work/study commute patterns, some groups make their trips earlier or are more regular than others, while other passengers have more diffuse activities, leading to a three-peak pattern. Even so, these latter passengers still exhibit a morning activity peak, particularly for the cluster with the greatest number of cards. Analyzing the evolution of cluster assignments of the same card over a period of multiple years reveals that even if some changes in the cluster emerge over the years, the clusters seem to maintain the same proportion of cards, and the majority of cards that move from clusters, move to clusters with temporal profiles that are similar to their original clusters.

2. A proposed solution for analysis of transport habits of the residents of the "Manastirski Livadi" neighborhood in Sofia

Our approach takes place in the field of public transport and focuses on mobility behavior using data collected through a GSM network provider. The data is anonymized and statistically summarized by him according to an algorithm developed by us.

For the purposes of this simulation, we obtained data that has the following structure:

- date
- sequence number of a period of one hour between 0:00 and 24:00
- location 1 - departure area (described with GPS coordinates)
- location 2 - arrival area (described with GPS coordinates)
- number of passengers who departed from location 1 and arrived at location 2 where they stayed for at least one hour

Thus, our proposed data collection algorithm allows us to obtain information on all realized trips between our chosen urban area and the rest of the city on an hourly basis. A cloud-based relational dimensional model is built for the analysis of this big data. Microsoft's cloud services are used for this purpose. The results of computer simulations are visualized with Power BI.

The relational scheme used for the purposes of cloud-based simulations of urban trips to and from „Manastirski livadi“ neighborhood in shown in fig. 6.

