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Raw driving data of passenger cars considering traffic conditions in Semnan city

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Abstract

This article analyzes raw driving data of passenger cars in the city of Semnan in Iran, with the objective of understanding the impact of traffic conditions at different times of day (morning, noon, evening, and night). For this study, two cars, the Toyota Prius and the Peugeot Pars (or the IKCO Persia), were used, and the data of speed, longitude, latitude, and altitude of the vehicles were acquired. This data was collected over a week (July 21–28, 2022) for a distance of 670 km (13 hr), with the help of the Global Positioning System application, and were presented for both cars. In addition to this, the data on fuel consumption and average speed, based on the Electronic Control Unit in the Prius, was also collected. Finally, a sensitivity analysis was done on the features of the raw data, based on the Principal Component Analysis method.

Keywords: Driving data; passenger car; Principal Component Analysis; Semnan city; traffic condition

Introduction

One important parameter that affects the driving cycles in a city is its traffic condition. Besides influencing driving behavior (Balsa-Barreiro et al., 2020), it also has an impact on the emission, energy, and fuel consumption of the vehicle (Gebisa et al., 2021; Lejri et al., 2018). Therefore, when engineers tend to develop a driving cycle for a city, the traffic condition must be considered during data acquisition.

In an urban environment, traffic congestion is dependent on the time and the route. If we take the time parameter, as expected, heavier traffic can usually be seen during weekdays and at peak times, while lighter traffic can be observed during weekends and public holidays (Abas et al., 2018). If analyzing the effect of routes, the traffic flow will be influenced by the topography, the road type, the density of population and business centers, weather conditions, *etc.*

In this regard, Fotouhi and Montazeri-Gh (2013) developed the Tehran (Iran) driving cycle by the K-means clustering approach. They clustered the driving data based on four traffic congestion types, namely congested, urban, extra-urban, and highway driving, based on the vehicle speeds. Chugh et al. (2012) extracted the Delhi (India) driving cycle based on monitoring the traffic conditions for three days. They also categorized traffic into congested, semi-urban, urban, and extra-urban. Pouresmaeili et al. (2018) used the hourly measurements of air pollutant stations to find the traffic condition in the city of Mashhad. The peaks were in the morning (7:00) and in the afternoon (16:00), based on the concentration of air pollutants.

In this dataset, the traffic conditions were considered for data acquisition of driving cycles by passenger cars in Semnan city.

Data description

After covering a distance of 670 km and driving for 13 hours over 7 days, the Global Positioning System (GPS) data were collected. More information about the process of data logging is provided in the section on *Experimental design, materials, and methods*. There were 96 unique data in the repository that each included three files with different file extensions. Tables 1–7 and 8–14 list the data for characteristics of driving cycles of the Toyota Prius and the Peugeot Pars (or the IKCO Persia), respectively. Note that each one was identical and there were no changes implemented during the process of data logging.

It should be noted that in these tables, the selected features for all driving data included the total time, total distance, idle time, cruise time, driving time, drive time spent for decelerating/accelerating, time for decelerating/accelerating, standing time, percentage of time driving, and time stopping. Other features included the average trip speed, average driving speed, standard deviation of speed, average or maximum speed, acceleration, and average negative/positive acceleration.

The results demonstrated that the time of day and the day of the week directly affect the time of driving and, consequently, other significant driving cycle characteristics in Semnan. Likewise, there are a lot of factors that can affect driving behavior, such as traffic congestion, pedestrian presence, the mood of the driver, and distraction factors during driving, which are not included in this article and could be tracked in further investigations.

In addition, to implement a sensitivity analysis, the Principal Component Analysis (PCA) method was used on the characteristics of raw data. Figure 1 shows the relative PCA coefficients of both vehicles *via* a double-legend bar chart.

As expected, the relative PCA coefficient of "*total distance*" was 97.37%, and that of the "*total time*" was evaluated at almost 2.4% for all logged data. Figure 2 illustrates the scatter plot of these two driving cycle characteristics. The same procedure was used for Persia-related data but this time with the relative PCA coefficient of 94.4% for the "*total distance*" and around 3.5% for the "*total time*". Figure 3 demonstrates the relation between them as well, for the Persia.

Comparing the obtained results to the literature (Joubert & Grabe, 2022; Miri et al., 2022; Onyekpe et al., 2021; Wawage & Deshpande, 2022), it could be claimed that there was an average error of 9% for the sensitivity of the most reliable PCA coefficients. Despite this, the order of the effective parameters was alike. In these references, many factors such as the driver behavior during driving (aggressive or defensive), the ground vehicle model (as mentioned in the literature (Joubert & Grabe, 2022; Miri et al., 2022; Onyekpe et al., 2021; Wawage & Deshpande, 2022): Ford Fiesta Titanium, Pars Khodro Tiba, Isuzu FTR850, and Ford Figo 1.2), the driver age, the environmental scenarios, the road states, the selected route, the GPS update rate, the country, and the data acquisition methods (a diverse model of smartphones) differed from this work.

