Innovations in European Smart Transportation using Geospatial Information System

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Abstract

The smart cities necessitate the advanced operational information and communication technology to share and improve efficiency with the nation. The datasets of high traffic roads were examined for 4 different European Countries namely Germany, Greece, Turkey, and Romania for this study. Moreover, the study involves the identifying the busy traffic time on the roads and identifies the solution of following the other routes enabling the commuter to reach the destination on time. This is carried out with deep learning techniques in GIS environment using ArcGIS to identify the different route-finding scenario. The Dijkstra’s algorithm is best suited for this routing model. This study revolves around multimodal transport planning within smart cities for smart traffic flow for smart living. A case study of Greece street roads was considered; the linear regression model was implemented for the datasets. The obtained p > |t| for average speed is Stratigou Makrigianni (0.906), Agias Annis (0.754), Mystra (0.675), and Komvos Ag.loanni Renti (0.470). The study reflects the traffic congestion on four European Countries with best roads and national highways in the world. However, the traffic in these countries seems to be heavy during the peak hours or unusual hours. With GIS, one can trace the traffic routes and also take proper decision to avoid the traffic, and move toward the destination with different paths. This approach will help the closeby places to be free from the pollution.

1. Introduction

According to Sun (2012), congestion alleviates urban traffic congestion. Wang (2018) suggests traffic congestion index reveals the traffic flow and Verhoef (1999), the vehicle speed differences. Zhu (2022) developed the traffic optimization decision system for solving the problem of traffic congestion. Wang (2013), the road characteristics such as speed, congestion, and road horizontal curvature were considered to be the reason for the road accidents. Moreover, identifying weather characteristics such as visibility, wind speed and temperature, Theofilatos (2014) & Othman (2007), along with the approach of the Post- and Pre-accident analysis on the traffic safety were an issue.

Santos (2010), remarks the sustainable road transport includes car-sharing and pooling, teleworking and teleshopping, eco-driving. Similarly, Pompigna (2022), Singh (2022), Dzemydienė (2021), and Borecka (2021) explores the multimodal smart systems that include railway and roadway which create a solution for travel. Kramarz (2021), the sustainable increased utilization, of multimodal transport and transit systems promotes socio-economic growth, demographic, spatial-activity pattern and global trade Taghvaee (2022) & Mishra (2012).

The significant time dependence between univariate time series historical data is analyzed by the statistical methods for such as supervised Naïve Bayes estimator, Zuev (2005); ARIMA and Kalman filtering, for short-term traffic flow prediction models, Zuev (2005). However, the prediction accuracy is influenced effortlessly by the unstable traffic state. The intelligent transportation policies and systems, minimizing environmental impact for a net zero future, Zhou (2021).

2. Discussion and Results

In this study of smart cities, the real-time data from four different European Countries Viz. Germany, Greece, Romania and Turkey were collected where the traffic is very high and then mapped accordingly. The data mapping is performed on ARCGIS (https://www.esri.com) and results are shown in figure 1. The smart city provides the present smart living style for very developed countries and addresses the various issues related to the traffic and reaching the destination on time.

Usually, on the cloudy, foggy and rainy day, the traffic is very high at the peak hour blocking all the roads. This creates heavy blockage of the vehicles on the roads and do not let any movement of vehicles. It creates unusual higher blood pressure, high chronic stress, and increases vehicle emissions, overheating of vehicles and is unable to reach train or airport, unable to reach the hospital appointment time and so on. Sometimes, it takes hours to clear the blockage. Hence, finding a solution to avoid the blockage. Let’s address the problem of blockage of vehicles on the roads:

1. Inspite of the wide road, the increasing traffic is causing the congestion. Hence, applying different lanes for different speeds of the vehicle may perhaps avoid the traffic congestion.
2. Identify the peak hours, when the traffic is actually high.
3. Identify the type of transportation used at the peak hour, possibly replace it with the multimodal.
4. Calculate the travel time for each vehicle.
5. Identify the alternate route for the vehicles to reach the destination using GIS.

