Door-to-door Travel Time Analysis from Paris to London and Amsterdam using Uber Data

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***Abstract*—SESAR Flightpath 2050 sets some ambitious goals for air travel, specifically regarding door-to-door travel times. Using Uber data, a reliable estimation of door-to-door travel times is possible which then enables a comparison of different travel modes such as rail and air. This model of the full door-to-door travel time for multi modal trips can also be used to evaluate where Europe stands with respect to SESAR's goals and how they should try to address the related difficulties.**

***Keywords*—Door-to-door travel times, Big Data, Multi-modal travel**

I. Introduction

Seamless door-to-door travel and data sharing was deemed as needed by the European Commission's 2011 White Paper [1]. Data sharing was already a main focus in the early 2000s and led at an air system level to the creation of the architecture SWIM - System Wide Information Management [2]. SESAR Flightpath 2050 [3] aims to take a more passenger-centric approach and sets some ambitious goals, including some that are not measurable yet due to lack of available data. Regarding door-to-door travel times, it aims at having 90% of travellers within Europe being able to complete their door-to-door journey within 4 hours. The shift from flight-centric information to passenger-centric metrics was first explored by Cook et al. [4] within the project POEM - Passenger Oriented Enhanced Metrics.

In the United States, Marzuoli et al. [5] presented a method to detect domestic air passengers on a nationwide scale using mobile phone data, enabling a per leg analysis of the full door-to-door trip though the main focus was on passengers' behavior at airports. The passengers' experience in airports under major perturbations using this method and additional data from social media was further studied in [6]. In Europe, within the BigData4ATM project[1], García-Albertos et al. [7] presented a methodology for measuring the door-to-door travel time using mobile phone data and applied it between two Spanish cities, Madrid and Barcelona. Mobile phone data is however proprietary data and difficult to access for research.

Sun et al. [8] implemented a door-to-door minimum travel time estimation based on open source maps and datasets in order to study the possible competitiveness of air taxis. This study is also based on readily available online data but aims in creating a method to measure the actual average door-to-door travel time once the trips are over enabling an analysis and comparison of the different modes. This method is here applied to two different European trips: from Paris to London and from Paris to Amsterdam.

This paper is organized as follows: Section II presents the model and data used to evaluate the full door-to-door journey time. Section III showcases some use cases of this model and Section IV concludes this paper and discusses further research directions.

[1] www.bigdata4atm.eu

II. Model

Similarly to [7] and [8], the full door-to-door travel time can be decomposed into the five following times:

$$T = t_{\text{to}} + t_{\text{dep}} + t_{\text{in}} + t_{\text{arr}} + t_{\text{from}} \tag{1}$$

where

- t_{to} is the time needed to go from the start of the journey to the selected modal station (e.g. airport or train station)
- t_{dep} is the time spent waiting and going through security processes at the departure station
- t_{in} is the time actually spent in the main mode's vehicle
- t_{arr} is the time spent going through security processes at the arrival station
- t_{from} is the time needed to go from the arrival modal station to the end of the journey

The measurement and estimation of these different times are described in the upcoming subsections. This study limits its scope to the two following modes: by air and by rail. The rail mode is then further separated between the Eurostar and the other rail services.

A. Time to and from the modal stations

Uber, a ride-sharing service implanted in major urban areas on six continents, recently released anonymized travel times data for certain of these urban areas. This data consist of the average travel time between zones (e.g. census tracts) within the serviced area from all Uber rides aggregated over each considered day. Depending on the availability of data, five additional different periods are considered:

- Early Morning: from midnight to 7am
- Morning: from 7am to 10am
- Midday: from 10am to 4pm
- Afternoon: from 4pm to 7pm
- Evening: from 7pm to midnight

Before this data release, several studies were already conducted on the impact of Uber in urban transit. Hall et al. [9] studied the impact of Uber on the use of public transit system based on Uber's entry date in different cities and focused on whether Uber complemented or substituted public transit. Similarly Li et al. [10] concluded that on average Uber tends to decrease congestion in US urban areas where it was introduced. Wang and Mu [11] studied Uber's accessibility in Atlanta, US by using the average wait time for a ride as a proxy and concluded that the use of Uber was not associated to a specific social category. Uber rides being part of the road traffic flow, this study considers Uber's travel times as accurate proxies of the actual travel time by road (whether by car or by bus). The scope of this paper limits itself to road access and egress to the modal stations considered, though subway alternatives should be considered by using schedules and real time data for a more exhaustive analysis of these legs of multi-modal trips.