For the Prius, based on data obtained by the Electronic Control Unit (ECU), the fuel consumption was measured and is reported in Tables 15 and 16. Higher values are denoted in red and lower values are denoted in green. From these data, the fuel consumption is found to be between 3.7 and 6.1 L/100 km. As expected, the fuel consumption was highest for the onward drive route in the evening, when the traffic condition was at its worst. In the return drive route, the highest fuel consumption was found to be at night. Based on Table 16, the fuel consumption is observed to be between 4.0 and 5.6 L/100 km. The change in the driving behavior in the onward and return drive routes was due to the road slope.

Furthermore, the average speed of the car is also depicted in Tables 17 and 18, based on the ECU data. Here, the implications of the colors green and red are reversed, with lower values being denoted with red and vice versa. The average speed was between 38.4 and 59.7 km/hr on the onward route and 43.5 and 63.1 km/hr on the return route. In both routes, the average speed of the Prius was lower at night as compared to the other times when data acquisition happened. In addition, speed was found to be higher

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Table 1. Characteristics of logged data on Thursday, July 21, 2022, for the Prius

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name (*.gpx*)	20,220,721–091152	20,220,721–092857	20,220,721–123,436	20,220,721–125,130	20,220,721–162,811	20,220,721–164,329	20,220,721–203,332	20,220,721–205,208
Total distance (*km*)	14.08	13.81	14.07	13.81	14.06	13.80	13.77	14.10
Total time (*s*)	968	892	983	928	887	842	1,017	1,050
Driving time (s)	966	891	982	927	886	841	1,016	1,046
Cruise time (s)	0	0	0	0	0	0	0	0
Drive time spent accelerating (s)	506	466	512	494	476	440	503	550
Drive time spent decelerating (s)	460	425	470	433	410	401	513	496
Standing time (s)	2	1	1	1	1	1	1	4
% of time driving	99.79	99.89	99.90	99.89	99.89	99.88	99.90	99.62
% of time cruising	0	0	0	0	0	0	0	0
% of time accelerating	52.27	52.24	52.09	53.23	53.66	52.26	49.46	52.38
% of time decelerating	47.52	47.65	47.81	46.66	46.22	47.62	50.44	47.24
% of time standing	0.21	0.11	0.10	0.11	0.11	0.12	0.10	0.38
Average trip speed $\left(\frac{km}{hr}\right)$	52.35	55.74	51.54	53.57	57.07	59.01	48.76	48.35
Average driving speed $\left(\frac{km}{hr}\right)$	52.46	55.80	51.59	53.63	57.14	59.08	48.81	48.54
Standard deviation of speed	58.50	62.22	58.16	61.15	64.06	65.85	56.30	55.26
Maximum speed $\left(\frac{km}{hr}\right)$	108.22	107.57	105.56	113.30	108.08	119.37	109.45	101.91
Average acceleration $\left(\frac{m}{s^2}\right)$	0	0	0	0	0	0	0	0
Average positive acceleration $\left(\frac{m}{s^2}\right)$	0.54	0.52	0.54	0.64	0.56	0.73	0.55	0.62
Average negative acceleration $\left(\frac{m}{s^2}\right)$	0.59	0.57	0.59	0.73	0.65	0.80	0.54	0.68
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	0.75	0.72	0.77	0.86	0.78	0.94	0.71	0.80

Table 2. Characteristics of logged data on Friday, July 22, 2022, for the Prius

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name (*.gpx*)	20,220,722–085504	20,220,722–090901	20,220,722–122,734	20,220,722–124,147	20,220,722–162,616	20,220,722–163,959	20,220,722–203,239	20,220,722–204,847
Total distance (km)	13.78	14.12	13.77	14.11	13.76	14.10	13.77	14.11
Total time (s)	800	895	823	865	786	856	930	1,018
Driving time (s)	799	894	822	864	785	855	929	1,017
Cruise time (s)	0	0	0	0	0	0	0	0
Drive time spent accelerating (s)	431	460	428	464	445	464	490	503
Drive time spent decelerating (s)	368	434	394	400	340	391	439	514
Standing time (s)	1	1	1	1	1	1	1	1
% of time driving	99.88	99.89	99.88	99.88	99.87	99.88	99.89	99.90
% of time cruising	0	0	0	0	0	0	0	0
% of time accelerating	53.88	51.40	52.00	53.64	56.62	54.21	52.69	49.41
% of time decelerating	46.00	48.49	47.87	46.24	43.26	45.68	47.20	50.49
% of time standing	0.13	0.11	0.12	0.12	0.13	0.12	0.11	0.10
Average trip speed $\left(\frac{km}{hr}\right)$	62.00	56.79	60.22	58.71	63.01	59.31	53.29	49.89
Average driving speed $\left(\frac{km}{hr}\right)$	62.08	56.85	60.30	58.78	63.09	59.38	53.35	49.94
Standard deviation of speed	67.69	61.63	65.31	64.32	67.56	64.88	59.30	54.80
Maximum speed $\left(\frac{km}{hr}\right)$	115.67	105.35	111.68	103.58	114.07	108.31	109.28	98.17
Average acceleration $\left(\frac{m}{s^2}\right)$	0	0	0	0	0	0	0	0
Average positive acceleration $\left(\frac{m}{s^2}\right)$	0.48	0.55	0.49	0.52	0.53	0.59	0.45	0.54
Average negative acceleration $\left(\frac{m}{s^2}\right)$	0.57	0.59	0.54	0.60	0.69	0.70	0.50	0.53
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	0.71	0.74	0.69	0.74	0.79	0.83	0.63	0.68