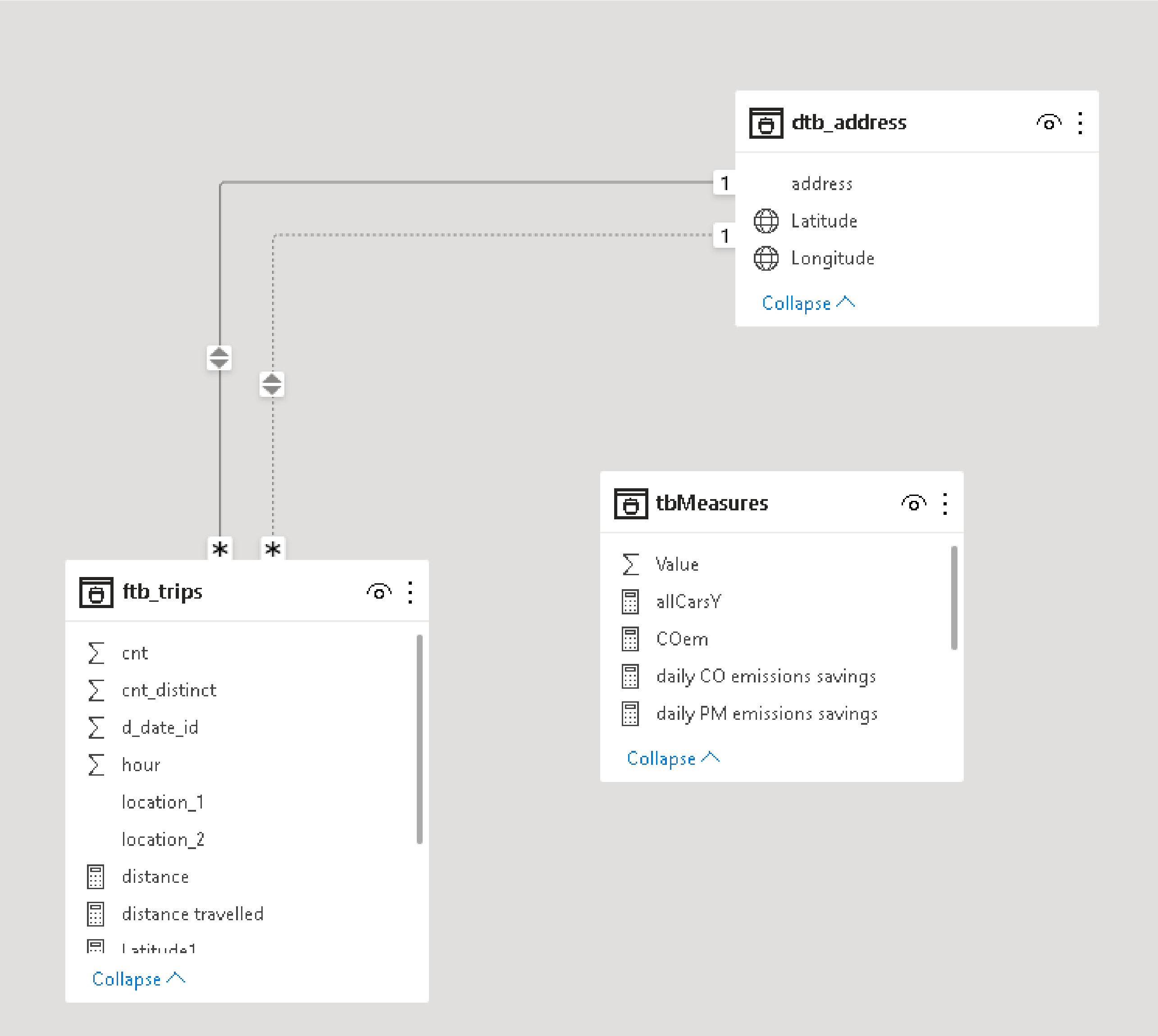
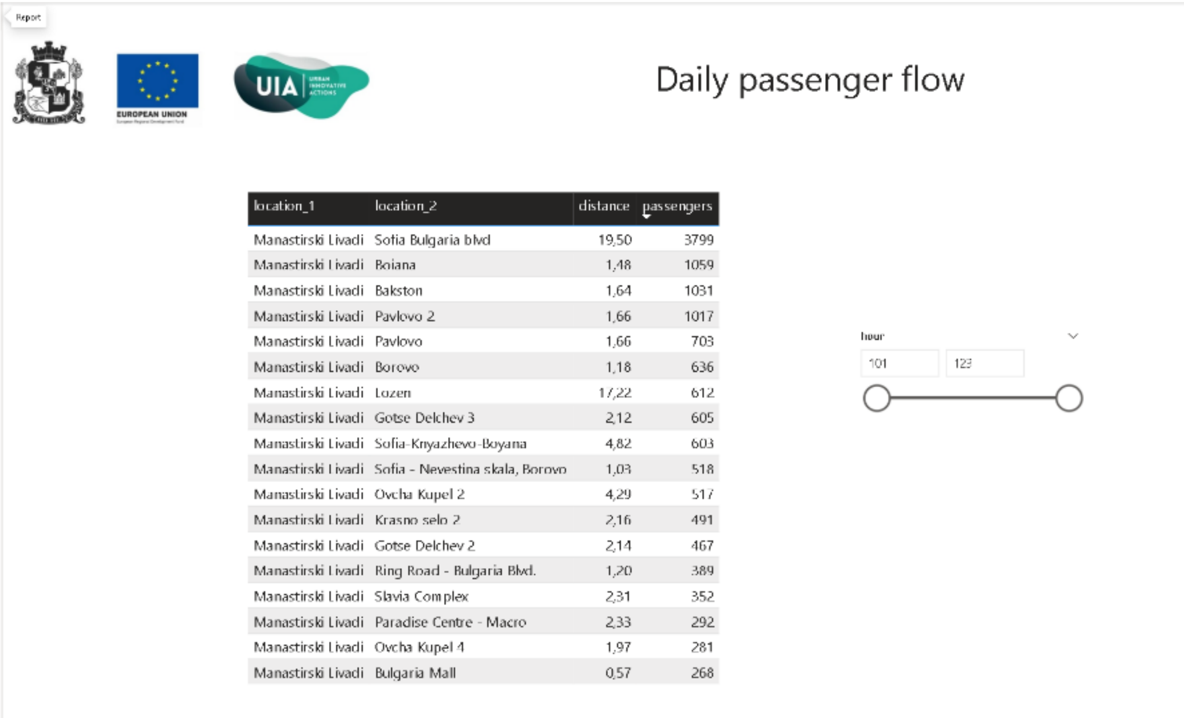