Data was gathered from Uber's Movement API[2] over the period of January 1st 2018 to March 31st 2018. Paris was divided into the IRIS zones used by INSEE for census, London into the Lower Super Outer Area (LSOA) division defined by the Greater London Authority, and Amsterdam into its official districts called *wijk*.

B. Time at the modal stations

For this study, the time spent at each modal station is considered to depend only on the mode and whether it is at boarding or unboarding process. Those times are based on the train stations websites for rail stations, and on the study of [5] for the time spent at airports. They are summarized in the following table:

TABLE I: TIME SPENT AT MODAL STATIONS

Mode	Time at departure	Time at arrival
Air	90 min	45 min
Rail	15 min	10 min
Eurostar	45 min	10 min

The difference between time spent at departure at a normal rail station and at the Eurostar station comes from the necessity of passport checking since the United Kingdom is not part of the Schengen passport-free area. Better estimates could be obtained using data gathered from GPS or mobile phone sources as well as WiFi beacons within airports.

[2]movement.uber.com

C. Time in main mode

For this study, it was assumed that the modes were on time and based on a weekly schedule. Future studies should consider using actual flight or train times, taking into account delays and perturbations. The Eurostar schedule was taken from its website[3] and is shown in Table II. The rail schedule between Paris and Amsterdam was based on a week's schedule from the month of July 2019 gathered using an online train booking service[4] and is summarized in Table III.

TABLE II: EUROSTAR WEEKLY SCHEDULE (LOCAL TIME) FROM PARIS TO LONDON

Mon	Tue	Wed	Thu	Fri	Sat	Sun	Paris	Lon.
x	x	x	x	x	x		07:13	08:32
x	x	x	x	x			07:43	09:00
					x	x	08:13	09:30
x					x		08:43	10:00
x	x	x	x	x	x	x	09:04	10:39
	x	x	x	x	x	x	10:13	11:30
x							10:13	11:43
x				x		x	10:43	12:09
x							11:13	12:39
	x	x	x	x	x		11:13	12:47
						x	11:28	13:09
x	x	x	x	x	x	x	12:13	13:30
x	x	x	x	x	x	x	13:13	14:39
						x	13:28	15:00
					x		14:13	15:39
x			x	x		x	14:43	16:02
x	x	x	x	x	x	x	15:13	16:39
						x	16:43	18:02
x	x	x	x	x	x		17:13	18:32
						x	17:43	19:00
x	x	x	x	x		x	18:13	19:39
	x	x	x				18:43	20:02
x	x	x	x	x	x	x	19:13	20:39
				x		x	19:43	21:09
x	x	x	x		x		20:13	21:49
				x		x	20:43	22:00
x	x	x	x	x		x	21:13	22:39

TABLE III: THALYS WEEKLY SCHEDULE (LOCAL TIME) FROM PARIS TO AMSTERDAM

Mon	Tue	Wed	Thu	Fri	Sat	Sun	Paris	Ams.
x	x	x	x	x			06:13	09:44
x	x	x	x	x	x		07:25	10:44
x	x	x	x	x	x	x	08:25	11:44
x	x	x	x	x	x	x	10:25	13:44
x	x	x	x	x			11:25	14:44
x	x	x	x	x			11:55	15:44
x	x	x	x	x			12:46	17:35
x	x	x	x	x			12:52	18:35
x	x	x	x	x			14:25	19:35
x	x	x	x	x	x		15:55	20:35
x	x	x	x	x	x	x	17:55	22:35
x	x	x	x	x	x		18:25	23:38
x	x	x	x	x			20:55	08:35
					x	x	12:25	15:44
					x	x	12:55	17:35
					x	x	14:25	17:44
					x		19:25	23:41
						x	16:25	19:44

[3]www.eurostar.com
[4]www.thetrainline.com

Similarly, the flight schedules from Paris Charles de Gaulle airport (CDG) to London Heathrow airport (LHR) and to Amsterdam Airport Schiphol (AMS) were extrapolated from the flight schedule of the third week of January 2019 gathered from CDG's website[5]. Both schedules can be found in Tables IV & V. Using the updated schedules with delays and cancellations would be a promising next step and easily integrated to this model.