Table 3. Characteristics of logged data on Saturday, July 23, 2022, for the Prius

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name (*.gpx*)	20,220,723–085943	20,220,723–091816	20,220,723–122,707	20,220,723–124,451	20,220,723–162,804	20,220,723–164,309	20,220,723–202,935	20,220,723–204,817
Total distance (km)	14.13	13.77	14.11	13.77	13.76	14.08	13.78	14.12
Total time (s)	961	862	982	925	825	888	1,030	1,090
Driving time (s)	960	861	981	924	824	887	1,029	1,089
Cruise time (s)	0	0	0	0	0	0	0	0
Drive time spent accelerating (s)	494	458	526	514	362	475	528	548
Drive time spent decelerating (s)	466	403	455	410	462	412	501	541
Standing time (s)	1	1	1	1	1	1	1	1
% of time driving	99.90	99.88	99.90	99.89	99.88	99.89	99.90	99.91
% of time cruising	0	0	0	0	0	0	0	0
% of time accelerating	51.40	53.13	53.56	55.57	43.88	53.49	51.26	50.28
% of time decelerating	48.49	46.75	46.33	44.32	56.00	46.40	48.64	49.63
% of time standing	0.10	0.12	0.10	0.11	0.12	0.11	0.10	0.09
Average trip speed $\left(\frac{km}{hr}\right)$	52.94	57.49	51.74	53.59	60.03	57.10	48.17	46.62
Average driving speed $\left(\frac{km}{hr}\right)$	52.99	57.56	51.80	53.65	60.10	57.16	48.22	46.67
Standard deviation of speed	59.71	63.39	59.88	61.01	65.83	62.79	55.80	54.31
Maximum speed $\left(\frac{km}{h}\right)$	107.77	107.93	109.78	114.21	116.79	108.45	109.78	101.92
Average acceleration $\left(\frac{m}{s^2}\right)$	0	0	0	0	0	0	0	0
Average positive acceleration $\left(\frac{m}{s^2}\right)$	0.56	0.47	0.55	0.54	1.49	0.53	0.46	0.49
Average negative acceleration $\left(\frac{m}{s^2}\right)$	0.59	0.53	0.64	0.68	1.17	0.61	0.48	0.49
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	0.74	0.67	0.80	0.86	1.67	0.75	0.63	0.66

Table 4. Characteristics of logged data on Sunday, July 24, 2022, for the Prius

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name (*.gpx*)	20,220,724–081711	20,220,724–083341	20,220,724–122,809	20,220,724–124,511	20,220,724–162,859	20,220,724–164,621	20,220,724–202,732	20,220,724–204,754
Total distance (km)	14.12	13.77	14.12	13.77	14.07	13.81	13.76	14.17
Total time (s)	916	816	935	921	951	818	1,139	1,328
Driving time (s)	915	815	934	918	947	817	1,137	1,288
Cruise time (s)	0	0	0	2	0	0	1	0
Drive time spent accelerating (s)	481	433	491	473	502	435	591	643
Drive time spent decelerating (s)	434	382	443	443	445	382	545	645
Standing time (s)	1	1	1	3	4	1	2	40
% of time driving	99.89	99.88	99.89	99.67	99.58	99.88	99.82	96.99
% of time cruising	0	0	0	0.22	0	0	0.09	0
% of time accelerating	52.51	53.06	52.51	51.36	52.79	53.18	51.89	48.42
% of time decelerating	47.38	46.81	47.38	48.10	46.79	46.70	47.85	48.57
% of time standing	0.11	0.12	0.11	0.33	0.42	0.12	0.18	3.01
Average trip speed $\left(\frac{km}{hr}\right)$	55.51	60.74	54.36	53.81	53.26	60.76	43.50	38.42
Average driving speed $\left(\frac{km}{hr}\right)$	55.57	60.81	54.41	53.99	53.48	60.84	43.58	39.61
Standard deviation of speed	61.51	66.22	59.82	61.38	60.28	66.41	52.96	49.28
Maximum speed $\left(\frac{km}{hr}\right)$	108.07	111.73	103.92	107.99	107.60	109.12	108.12	104.96
Average acceleration $\left(\frac{m}{s^2}\right)$	0	0	0	0	0	0	0	0
Average positive acceleration $\left(\frac{m}{s^2}\right)$	0.50	0.49	0.51	0.41	0.52	0.40	0.39	0.45
Average negative acceleration $\left(\frac{m}{s^2}\right)$	0.56	0.56	0.57	0.44	0.58	0.46	0.42	0.45
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	0.70	0.71	0.72	0.59	0.75	0.60	0.57	0.59