6. To estimate the air pollutants in the atmosphere during the heavy traffic.

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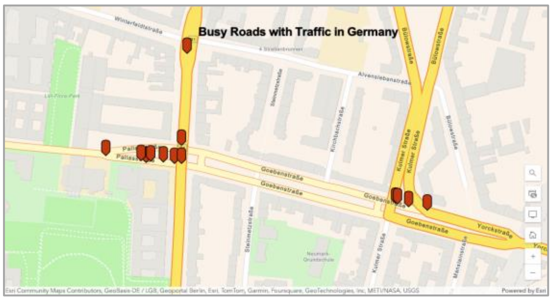


a. Germany

b. Greece

c. Turkey

d. Romania

Figure 1. The heavy traffic mapping in four European roads

Figure 2a. Attiki Odos Airport Entrance Interchange, Greece

Figure 2b. Transfagarasan Highway, Romania

Figure 3a. Intersection of E42 and E451, Frankfurt Airport, Germany

Considering figures 2 & 3, one can view the world’s most beautiful roads in this four different countries. Transfagarasan is known for the famous mountain roads in the world. Yet, one sees the heavy traffic and traffic congestion on Bosphorus Bridge in Figure 4. Istanbul, megacity is known to have compete with London, Paris and New York. Here, the traffic congestion lasted long hours on certain days due to road maintenance. The busy and heavy traffic roads in four different streets in Greece using Google Maps are shown in Figure 5.

Figure 3b. The D.100 in Kadıköy, Istanbul, Turkey

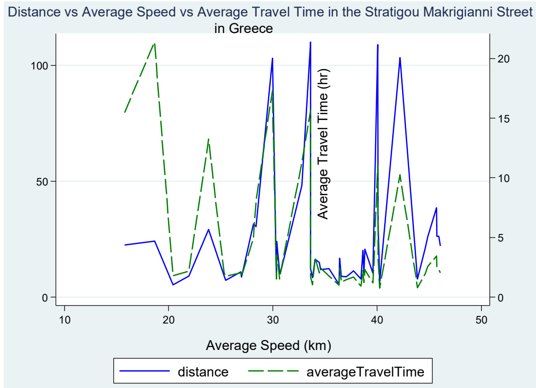
Figure 4a. Bosphorus Bridge, Istanbul

Figure 4b. Traffic congestion on Bosphorus Bridge, Istanbul, Turkey.

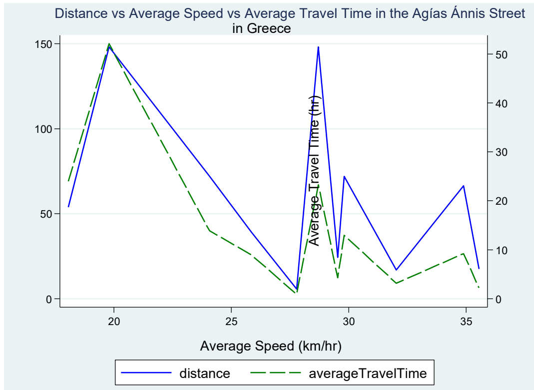
Figure 5. Roads in GREECE using Google maps

2.1 Statistical analysis of GREECE traffic data using STATA

The Greece traffic dataset is obtained from open data source https://www.xmap.ai/data-catalogs/greece-road-traffic-data and is analyzed for four different busy streets. The plot represent distance vs average speed vs average travel time in the streets of Stratigou Makrigianni, Mystra, Komvos Ag.loanni Renti and Agias Annis shown in Figure 6.