TABLE IV: SIMULATED WEEKLY SCHEDULE FOR FLIGHTS BETWEEN CDG AND AMS (LOCAL TIME)

Mon	Tue	Wed	Thu	Fri	Sat	Sun	CDG	AMS
x	x	x	x	x	x	x	07:10	08:30
x	x	x	x	x		x	08:05	09:25
					x		08:15	09:35
	x		x				08:55	10:15
x		x		x	x	x	09:05	10:25
x	x	x	x	x			09:35	10:55
x	x	x	x	x	x	x	10:20	11:40
x	x	x	x	x	x	x	11:45	13:05
x	x	x	x	x	x	x	12:40	14:00
x	x	x	x	x	x	x	14:30	15:50
x	x	x	x	x		x	16:55	18:15
x	x	x	x	x	x	x	18:10	19:30
x	x	x	x	x	x	x	18:40	20:00
x	x	x	x	x	x	x	20:25	21:45

TABLE V: SIMULATED WEEKLY SCHEDULE FOR FLIGHTS BETWEEN CDG AND LHR (LOCAL TIME)

Mon	Tue	Wed	Thu	Fri	Sat	Sun	CDG	LHR
				x	x	x	07:15	07:40
x	x	x	x	x	x	x	07:20	07:45
	x						07:30	07:55
x		x	x				07:35	08:00
x	x	x	x	x	x	x	10:00	10:25
			x	x			10:20	10:45
x					x	x	10:25	10:50
	x	x					10:35	11:00
x		x		x	x	x	11:45	12:10
	x		x				11:50	12:15
x	x	x	x	x	x	x	13:20	13:45
	x		x			x	14:55	15:20
x		x					15:05	15:30
				x			15:20	15:45
x	x	x	x	x	x		16:10	16:35
x	x	x	x	x	x	x	16:15	16:40
x	x	x	x	x	x	x	18:05	18:30
x	x	x	x	x		x	20:35	21:00
x	x	x	x	x	x	x	21:20	21:45

D. Full door-to-door time

For this study, it was assumed that the main mode of transport would leave on time and that travellers planned their departure time to arrive at the departure station exactly t_{dep} minutes before the scheduled departure time. This assumption is necessary to determine which period of the day to consider when retrieving the Uber average time between the initial zone and the departure station to determine t_{to}. For days and zones where only daily aggregates were available in the Uber data, the daily aggregated times were used for each period of the day as a proxy. The same process was implemented to select the value of t_{from}.

[5]https://www.parisaeroport.fr

III. APPLICATIONS

A. Modal comparison

Using this model and the available data makes it possible to analyze at what time of the day it is usually best to start the journey from Paris. This analysis enables an easy hourly modal comparison as well. As an example, this study considers the case of a tourist visiting the Eiffel Tower in Paris and having to go back to London or Amsterdam directly from there. Travel times for each scheduled flight and each scheduled train were extracted for the period of January to March 2018.

1) From Paris to London: Fig. 1 shows the hourly boxplots of the full door-to-door travel time for a Londoner using either the Eurostar train or flying from CDG to LHR. The four hour goal is marked in red. A first observation is that this time goal is for the moment reached only by taking the train, even though most of London's LSOAs are not reachable within that time limit. Regarding the train, there are only two hours in the day that fare poorly compared to the otherwise constant behavior of this mode: the 9am rush and at 4pm, just before the closing of businesses.

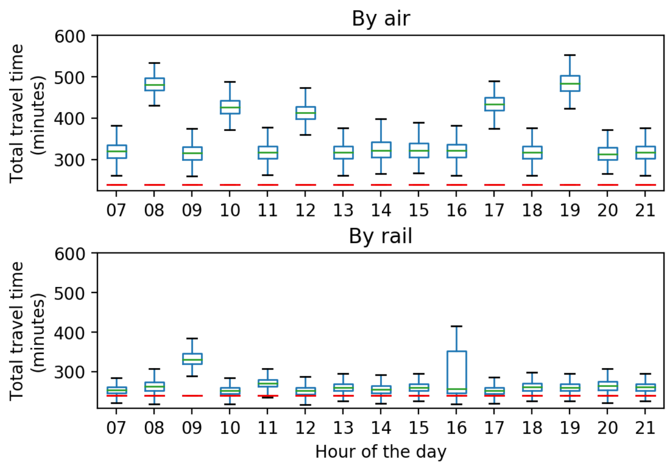

Figure 1: Hourly boxplots of door-to-door travel times to London starting from the Eiffel Tower in Paris. The top figure shows the boxplot related to air travel, the bottom figure the ones related to train travel.