Table 5. Characteristics of logged data on Monday, July 25, 2022, for the Prius

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name (*.gpx*)	—	—	20,220,725–122,904	20,220,725–124,625	20,220,725–162,857	20,220,725–164,644	20,220,725–203,118	20,220,725–205,048
Total distance (km)	—	—	14.13	13.76	14.09	13.76	13.80	14.15
Total time (s)	—	—	956	914	913	830	1,031	1,082
Driving time (s)	—	—	955	913	912	829	1,030	1,081
Cruise time (s)	—	—	0	0	0	0	0	0
Drive time spent accelerating (s)	—	—	524	502	466	455	551	548
Drive time spent decelerating (s)	—	—	431	411	446	374	479	533
Standing time (s)	—	—	1	1	1	1	1	1
% of time driving	—	—	99.90	99.89	99.89	99.88	99.90	99.91
% of time cruising	—	—	0	0	0	0	0	0
% of time accelerating	—	—	54.81	54.92	51.04	54.82	53.44	50.65
% of time decelerating	—	—	45.08	44.97	48.85	45.06	46.46	49.26
% of time standing	—	—	0.10	0.11	0.11	0.12	0.10	0.09
Average trip speed $\left(\frac{km}{hr}\right)$	—	—	53.21	54.19	55.55	59.68	48.17	47.07
Average driving speed $\left(\frac{km}{hr}\right)$	—	—	53.27	54.25	55.61	59.75	48.22	47.11
Standard deviation of speed	—	—	60.04	61.48	63.13	66.01	57.79	55.13
Maximum speed $\left(\frac{km}{hr}\right)$	—	—	108.55	109.42	106.86	116.70	117.41	104.53
Average acceleration $\left(\frac{m}{s^2}\right)$	—	—	0	0	0	0	0	0
Average positive acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.45	0.41	0.52	0.43	0.49	0.52
Average negative acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.55	0.50	0.55	0.52	0.56	0.54
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.67	0.62	0.74	0.66	0.72	0.70

Table 6. Characteristics of logged data on Wednesday, July 27, 2022, for the Prius

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name (*.gpx*)	—	—	20,220,727–122,920	20,220,727–124,540	20,220,727–162,556	20,220,727–164,232	20,220,727–202,947	20,220,727–204,759
Total distance (km)	—	—	14.12	13.78	14.14	13.76	13.77	14.14
Total time (s)	—	—	934	899	933	834	1,017	993
Driving time (s)	—	—	933	898	932	833	1,016	992
Cruise time (s)	—	—	0	0	0	0	1	0
Drive time spent accelerating (s)	—	—	490	486	505	447	491	517
Drive time spent decelerating (s)	—	—	443	412	427	386	524	475
Standing time (s)	—	—	1	1	1	1	1	1
% of time driving	—	—	99.89	99.89	99.89	99.88	99.90	99.90
% of time cruising	—	—	0.0	0.0	0.0	0.0	0.1	0.0
% of time accelerating	—	—	52.46	54.06	54.13	53.60	48.28	52.06
% of time decelerating	—	—	47.43	45.83	45.77	46.28	51.52	47.83
% of time standing	—	—	0.11	0.11	0.11	0.12	0.10	0.10
Average trip speed $\left(\frac{km}{hr}\right)$	—	—	54.43	55.20	54.55	59.40	48.76	51.25
Average driving speed $\left(\frac{km}{hr}\right)$	—	—	54.49	55.26	54.61	59.47	48.81	51.30
Standard deviation of speed	—	—	61.66	62.71	59.87	65.73	57.86	58.99
Maximum speed $\left(\frac{km}{hr}\right)$	—	—	114.45	117.05	106.12	116.39	118.04	107.26
Average acceleration $\left(\frac{m}{s^2}\right)$	—	—	0	0	0	0	0	0
Average positive acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.55	0.50	0.54	0.59	0.66	0.49
Average negative acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.61	0.59	0.64	0.68	0.62	0.53
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.75	0.73	0.77	0.83	0.83	0.68

Table 7. Characteristics of logged data on Thursday, July 28, 2022, for the Prius

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name (*gpx*)	—	—	20,220,728–123,454	20,220,728–125,126	20,220,728–163,120	20,220,728–164,632	—	—
Total distance (km)	—	—	14.14	13.76	14.10	13.78	—	—
Total time (s)	—	—	925	890	852	833	—	—
Driving time (s)	—	—	924	888	851	832	—	—
Cruise time (s)	—	—	0	0	0	0	—	—
Drive time spent accelerating (s)	—	—	502	483	453	441	—	—
Drive time spent decelerating (s)	—	—	422	405	398	391	—	—
Standing time (s)	—	—	1	2	1	1	—	—
% of time driving	—	—	99.89	99.78	99.88	99.88	—	—
% of time cruising	—	—	0	0	0	0	—	—
% of time accelerating	—	—	54.27	54.27	53.17	52.94	—	—
% of time decelerating	—	—	45.62	45.51	46.71	46.94	—	—
% of time standing	—	—	0.11	0.22	0.12	0.12	—	—
Average trip speed $\left(\frac{km}{hr}\right)$	—	—	55.02	55.66	59.60	59.56	—	—
Average driving speed $\left(\frac{km}{hr}\right)$	—	—	55.08	55.79	59.67	59.64	—	—
Standard deviation of speed	—	—	62.20	62.82	65.77	64.05	—	—
Maximum speed $\left(\frac{km}{hr}\right)$	—	—	111.25	111.69	111.00	103.82	—	—
Average acceleration $\left(\frac{m}{s^2}\right)$	—	—	0	0	0	0	—	—
Average positive acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.54	0.56	0.56	0.49	—	—
Average negative acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.63	0.66	0.64	0.55	—	—
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.77	0.82	0.79	0.68	—	—