Fig. 6 Relational scheme used for the purposes of cloud-based simulations of urban trips to and from „Manastirski livadi" district

3. Self-service analytical reports

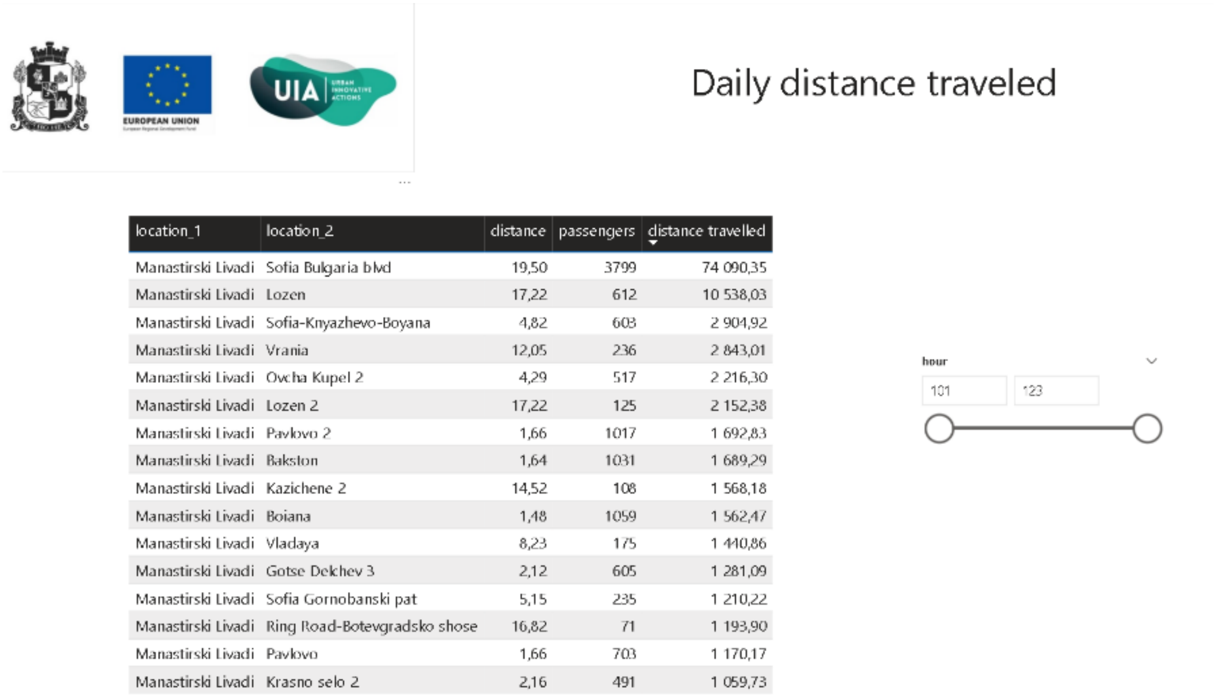
A series of calculated indicators (measures) are programmed for simulation purposes.