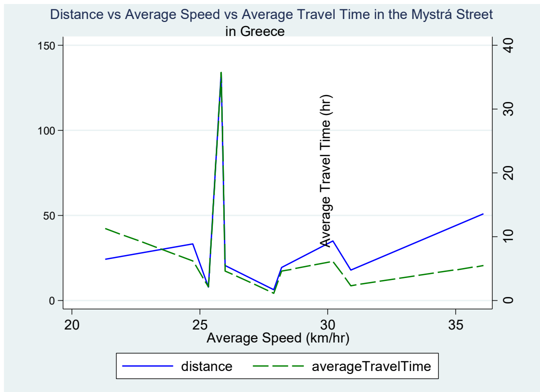


a. Stratigou Makrigianni



c

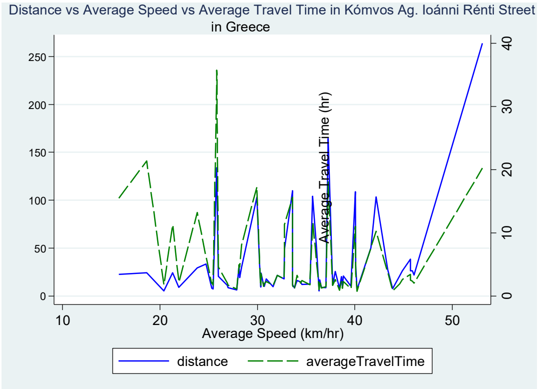
b. Agias Annis



c. Mystra

With the speed limit 50, the distance travelled in km in the different streets i.e Stratigou Makrigianni(SM), Kómvos Ag. Ioánni Rénti (KALR), Mystrá (MY), and Agias Annis (AA). The linear regression model was implemented to find the significance of P.

From Table 10 (Appendix -I), RMSE for SM (9.5062), MY (5.9093), KALR (16.373) and AA (23.072) was obtained and R-square <= 1 with P <= 1.



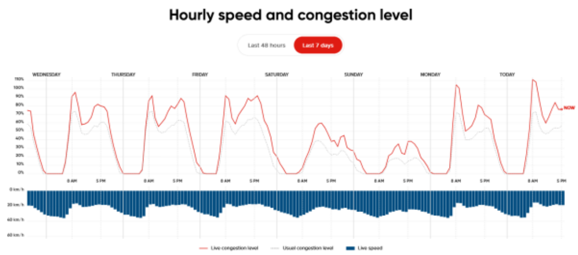
d. Komvos Ag.loanni Renti

Figure 6. The trends of the traffic streets in Greece.

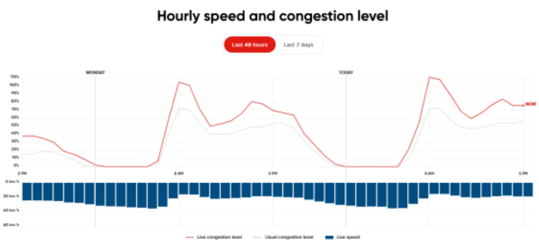
2.2 Real time traffic congestion in four European countries

The live traffic congestion data and trends for 7-days and 48-hours are obtained from the open source https://www.tomtom.com/traffic-index/athens-traffic/ for the four European countries shown below in Figure 7, 8, 9 and 10. The live speed, usual congestion level and live congestion levels are mentioned in the 48-hours and 7-days traffic congestion table for each country in tables 1, 2, 3, 4, 5, 6, 7 and 8.

a. Traffic flow in Athens



b. 7-days hourly speed and congestion level



c. 48 hours -hourly speed and congestion level

Figure 7. Live Traffic Congestion in Athens, Greece.

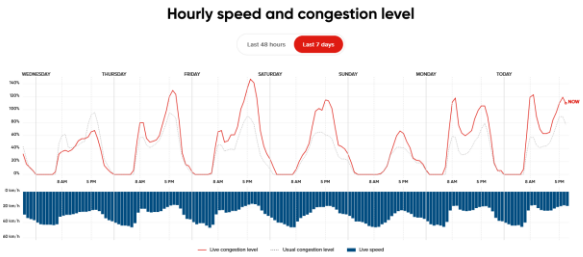
Last 48 hours traffic at Athens, Greece in February 2025 at 5:00 PM			
Date & Time	Feb 16 (Sunday)	Feb 17 (Monday)	Feb 18 (Tuesday)
Live speed (km/hr)	24	19	19
Usual Congestion level (%)	15	53	57
Live Congestion level (%)	38	70	76