Table 8. Characteristics of logged data on Thursday, July 21, 2022, for the Persia

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name (*.gpx*)	20,220,721–091147—1	20,220,721–092836—2	20,220,721–123,428—3	20,220,721–125,125—4	20,220,721–162,800—5	20,220,721–164,327—6	20,220,721–203,336—7	20,220,721–205,203—7
Total distance (km)	14.11	13.84	14.10	13.84	14.10	13.84	13.82	14.15
Total time (s)	980	917	998	937	903	850	1,019	1,064
Driving time (s)	963	885	968	911	897	823	994	1,040
Cruise time (s)	0	0	0	0	1	0	0	0
Drive time spent accelerating (s)	541	449	534	462	496	446	509	557
Drive time spent decelerating (s)	422	436	434	449	400	377	485	483
Standing time (s)	17	32	30	26	6	27	25	24
% of time driving	98.27	96.51	96.99	97.23	99.34	96.82	97.55	97.74
% of time cruising	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
% of time accelerating	55.20	48.96	53.51	49.31	54.93	52.47	49.95	52.35
% of time decelerating	43.06	47.55	43.49	47.92	44.30	44.35	47.60	45.39
% of time standing	1.73	3.49	3.01	2.77	0.66	3.18	2.45	2.26
Average trip speed $\left(\frac{km}{hr}\right)$	51.83	54.35	50.87	53.19	56.22	58.62	48.82	47.88
Average driving speed $\left(\frac{km}{hr}\right)$	52.74	56.32	52.44	54.71	56.59	60.54	50.04	48.98
Standard deviation of speed	58.27	62.21	57.97	60.85	63.69	65.13	56.51	54.96
Maximum speed $\left(\frac{km}{hr}\right)$	105.96	113.87	111.62	122.26	117.70	117.84	107.80	106.83
Average acceleration $\left(\frac{m}{s^2}\right)$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average positive acceleration $\left(\frac{m}{s^2}\right)$	0.50	0.52	0.51	0.53	0.49	0.47	0.50	0.51
Average negative acceleration $\left(\frac{m}{s^2}\right)$	0.64	0.54	0.63	0.55	0.61	0.56	0.52	0.59
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	0.75	0.71	0.75	0.73	0.73	0.69	0.68	0.73

Table 9. Characteristics of logged data on Friday, July 22, 2022, for the Persia

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name $(.gpx)$	20,220,722–085459—10	20,220,722–090851—9	20,220,722–122,732—12	20,220,722–124,144—11	20,220,722–162,610—14	20,220,722–163,953—13	20,220,722–203,307—16	20,220,722–204,851—15
Total distance (km)	13.81	14.16	13.78	14.15	13.80	14.15	13.79	14.13
Total time (s)	811	908	827	873	800	878	905	1,031
Driving time (s)	803	900	822	870	788	867	904	1,014
Cruise time (s)	0	0	0	0	0	0	0	0
Drive time spent accelerating (s)	440	472	448	477	403	473	474	519
Drive time spent decelerating (s)	363	428	374	393	385	394	430	495
Standing time (s)	8	8	5	3	12	11	1	17
% of time driving	99.01	99.12	99.40	99.66	98.50	98.75	99.89	98.35
% of time cruising	0	0	0	0	0	0	0	0
% of time accelerating	54.25	51.98	54.17	54.64	50.38	53.87	52.38	50.34
% of time decelerating	44.76	47.14	45.22	45.02	48.13	44.87	47.51	48.01
% of time standing	0.99	0.88	0.60	0.34	1.50	1.25	0.11	1.65
Average trip speed $\left(\frac{km}{hr}\right)$	61.31	56.13	59.97	58.36	62.10	58.03	54.87	49.34
Average driving speed $\left(\frac{km}{hr}\right)$	61.92	56.63	60.34	58.56	63.04	58.76	54.93	50.17
Standard deviation of speed	67.40	61.26	65.02	64.50	67.16	64.48	61.11	54.57
Maximum speed $\left(\frac{km}{hr}\right)$	117.17	104.82	111.67	108.29	120.20	117.21	112.65	98.75
Average acceleration $\left(\frac{m}{s^2}\right)$	0	0	0	0	0	0	0	0
Average positive acceleration $\left(\frac{m}{s^2}\right)$	0.46	0.57	0.45	0.49	0.51	0.49	0.51	0.52
Average negative acceleration $\left(\frac{m}{s^2}\right)$	0.56	0.63	0.54	0.59	0.53	0.59	0.56	0.54
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	0.71	0.82	0.70	0.73	0.69	0.75	0.73	0.70

Table 10. Characteristics of logged data on Saturday, July 23, 2022, for the Persia