Fig. 2 shows the boxplots per day of the week of these full door-to-door travel time along with the four hour goal mark. Regarding this time limit, it is achieved every day of the week via train for some areas of London. These boxplots also indicate that the best days to travel to London from the center of Paris are not the same depending on the chosen mode. When taking the plane, it is best to fly on Saturdays and Sundays, while it is best to take the train on Mondays, Tuesdays and Saturdays.

Using this model, it also possible to determine which zones in the destination city can be most easily reached depending on the chosen mode. Fig. 3 shows which zones were reached using Uber rides from the train station on January 8, 2018 at

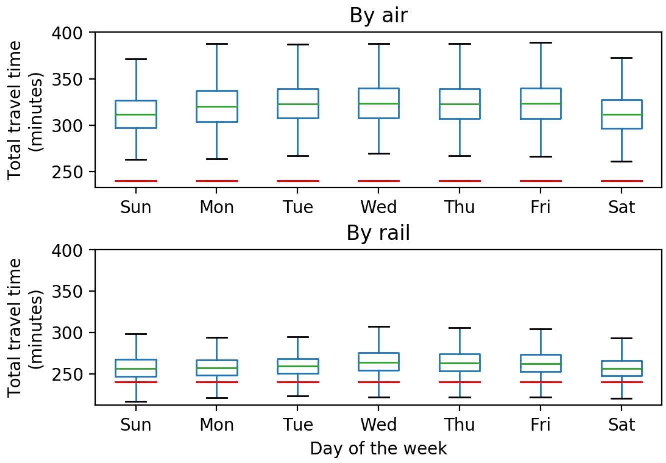

Figure 2: Day-of-week boxplots of door-to-door travel times to London starting from the Eiffel Tower in Paris. The top figure shows the boxplot related to air travel, the bottom figure the ones related to train travel.

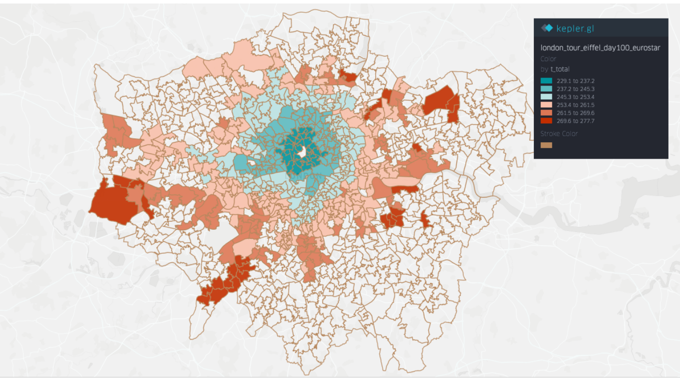

Figure 3: Door-to-door travel times to London starting from the Eiffel Tower in Paris using the Eurostar train

18:00, these zones being colored based on the full door-to-door travel time needed from the Eiffel Tower. Fig. 4 shows the same map for air travelers on January 12, 2018 at 13:15 but with a different color scaling. The LSOAs colored with the

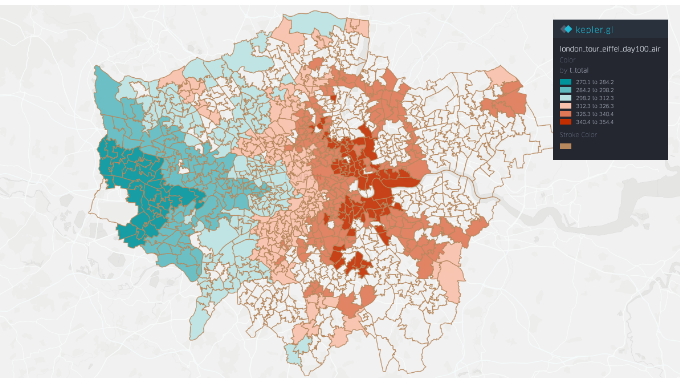

Figure 4: Door-to-door travel times to London starting from the Eiffel Tower in Paris by plane via CDG and LHR

two darker greens are the zones reachable in four hours or less in the Eurostar case (Fig. 3), which corresponds to the center of London. By plane, the fastest time is 4h30 for the surrounding of the airport, while reaching the center of London takes around five hours.

2) From Paris to Amsterdam: Fig. 5 shows the hourly box-plots of the full door-to-door travel time for a Amsterdamer using either the train or flying from CDG to AMS. A first observation is that the four hour limit is not reached by either mode. Taking the train brings you closer to this goal than taking the plane in the morning, except at rush hour 9am. In the afternoon it is fastest to take the plane, except for those who prefer night trains in order to arrive early in the morning of the next day.