Table 1. The congestion details of 48 hours traffic at Athens

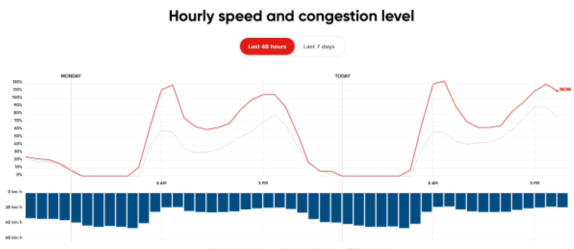
Last 7 days traffic at Athens, Greece in February 2025 at 8:00 AM			
Date & Time	Feb 15 (Saturday)	Feb 17 (Monday)	Feb 18 (Tuesday)
Live speed (km/hr)	31	16	15
Usual Congestion level (%)	2	72	72
Live Congestion level (%)	7	105	111

Table 2. The congestion details of 7-days live traffic in Athens

a. Traffic flow in Istanbul



b. 7-days hourly speed and congestion level



c. 48 hours -hourly speed and congestion level

Figure 8. Live Traffic Congestion in Istanbul, Turkey

In Athens, the traffic count seems to be 107 with the length of 48.8 km on February 18, 2025 including fast roads and highways. Similarly, in the city Istanbul, the traffic jams was nearly 422 count with the length of 229.6 km. However, Frankfurt am Main has the traffic jams count 33, with the traffic length of 14.8 km and finally, the traffic jam count 52 with the length 25.9 km was found in Bucharest.

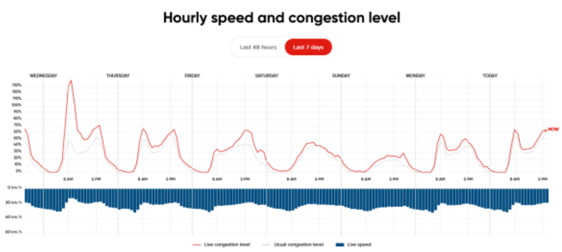
Last 48 hours traffic at Istanbul, Turkey in February 2025 at 8:00 PM			
Date & Time	Feb 16 (Sunday)	Feb 17 (Monday)	Feb 18 (Tuesday)
Live speed (km/hr)	33	26	19
Usual Congestion level (%)	24	39	77
Live Congestion level (%)	25	55	110

Table 3. The congestion details of 48 hours traffic in Istanbul

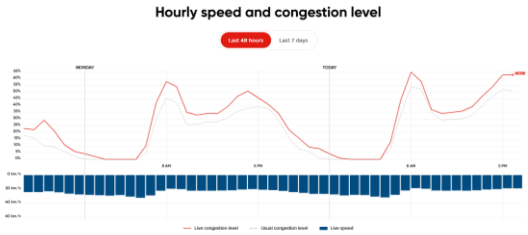
Last 7 days traffic at Istanbul, Turkey in February 2025 at 6:00 PM			
Date & Time	Feb 14 (Friday)	Feb 15 (Saturday)	Feb 17 (Monday)
Live speed (km/hr)	16	18	19
Usual Congestion level (%)	87	60	79
Live Congestion level (%)	147	114	106

Table 4. The congestion details of 7-days live traffic in Istanbul

a. Traffic flow in Frankfurt am Main



b. 7-days hourly speed and congestion level



c. 48 hours- hourly speed and congestion level

Figure 9. Live Traffic Congestion in Frankfurt am Main, Germany

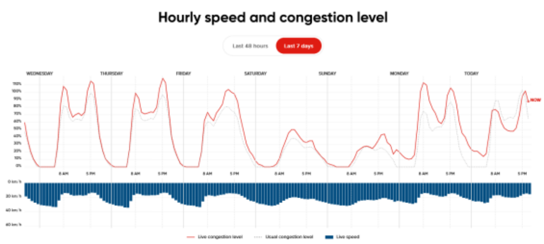
Last 48 hours traffic at Frankfurt am Main in February 2025 at 8:00 PM			
Date & Time	Feb 16 (Sunday)	Feb 17 (Monday)	Feb 18 (Tuesday)
Live speed (km/hr)	23	24	19
Usual Congestion level (%)	10	16	51
Live Congestion level (%)	29	22	63