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name (*.gpx*)	20,220,723–085920—17	20,220,723–091613—18	20,220,723–122,650—19	20,220,723–124,415—20	20,220,723–162,756—22	20,220,723–164,227—21	20,220,723–202,941—24	20,220,723–204,824—23
Total distance (km)	14.16	13.81	14.15	13.81	13.78	14.15	13.81	14.15
Total time (s)	988	994	1,009	972	843	940	1,035	1,089
Driving time (s)	974	885	940	923	825	917	1,030	1,074
Cruise time (s)	0	0	0	0	0	0	0	0
Drive time spent accelerating (s)	502	445	470	463	435	493	537	551
Drive time spent decelerating (s)	472	440	470	460	390	424	493	523
Standing time (s)	14	109	69	49	18	23	5	15
% of time driving	98.58	89.03	93.16	94.96	97.86	97.55	99.52	98.62
% of time cruising	0	0	0	0	0	0	0	0
% of time accelerating	50.81	44.77	46.58	47.63	51.60	52.45	51.88	50.60
% of time decelerating	47.77	44.27	46.58	47.33	46.26	45.11	47.63	48.03
% of time standing	1.42	10.97	6.84	5.04	2.14	2.45	0.48	1.38
Average trip speed $\left(\frac{km}{hr}\right)$	51.58	50.02	50.49	51.16	58.86	54.17	48.02	46.79
Average driving speed $\left(\frac{km}{hr}\right)$	52.32	56.18	54.20	53.87	60.15	55.53	48.25	47.44
Standard deviation of speed	58.50	61.13	59.11	59.76	64.98	61.32	54.83	54.04
Maximum speed $\left(\frac{km}{hr}\right)$	105.51	107.55	110.32	111.73	109.12	111.14	103.07	100.52
Average acceleration $\left(\frac{m}{s^2}\right)$	0	0	0	0	0	0	0	0
Average positive acceleration $\left(\frac{m}{s^2}\right)$	0.52	0.48	0.51	0.47	0.44	0.48	0.45	0.47
Average negative acceleration $\left(\frac{m}{s^2}\right)$	0.55	0.48	0.51	0.47	0.49	0.55	0.49	0.50
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	0.70	0.64	0.66	0.63	0.63	0.69	0.63	0.64

Table 11. Characteristics of logged data on Sunday, July 24, 2022, for the Persia

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name $(.gpx)$	20,220,724–081719—25	20,220,724–083342—26	20,220,724–122,814—27	20,220,724–124,523—28	20,220,724–162,907—29	20,220,724–164,626—30	20,220,724–202,736—32	20,220,724–204,802—31
Total distance (km)	14.15	13.79	14.17	13.78	14.12	13.86	13.81	14.21
Total time (s)	918	825	936	924	955	831	1,159	1,337
Driving time (s)	913	813	932	893	925	827	1,099	1,203
Cruise time (s)	0	0	0	0	0	0	0	0
Drive time spent accelerating (s)	480	415	485	450	478	449	551	616
Drive time spent decelerating (s)	433	398	447	443	447	378	548	587
Standing time (s)	5	12	4	31	30	4	60	134
% of time driving	99.46	98.55	99.57	96.65	96.86	99.52	94.82	89.98
% of time cruising	0	0	0	0	0	0	0	0
% of time accelerating	52.29	50.30	51.82	48.70	50.05	54.03	47.54	46.07
% of time decelerating	47.17	48.24	47.76	47.94	46.81	45.49	47.28	43.90
% of time standing	0.54	1.45	0.43	3.35	3.14	0.48	5.18	10.02
Average trip speed $\left(\frac{km}{hr}\right)$	55.49	60.18	54.51	53.70	53.22	60.03	42.88	38.25
Average driving speed $\left(\frac{km}{hr}\right)$	55.80	61.07	54.74	55.57	54.94	60.32	45.22	42.51
Standard deviation of speed	61.61	66.06	60.32	61.44	59.76	65.18	51.54	48.85
Maximum speed $\left(\frac{km}{hr}\right)$	115.22	118.31	103.54	122.97	108.15	108.69	97.80	101.19
Average acceleration $\left(\frac{m}{s^2}\right)$	0.00	0.00	0.00	−0.01	0.00	0.00	0.00	0.00
Average positive acceleration $\left(\frac{m}{s^2}\right)$	0.49	0.50	0.46	0.52	0.46	0.41	0.48	0.50
Average negative acceleration $\left(\frac{m}{s^2}\right)$	0.55	0.52	0.50	0.52	0.49	0.49	0.49	0.52
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	0.68	0.68	0.63	0.74	0.63	0.63	0.63	0.66

Table 12. Characteristics of logged data on Monday, July 25, 2022, for the Persia

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name $(.gpx)$	—	—	20,220,725–122,910—33	20,220,725–124,553—34	20,220,725–162,905—35	20,220,725–164,651—36	20,220,725–203,124—38	20,220,725–205,055—37
Total distance (km)	—	—	14.18	13.83	14.13	13.79	13.80	14.16
Total time (s)	—	—	957	960	906	836	1,139	1,122
Driving time (s)	—	—	937	949	863	832	1,060	1,085
Cruise time (s)	—	—	0	0	0	0	1	0
Drive time spent accelerating (s)	—	—	492	472	461	425	544	569
Drive time spent decelerating (s)	—	—	445	477	402	407	515	516
Standing time (s)	—	—	20	11	43	4	79	37
% of time driving	—	—	97.91	98.85	95.25	99.52	93.06	96.70
% of time cruising	—	—	0.00	0.00	0.00	0.00	0.09	0.00
% of time accelerating	—	—	51.41	49.17	50.88	50.84	47.76	50.71
% of time decelerating	—	—	46.50	49.69	44.37	48.68	45.22	45.99
% of time standing	—	—	2.09	1.15	4.75	0.48	6.94	3.30
Average trip speed $\left(\frac{km}{hr}\right)$	—	—	53.32	51.86	56.16	59.39	43.61	45.43
Average driving speed $\left(\frac{km}{hr}\right)$	—	—	54.46	52.46	58.95	59.68	46.86	46.98
Standard deviation of speed	—	—	60.84	60.80	64.05	65.26	54.74	53.91
Maximum speed $\left(\frac{km}{hr}\right)$	—	—	113.83	112.11	117.83	114.94	113.64	100.32
Average acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.00	0.00	0.00	0.00	0.00	0.00
Average positive acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.48	0.48	0.53	0.47	0.54	0.55
Average negative acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.53	0.51	0.61	0.49	0.57	0.61
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.67	0.69	0.74	0.64	0.72	0.77