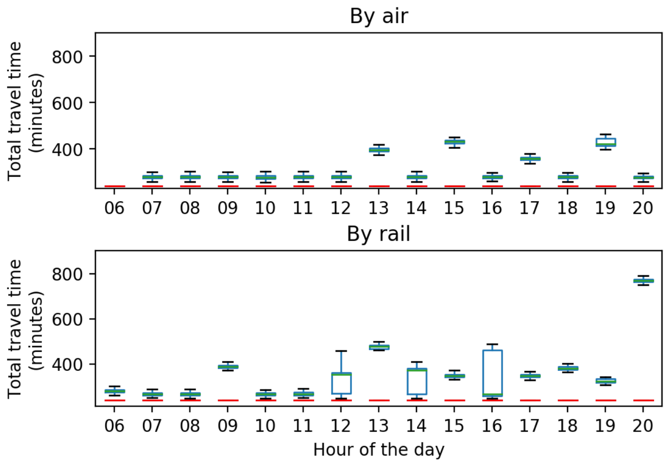

Figure 5: Hourly boxplots of door-to-door travel times to Amsterdam starting from the Eiffel Tower in Paris. The top figure shows the boxplot related to air travel, the bottom figure the ones related to train travel.

Fig. 6 shows the boxplots per day of the week of these full door-to-door travel time along with the four hour goal mark. There is a striking contrast between taking the plane and taking

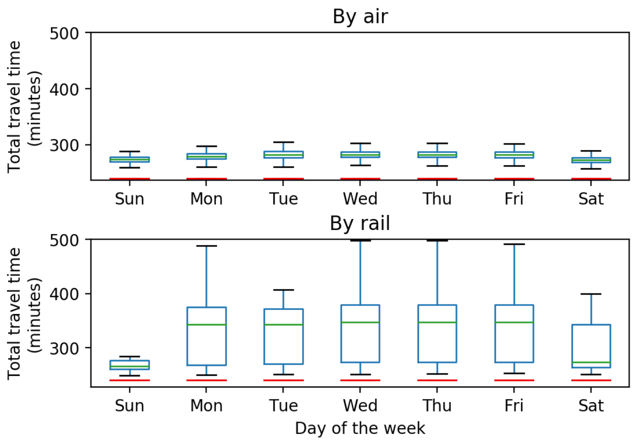

Figure 6: Day-of-week boxplots of door-to-door travel times to Amsterdam starting from the Eiffel Tower in Paris. The top figure shows the boxplot related to air travel, the bottom figure the ones related to train travel.

the train shown in these boxplots: While the full door-to-door travel time distribution is nearly constant by plane, there is a major difference between traveling by rail during weekdays and on the weekend: the median traveling time on weekdays is higher by around ninety minutes than on weekends.

Fig. 7 shows which zones were reached using Uber rides from the train station on January 11, 2018 at 17:50, these zones being colored based on the full door-to-door travel time needed from the Eiffel Tower. Fig. 8 shows the same map for air travelers on January 11, 2018 at 08:00 but with a different color scaling. For these dates, taking the plane is faster than the train for every considered *wijk*.

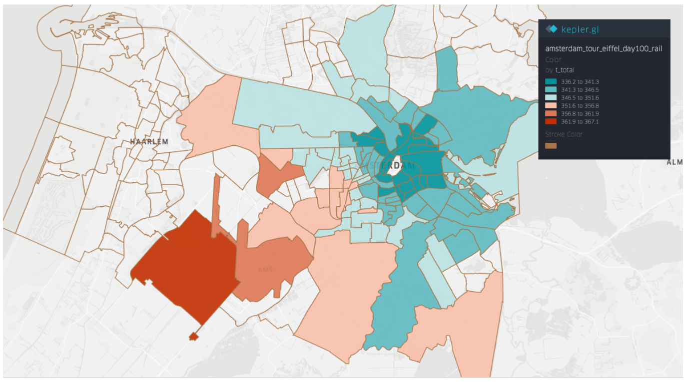

Figure 7: Door-to-door travel times to Amsterdam starting from the Eiffel Tower in Paris using the train