Table 5. The congestion details of 48 hours traffic in Frankfurt

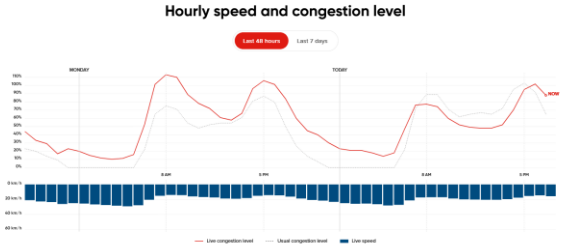
Last 7 days traffic at Frankfurt am Main, Germany in February 2025 at 9:00 AM			
Date & Time	Feb 12 (Wednesday)	Feb 13 (Thursday)	Feb 14 (Friday)
Live speed (km/hr)	13	19	23
Usual Congestion level (%)	45	48	27
Live Congestion level (%)	139	61	31

Table 6. The congestion details of 7 days traffic in Frankfurt

a. Traffic flow in Bucharest



b. 7 days hourly speed and congestion level



c. 48 hours- hourly speed and congestion level

Figure 10. Live Traffic Congestion in Bucharest, Romania

Last 48 hours traffic at Bucharest, Romania in February 2025 at 7:00 PM			
Date &Time	Feb 16 (Sunday)	Feb 17 (Monday)	Feb 18 (Tuesday)
Live speed (km/hr)	21	16	16
Usual Congestion level (%)	23	50	65
Live Congestion level (%)	44	84	88

Table 7. The congestion details of 48 hours traffic in Bucharest

Last 7 days traffic at Bucharest, Romania in February 2025 at 5:00 PM			
Date & Time	Feb 12 (Wednesday)	Feb 13 (Thursday)	Feb 14 (Friday)
Live speed (km/hr)	14	13	15
Usual Congestion level (%)	95	97	73
Live Congestion level (%)	115	119	98

Table 8. The congestion details of 7 days traffic in Bucharest

street		SS	MS	Prob > F	R-Sq	RMSE
SM	Mod	29783.99	4963.99	0.0000	0.8966	9.5062
	Res	3433.99	90.3683			
MY	Mod	12350.30	2058.3	0.0033	0.9916	5.9093
	Res	104.760	34.9200			
KALR	Mod	110289.4	18381.5	0.0000	0.8783	16.373
	Res	15280.23	268.074			
AA	Mod	22060.63	3676.77	0.0412	0.9120	23.072
	Res	2129.29	532.324			

Table 9. Linear Regression models for four different streets

The regression model results of four streets are shown in Table 9 and Table 10 (Appendix –I). The RMSE for Stratigou Makrigianni(9.5062), Kómvos Ag. Ioánni Rénti (16.373), Mystrá (5.9093), and Agias Annis (23.072) were obtained.

Figure 11a. The original image of the roads

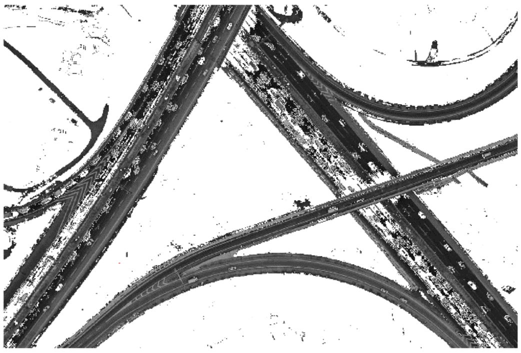


Figure 11b. The extracted roads using ArcGIS

The transportation pollutes the environment, during traffic congestion, and moreover, heavy pollution is seen. To avoid, the congestion and thereby the pollution, one can avoid getting into the congested traffic. This is analyzed by choosing the other free routes using GIS. The roads in figure 11b were extracted using extracting technique can also be carried out by the deep learning approach in ArcGIS, with traffic on roads represents spatial real-time data, Hence, GIS spatial analysis approach of extracting is more efficient and convenient. This approach helps to prevent the traffic or getting struck in the traffic for a longer time. According to Nina (2024), it provides a way for sustainable roads leading to Net Zero pollution.

