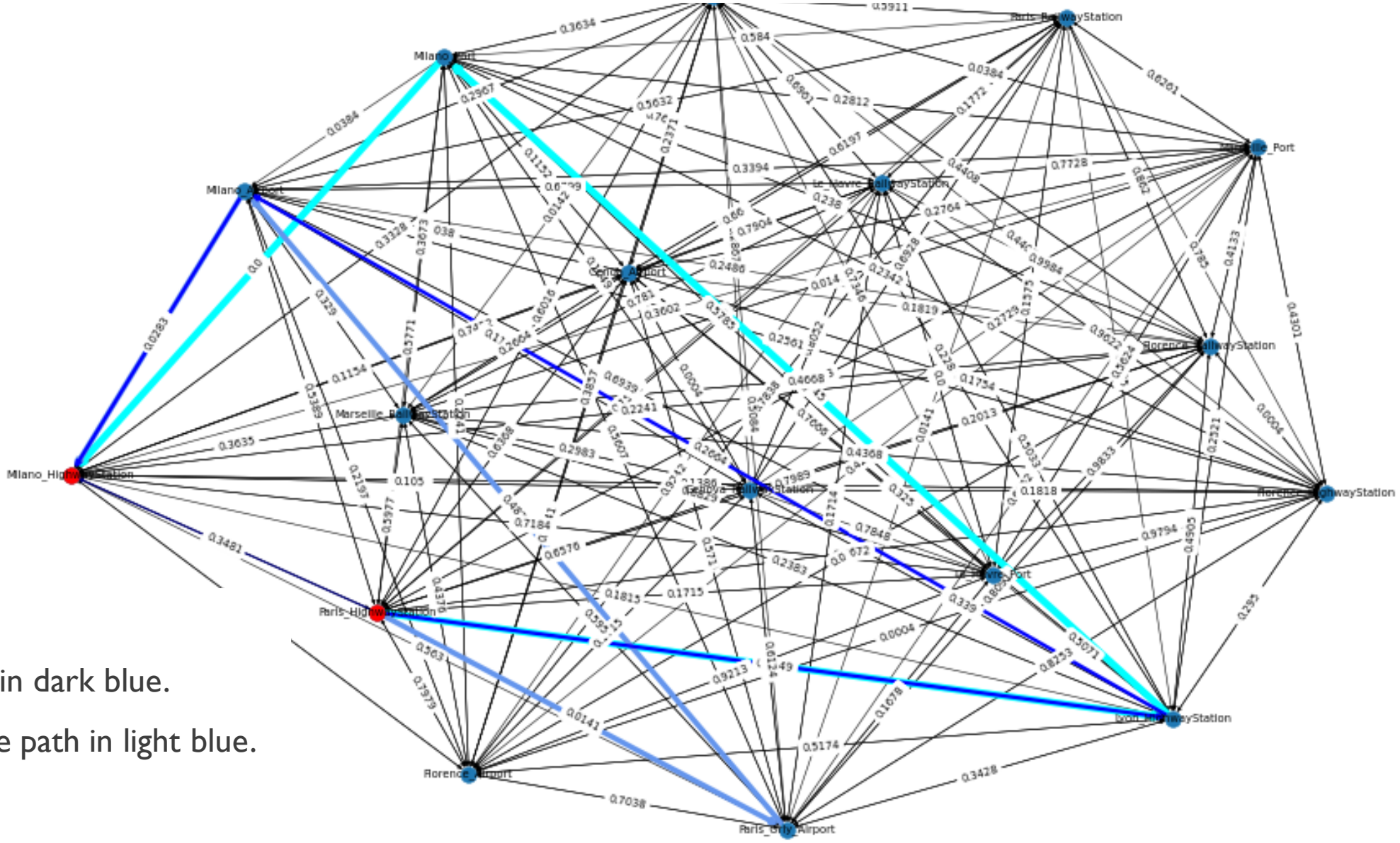
NEXT ALTERNATIVES

- As intendend, best path has minimum mixed_objective at 0.35 but other paths are quite similar. However differences can be seen on specific features.
- Considering only duration influence, best path is found to be the option 2 using air cargo during part of the trip.
- Considering only cost influence, best path is found to be the optimal solution because it only uses tracot trailer which is an effective option.
- Considering only CO2 emissions influence, all paths are quite similar except option 2 which uses air cargo.




```
Optimal path transport types : ['Tractor_trailer']
1st sub optimal path transport types : ['Tractor_trailer', 'Truck_trailer', 'Truck_trailer']
2nd sub optimal path transport types : ['Truck_trailer', 'Air_cargo', 'Truck_trailer']
3rd sub optimal path transport types : ['Tractor_trailer', 'Truck_trailer', 'Truck_trailer']
```

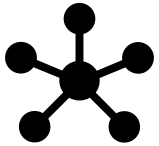
```
Optimal path after Mixed_objective criterion is : ['Paris_HighwayStation', 'Milano_HighwayStation']
1st sub optimal path after Mixed_objective criterion is : ['Paris_HighwayStation', 'Lyon_HighwayStation', 'Milano_Airpor
t', 'Milano_HighwayStation']
2nd sub optimal path after Mixed_objective criterion is : ['Paris_HighwayStation', 'Paris_Orly_Airport', 'Milano_Airport',
'Milano_HighwayStation']
3rd sub optimal path after Mixed_objective criterion is : ['Paris_HighwayStation', 'Lyon_HighwayStation', 'Milano_Port',
'Milano_HighwayStation']
```



- Best path is drawn in dark blue.
- 3rd more expensive path in light blue.

CONCLUSION

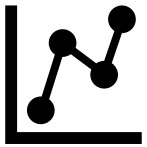
Proof-of-concept of path optimization 



Considering various parameters and multimodal transport systems throughout a weighted network

Best path with all information along the trip 

3 next best alternatives to ensure a complete solution

For larger dataset, a more robust A* algorithm should be more suitable 

The best solutions…

… for your multimodal transport trip