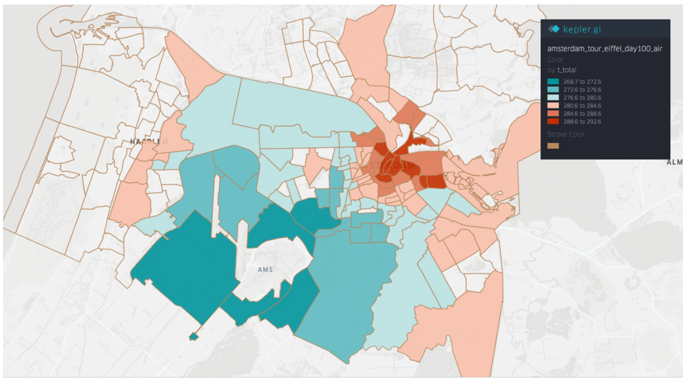

Figure 8: Door-to-door travel times to Amsterdam starting from the Eiffel Tower in Paris by plane via CDG and AMS

B. SESAR Flightpath 2050 objectives

With the Flightpath 2050 in mind, this model can also be used to assess on which phase of air travels improvements should be made, assuming the 4 hour door-to-door travel time limit is to be achieved by means of air transportation. The following analysis could be similarly conducted to assess rail transportation system. Fig. 9 shows the boxplots of the time spent in the different segments using air and rail in order to reach to London assuming the traveler is leaving from the Eiffel Tower area. It is to be noted that the time spent leaving the airport has a greater variation than the time going to the airport due to the fact that the starting zone is fixed (the Eiffel Tower area) whereas all zones reached by Uber rides from the arriving airport are considered. By rail, the traveler spends the most time in the train, whereas an air traveler spends more time waiting at the departure airport than in flight and can spend more time reaching its destination in London than in any other segment. Improving airports processes at departure and thus decreasing the time spent within the departure airport could be a first step in reaching the 4 hour goal.

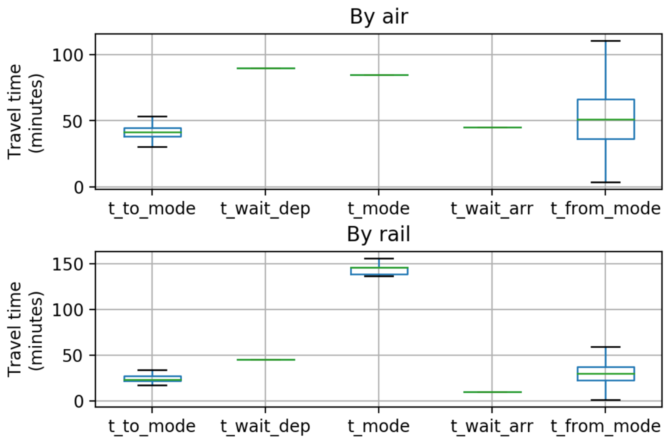

Figure 9: Travel time boxplots for the different phases of travel to London starting from the Eiffel Tower in Paris. The top figure shows the boxplot related to air travel, the bottom figure the ones related to train travel.

Fig. 10 shows the boxplots of the time spent in the different segments using air and rail in order to reach to Amsterdam assuming the traveler is leaving from the Eiffel Tower area. Unlike the trip to London, the air traveler spends less time leaving the airport than for any other phase. The 90 minute wait time at the departure airport is here again the most consuming. Regarding rail travels, the time spent in the train is dominant compared to any other travel phase and needs to be addressed if the 4 hour limit is to be applied to rail transit as well.

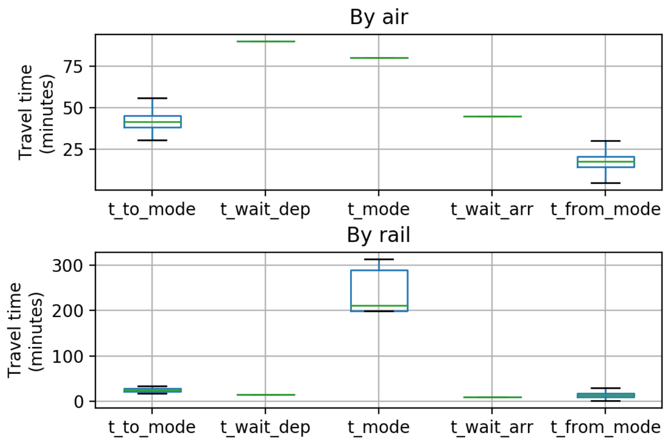

Figure 10: Travel time boxplots for the different phases of travel to Amsterdam starting from the Eiffel Tower in Paris. The top figure shows the boxplot related to air travel, the bottom figure the ones related to train travel.