The advancement of smart road technologies offers a promising solution to the challenges posed by increased vehicular traffic and its environmental impact. By integrating IoT connectivity, smart roads can provide real-time data on traffic conditions, enabling more efficient traffic management and reducing congestion. Cameras and sensors enhance this system by identifying traffic incidents and monitoring vehicle loads, ensuring safer and more efficient road use. However, the implementation of smart road technologies faces several challenges. Additionally, integrating new technologies with existing systems can be complex and may face resistance from stakeholders accustomed to traditional methods.

Cybersecurity is another critical aspect with all the intelligent transportation systems become more interconnected, which are vulnerable to cyber-attacks, which could disrupt traffic management and pose significant risks to public safety.

Conclusion

The traffic congestion in four European Countries with best roads and national highways in the world is seen due to peak rush to reach the workplace. However, the traffic in these countries, also seems to be heavy during the peak hours or unusual hours. With GIS, one can trace the traffic routes and also take proper decision to avoid the traffic, and move toward the destination with different paths. The multimodal approach also reduces the traffic and save fuel and time. The less traffic leads to less air pollution. This approach will help the nearby places to be Net Zero pollution with sustainable roads and smooth traffic flow.

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APPENDIX – I

Distance	Street	Coef.	Std. Err.	t	P>|t|	95% CI
harmonicAvgSpeed	SM	-2.0881	0.7580	-2.75	0.009	-3.6226 – -0.5534
	MY	0.7420	2.6521	0.28	0.798	-7.6983 - 9.1824
	KALR	-1.4936	1.1259	-1.33	0.190	-3.7483 - 0.7610
	AA	2.1516	9.3357	0.23	0.829	-23.7686 – 28.0720
medianSpeed	SM	2.3281	1.5187	1.53	0.134	-0.7465 - 5.4027
	MY	4.7556	5.9921	0.79	0.485	-14.3140 - 23.8253
	KALR	4.3071	2.0332	2.12	0.039	0.2356 – 8.3786
	AA	8.7375	12.6304	0.69	0.527	-26.330 – 43.8051
AvgSpeed	SM	0.2537	2.1238	0.12	0.906	-4.0458 - 4.5533
	MY	-3.7077	8.0163	-0.46	0.675	-29.2193 - 21.8037
	KALR	-2.1632	2.9726	-0.73	0.470	-8.1159 – 3.7894
	AA	-7.8772	23.4932	-0.34	0.754	-73.1050 – 57.3505
SD_Speed	SM	-1.8934	0.8458	-2.24	0.031	-3.6056 - 0.1811
	MY	2.0881	3.1858	0.66	0.559	-8.0505 - 12.2269
	KALR	-0.1209	1.1317	-0.11	0.915	-2.3873 – 2.1453
	AA	2.9815	9.3036	0.32	0.765	-22.8494 – 28.8124
Travel_Time_SD	SM	-7.6101	1.2211	-6.23	0.000	-10.0821 -5.1383
	MY	-3.1773	2.3143	-1.37	0.263	-10.5427 - 4.1879
	KALR	-8.7725	1.4654	-5.99	0.000	-11.7071 – -5.8380
	AA	-10.9325	6.9286	-1.58	0.190	-30.169 – 8.3044
Avg_Travel_Time	SM	11.9192	1.11069	10.73	0.000	9.6707 - 14.1677
	MY	6.6577	2.0062	3.32	0.045	0.2731 - 13.0424
	KALR	12.7492	1.1792	10.81	0.000	10.3879 – 15.1105
	AA	14.1205	6.8110	2.07	0.107	-4.7900 – 33.0310
_cons	SM	1.4017	10.4135	0.13	0.894	-19.6793 - 22.4829
	MY	-59.4084	31.7274	-1.87	0.158	-160.379 - 41.5623
	KALR	-19.2707	14.8872	-1.29	0.201	-49.0819 – 10.5404
	AA	-89.1680	89.3360	-1.00	0.375	-337.204 – 158.868

Table 10. Greece Street with the detailed Linear regression models