With Power BI tools, number of self-service analytical reports were created, which are shown in fig. 7 and fig. 8.



location_1	location_2	distance	passengers
Manastirski Livadi	Sofia Bulgaria blvd	19,50	3799
Manastirski Livadi	Boiana	1,48	1059
Manastirski Livadi	Bakston	1,64	1031
Manastirski Livadi	Pavlovo 2	1,66	1017
Manastirski Livadi	Pavlovo	1,66	703
Manastirski Livadi	Borovo	1,18	636
Manastirski Livadi	Lozen	17,22	612
Manastirski Livadi	Gotse Delchev 3	2,12	605
Manastirski Livadi	Sofia-Knyazhevo-Boyana	4,82	603
Manastirski Livadi	Sofia - Nevestina skala, Borovo	1,03	518
Manastirski Livadi	Ovcha Kupel 2	4,29	517
Manastirski Livadi	Krasno selo 2	2,16	491
Manastirski Livadi	Gotse Delchev 2	2,14	467
Manastirski Livadi	Ring Road - Bulgaria Blvd.	1,20	389
Manastirski Livadi	Slavia Complex	2,31	352
Manastirski Livadi	Paradise Centre - Macro	2,33	292
Manastirski Livadi	Ovcha Kupel 4	1,97	281
Manastirski Livadi	Bulgaria Mall	0,57	268

Fig. 7 Cloud-based self-service analytical report for daily passenger flow from „Manastirski livadi“ district



location_1	location_2	distance	passengers	distance travelled
Manastirski Livadi	Sofia Bulgaria blvd	19,50	3799	74 090,35
Manastirski Livadi	Lozen	17,22	612	10 538,03
Manastirski Livadi	Sofia-Knyazhevo-Boyana	4,82	603	2 904,92
Manastirski Livadi	Vrania	12,05	236	2 843,01
Manastirski Livadi	Ovcha Kupel 2	4,29	517	2 216,30
Manastirski Livadi	Lozen 2	17,22	125	2 152,38
Manastirski Livadi	Pavlovo 2	1,66	1017	1 692,83
Manastirski Livadi	Bakston	1,64	1031	1 689,29
Manastirski Livadi	Kazichene 2	14,52	108	1 568,18
Manastirski Livadi	Boiana	1,48	1059	1 562,47
Manastirski Livadi	Vladaya	8,23	175	1 440,86
Manastirski Livadi	Gotse Delchev 3	2,12	605	1 281,09
Manastirski Livadi	Sofia Gornobanski pat	5,15	235	1 210,22
Manastirski Livadi	Ring Road-Botevgradsko shose	16,82	71	1 193,90
Manastirski Livadi	Pavlovo	1,66	703	1 170,17
Manastirski Livadi	Krasno selo 2	2,16	491	1 059,73

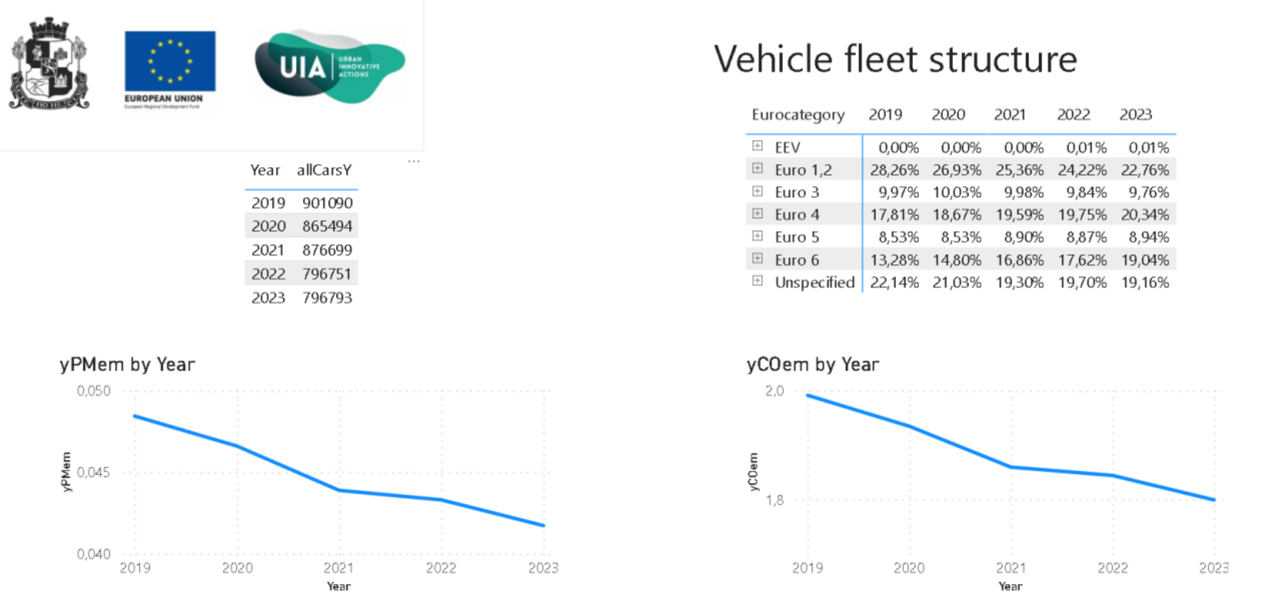
Fig. 8 Cloud-based self-service analytical report for daily distance traveled