This model has assumed fixed wait times at airports based on a recent study [5], yet these times can be modified in order to assess the impact of improving the airport's processing of passengers. The following examples assumes that the wait time at arrival drops at an average of thirty minutes and investigates the drop necessary in the processing time at the departure airport. Fig. 11 shows the hourly boxplots of the full door-to-door travel time for a Londoner flying from CDG to LHR using three different wait times at the departure airport: 30, 60 and 90 minutes. Clearly dropping only the processing time at arrival is not enough for this trip. Reducing the processing time at the departure airport to 30 or 60 minutes enables to reach some zones in London in less than 4 hours, but never the totality. And for five rush hours (8am, 10am, noon, 5pm and 7pm), these drops are not enough to reach any of London's LSOA in less than 4 hours.

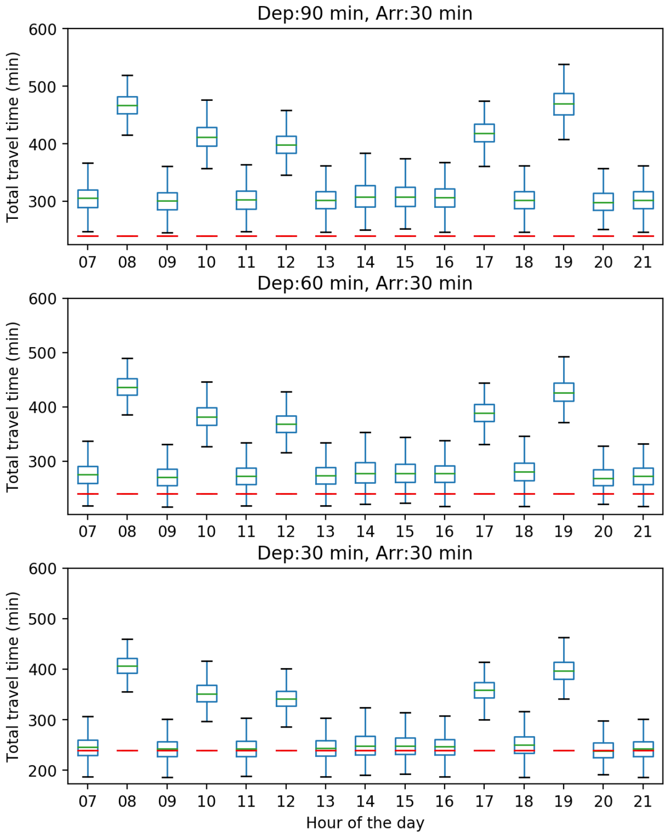

Figure 11: Hourly boxplots of door-to-door air travel times to London starting from the Eiffel Tower in Paris for varying wait times at the departing airport

Fig. 12 shows the hourly boxplots of the full door-to-door travel time for a Amsterdamer flying from CDG to AMS using the same three different wait times at the departure airport. As for London, only reducing the arrival processing time is not enough to reach the 4 hour time limit. However, reducing the processing time at the departure airport to an hour is enough to reach most of Amsterdam's *wijken* with the exception of four rush hours (1pm, 3pm, 5pm and 7pm). Decreasing further the processing time to half an hour ensures that the 4 hour limit is reached for the quasi majority of *wijken*, with the exception of the same four rush hours. This first study indicates that reducing the processing time at airports is a necessary step to achieve the Flightpath 2050 goal, however it is not sufficient: access to and from the airports has to be improved since rush hours can jeopardise the overall achievement of this 4 hour limit. It is to be noted that the effect of these rush hours could be mitigated by the use of other types of access modes such as the subway.