Table 13. Characteristics of logged data on Wednesday, July 27, 2022, for the Persia

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name (*.gpx*)	—	—	20,220,727–122,926—39	20,220,727–124,554—40	20,220,727–162,604—41	20,220,727–164,236—42	20,220,727–203,016—44	20,220,727–204,813—43
Total distance (km)	—	—	14.17	13.80	14.17	13.79	13.81	14.18
Total time (s)	—	—	937	891	928	834	1,031	992
Driving time (s)	—	—	924	888	902	829	998	984
Cruise time (s)	—	—	0	0	0	0	0	0
Drive time spent accelerating (s)	—	—	491	452	527	431	528	489
Drive time spent decelerating (s)	—	—	433	436	375	398	470	495
Standing time (s)	—	—	13	3	26	5	33	8
% of time driving	—	—	98.61	99.66	97.20	99.40	96.80	99.19
% of time cruising	—	—	0	0	0	0	0	0
% of time accelerating	—	—	52.40	50.73	56.79	51.68	51.21	49.29
% of time decelerating	—	—	46.21	48.93	40.41	47.72	45.59	49.90
% of time standing	—	—	1.39	0.34	2.80	0.60	3.20	0.81
Average trip speed $\left(\frac{km}{hr}\right)$	—	—	54.42	55.74	54.98	59.53	48.22	51.47
Average driving speed $\left(\frac{km}{hr}\right)$	—	—	55.19	55.93	56.57	59.89	49.81	51.88
Standard deviation of speed	—	—	62.41	62.93	61.05	65.57	56.25	59.04
Maximum speed $\left(\frac{km}{hr}\right)$	—	—	122.69	116.22	111.21	113.91	116.96	106.88
Average acceleration $\left(\frac{m}{s^2}\right)$	—	—	0	0	0	0	0	0
Average positive acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.51	0.52	0.47	0.48	0.53	0.54
Average negative acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.58	0.54	0.66	0.52	0.60	0.53
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.73	0.74	0.73	0.68	0.74	0.73

Table 14. Characteristics of logged data on Thursday, July 28, 2022, for the Persia

Time of the day	Morning		Noon		Evening		Night	
Onward/Return	Onward	Return	Onward	Return	Onward	Return	Onward	Return
File name $(.gpx)$	—	—	20,220,728–123, 511—45	20,220,728–125, 130—46	20,220,728–163, 126—47	20,220,728–164, 644—48	—	—
Total distance (km)	—	—	14.15	13.81	14.13	13.82	—	—
Total time (s)	—	—	910	894	853	831	—	—
Driving time (s)	—	—	909	863	851	826	—	—
Cruise time (s)	—	—	0	0	0	0	—	—
Drive time spent accelerating (s)	—	—	491	461	450	424	—	—
Drive time spent decelerating (s)	—	—	418	402	401	402	—	—
Standing time (s)	—	—	1	31	2	5	—	—
% of time driving	—	—	99.89	96.53	99.77	99.40	—	—
% of time cruising	—	—	0	0	0	0	—	—
% of time accelerating	—	—	53.96	51.57	52.75	51.02	—	—
% of time decelerating	—	—	45.93	44.97	47.01	48.38	—	—
% of time standing	—	—	0.11	3.47	0.23	0.60	—	—
Average trip speed $\left(\frac{km}{hr}\right)$	—	—	56.00	55.62	59.62	59.88	—	—
Average driving speed $\left(\frac{km}{hr}\right)$	—	—	56.06	57.61	59.76	60.24	—	—
Standard deviation of speed	—	—	63.15	63.09	64.89	64.18	—	—
Maximum speed $\left(\frac{km}{hr}\right)$	—	—	115.18	110.91	99.43	104.29	—	—
Average acceleration $\left(\frac{m}{s^2}\right)$	—	—	0	0	0	0	—	—
Average positive acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.50	0.47	0.49	0.46	—	—
Average negative acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.59	0.54	0.55	0.49	—	—
Standard deviation of acceleration $\left(\frac{m}{s^2}\right)$	—	—	0.72	0.69	0.69	0.65	—	—