Conclusion

With the help of analytical geometry and vector mathematics, an answer was given to the question ***in which direction*** a structure changes. The obtained results were used to analyze changes in the structure of the passenger cars from 2019 to 2022. A forecast was made for the structure of the passenger cars in 2023. The relative frequencies of the predicted structure were used as weights in the weighted averaging of carbon monoxide and particulates emissions. In this way, the estimated pollution of an average car in 2023 was obtained.

Based on the big data provided to us by a GSM network connectivity provider about their customers' mobility was modeled and analyzed transport habits of the residents of the "Manastirski Livadi" region in Sofia.

On this basis, two cloud-based simulation was created that allows us to measure the effects of the introduction of green urban transport. (Fig. 9 and Fig. 10)



Year	allCarsY
2019	901090
2020	865494
2021	876699
2022	796751
2023	796793

Eurocategory	2019	2020	2021	2022	2023
EEV	0,00%	0,00%	0,00%	0,01%	0,01%
Euro 1,2	28,26%	26,93%	25,36%	24,22%	22,76%
Euro 3	9,97%	10,03%	9,98%	9,84%	9,76%
Euro 4	17,81%	18,67%	19,59%	19,75%	20,34%
Euro 5	8,53%	8,53%	8,90%	8,87%	8,94%
Euro 6	13,28%	14,80%	16,86%	17,62%	19,04%
Unspecified	22,14%	21,03%	19,30%	19,70%	19,16%

Average amount of CO emissions for one kilometer for the Sofia-specific structure of the car fleet.

Average amount of PM emissions for one kilometer for the Sofia-specific structure of the car fleet.

The data for the year 2023 are estimated by the model we propose.

Fig. 9 cloud-based simulation for predicted average amount of CO emissions for one kilometer for the Sofia-specific structure of the car fleet and predicted Average amount of PM emissions for one kilometer for the Sofia-specific structure of the car fleet.