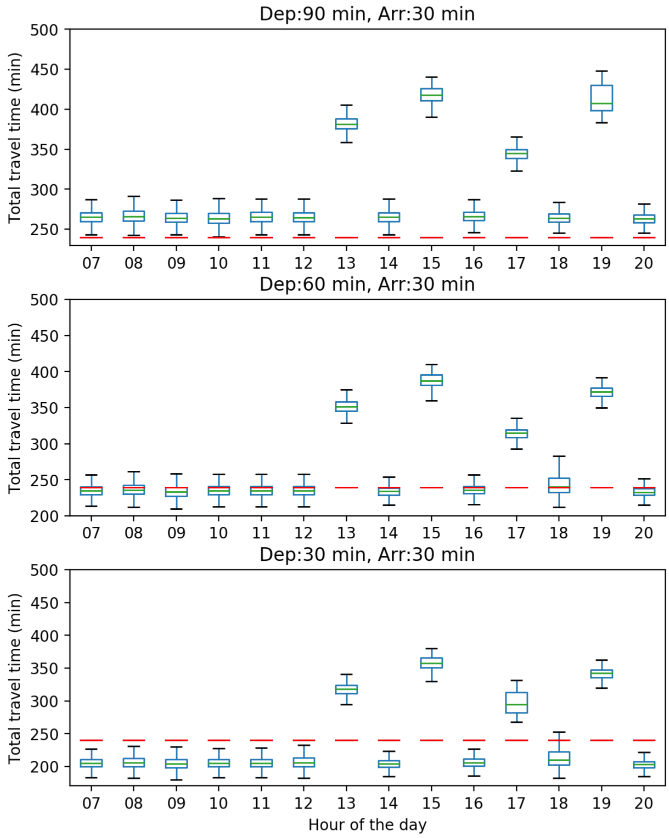

Figure 12: Hourly boxplots of door-to-door air travel times to Amsterdam starting from the Eiffel Tower in Paris for varying wait times at the departing airport

IV. Conclusion

This paper leveraged Uber's recently released data in order to create a model of the full door-to-door travel time between two pairs of European cities using either the train or the plane. It could however be implemented for any world city pairs with available ride-sharing or taxi data. This model enables the comparison of the different traveling modes between two cities on at least two different levels: a first approach is to compare the time spent in the different phases of the trip, while a second approach assumes the existence of a time limit and compares the reach of each considered mode. This model also has two additional benefits with respect to SESAR's Flightpath 2050: it can be used both to evaluate where Europe stands regarding its objectives as well as which directions to consider in order to reach these goals.

Further studies should consider using actual schedules of the different modes when evaluating the full door-to-door travel time, as well as alternative modes to reach the airport or train stations such as the subway. Additionally, knowing the daily proportion of travellers using the different approaches would enable a single daily evaluation of the full door-to-door travel time. A possible method to determine this proportion would be by using aggregated information from GPS or mobile phone sources.

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REFERENCES

[1] E. Commission, *White Paper: Roadmap to a Single European Transport Area - Towards a Competitive and Resource Efficient Transport System*, Brussels, Mar. 2011.

[2] J. Meserole and J. Moore, "What is System Wide Information Management (SWIM)?" in *2006 IEEE/AIAA 25TH Digital Avionics Systems Conference*. Portland, OR, USA: IEEE, Oct. 2006, pp. 1–8.

[3] E. Commission, Ed., *Flightpath 2050: Europe's Vision for Aviation ; Maintaining Global Leadership and Serving Society's Needs ; Report of the High-Level Group on Aviation Research*, ser. Policy / European Commission. Luxembourg: Publ. Off. of the Europ. Union, 2011, oCLC: 930887434.

[4] A. Cook, G. Tanner, S. Cristóbal, and M. Zanin, "Passenger-Oriented Enhanced Metrics," p. 8, 2012.

[5] A. Marzuoli, E. Boidot, E. Feron, and A. Srivastava, "Implementing and validating air passenger-centric metrics using mobile phone data," *Journal of Aerospace Information Systems*, 2018.

[6] A. Marzuoli, P. Monmousseau, and E. Feron, "Passenger-centric metrics for Air Transportation leveraging mobile phone and Twitter data," in *Data-Driven Intelligent Transportation Workshop - IEEE International Conference on Data Mining 2018*, Singapore, Nov. 2018.

[7] P. García-Albertos, O. G. C. Ros, and C. Ciruelos, "Understanding Door-to-Door Travel Times from Opportunistically Collected Mobile Phone Records," p. 8, 2017.

[8] X. Sun, S. Wandelt, and E. Stumpf, "Competitiveness of on-demand air taxis regarding door-to-door travel time: A race through Europe," *Transportation Research Part E: Logistics and Transportation Review*, vol. 119, pp. 1–18, Nov. 2018.

[9] J. D. Hall, C. Palsson, and J. Price, "Is Uber a substitute or complement for public transit?" *Journal of Urban Economics*, vol. 108, pp. 36–50, Nov. 2018.

[10] Z. Li, Y. Hong, and Z. Zhang, "Do On-demand Ride-sharing Services Affect Traffic Congestion? Evidence from Uber Entry," p. 35, 2016.

[11] M. Wang and L. Mu, "Spatial disparities of Uber accessibility: An exploratory analysis in Atlanta, USA," *Computers, Environment and Urban Systems*, vol. 67, pp. 169–175, Jan. 2018.