Expected emissions savings from the introduction of green urban transport

Year: 2019 | 2020 | 2021 | 2022 | **2023**

public transport trips %: (●) 10,00% ( ) 30,00% ( ) 50,00% ( ) 70,00%

location_1	location_2	distance	passengers	distance travelled	daily CO emissions savings	daily PM emissions savings
Manastirski Livadi	Sofia Bulgaria blvd	19,50	3799	74 090,35	13 330,29	309,19
Manastirski Livadi	Lozen	17,22	612	10 538,03	1 896,00	43,98
Manastirski Livadi	Sofia-Knyazhevo-Boyana	4,82	603	2 904,92	522,65	12,12
Manastirski Livadi	Vrania	12,05	236	2 843,01	511,51	11,86
Manastirski Livadi	Ovcha Kupel 2	4,29	517	2 216,30	398,75	9,25
Manastirski Livadi	Lozen 2	17,22	125	2 152,38	387,25	8,98
Manastirski Livadi	Pavlovo 2	1,66	1017	1 692,83	304,57	7,06
Manastirski Livadi	Bakston	1,64	1031	1 689,29	303,94	7,05
Manastirski Livadi	Kazichene 2	14,52	108	1 568,18	282,15	6,54
Manastirski Livadi	Boiana	1,48	1059	1 562,47	281,12	6,52
Manastirski Livadi	Vladaya	8,23	175	1 440,86	259,24	6,01
Manastirski Livadi	Gotse Delchev 3	2,12	605	1 281,09	230,49	5,35
Manastirski Livadi	Sofia Gornobanski pat	5,15	235	1 210,22	217,74	5,05
Manastirski Livadi	Ring Road-Botevgradsko shose	16,82	71	1 193,90	214,81	4,98
Manastirski Livadi	Pavlovo	1,66	703	1 170,17	210,54	4,88
Manastirski Livadi	Krasno selo 2	2,16	491	1 059,73	190,67	4,42

10,00%
Average of public transport trips %

The data for the year 2023 are estimated by the model we propose.

Fig. 10 Cloud-based simulation for expected emissions savings from the introduction of green urban transport.

With Power BI tools, number of self-service analytical reports were created, which are shown in fig. 7 and fig. 8.

Cloud-based simulations are accessible with a username and password online :

URL: POWER BI APP

- **UserID**: InnoAir@office365faculty.uni-sofia.bg
- **Password**: CloudSimulation5.5.1

References:

Anne-Sarah Briand, Etienne Côme, Martin Trépanier, Latifa Oukhellou, Analyzing year-to-year changes in public transport passenger behaviour using smart card data, Transportation Research Part C: Emerging Technologies, Volume 79, 2017, Pages 274-289,ISSN 0968-090X, https://doi.org/10.1016/j.trc.2017.03.021

Érika Martins Silva Ramos, Cecilia Jakobsson Bergstad, Jonas Nässén, Understanding daily car use: Driving habits, motives, attitudes, and norms across trip purposes, Transportation Research Part F: Traffic Psychology and Behaviour, Volume 68,2020,Pages 306-315,ISSN 1369-8478,https://doi.org/10.1016/j.trf.2019.11.013

Gatev, K., D. Koseva, A. Spasov. (1991) General Theory of Statistics. Sofia: Science and Art. (in Bulgarian)

Kirkorov, I., K. Bonev, E. Petkov. (1974) Higher Mathematics. Sofia: Science and Art. (in Bulgarian)

Hristov, E. (1993) Measures of Structural Change and Their Effects in Demographic Analysis. Population, No. 3 (in Bulgarian)

Hristov, E. (1999) Measures of Generalized Structural Differences (Changes). Statistics, No. 2 (in Bulgarian)

Hristov, E. (2000) Effects of Changes in the Elderly Mortality Rate and the Age Structure of the Population on the Change in Gross Mortality (Methodological Decisions and Empirical Analysis). Population, Anniversary issue "10 Years Population" (in Bulgarian)

Hristov, E. (2001) Generalized Measures of Basic Types of Structural Differences in Economic and Social Research. Statistics, No. 6 (in Bulgarian)

Rachel Cardell-Oliver, Doina Olaru, CIAM: A data-driven approach for classifying long-term engagement of public transport riders at multiple temporal scales, Transportation Research Part A: Policy and Practice, Volume 165,2022, Pages 321-336,ISSN 0965-8564, https://doi.org/10.1016/j.tra.2022.09.002

Yankova, N. (2001a) Research of the Development of the Age Structure of the Population in Bulgaria for the Period 1920-1999. Statistics, No. 5 (in Bulgarian)

Yankova, N. (2001b) Comparative Analysis of Generalized Measures of Structural Changes (Differences). Statistics, No. 2 (in Bulgarian)