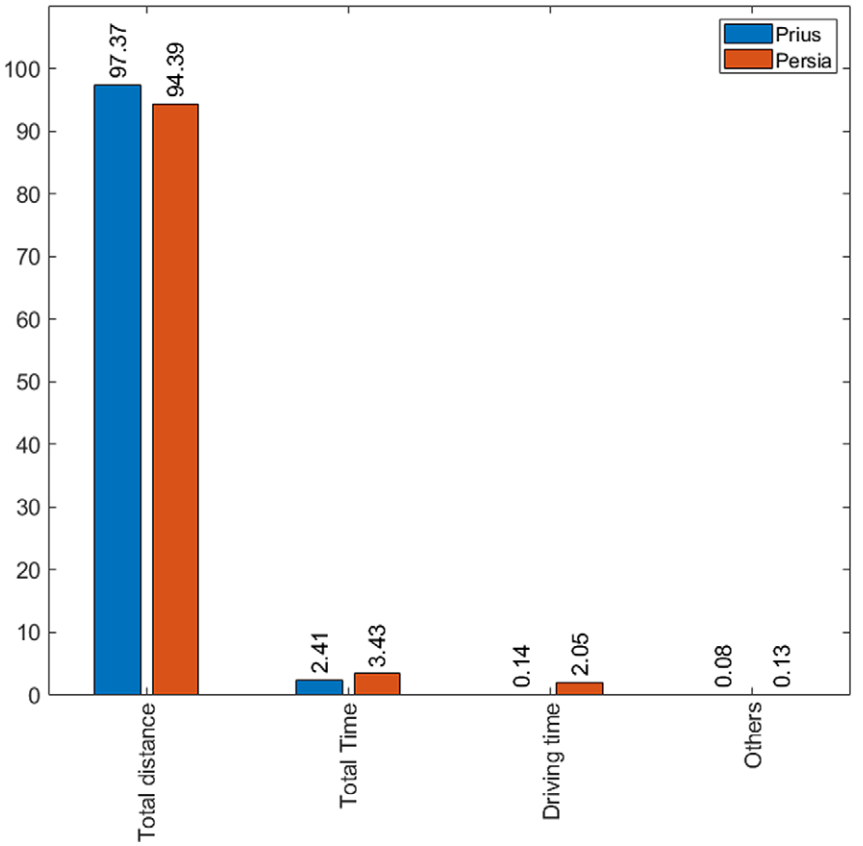

Figure 1. Relative PCA coefficients of both vehicles.

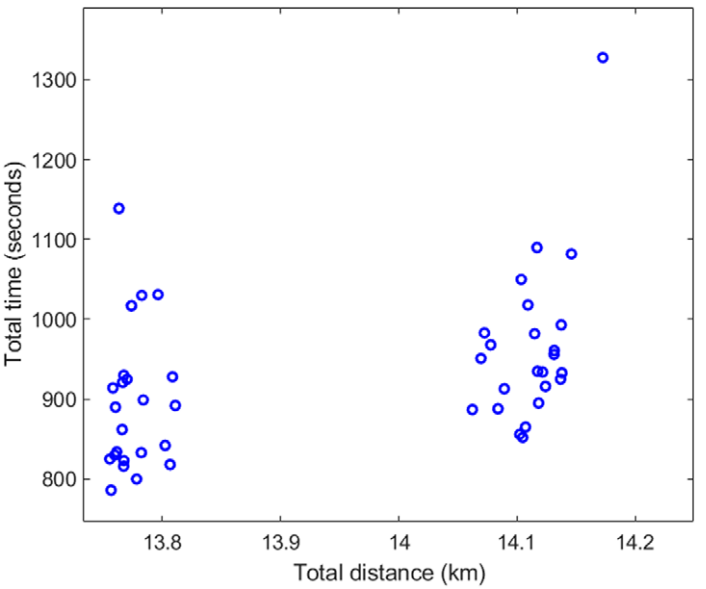

Figure 2. The scatter plot for two main parameters of data for the Prius.

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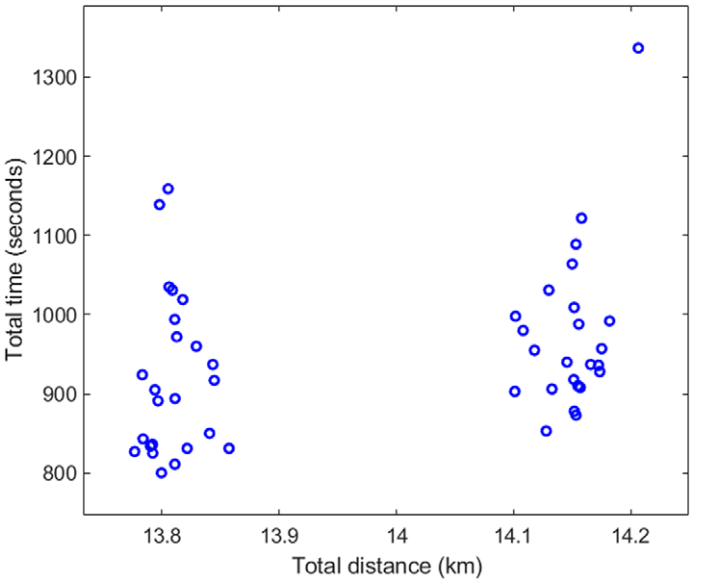

Figure 3. The scatter plot for two main parameters of data for the Persia.

Table 15. The fuel consumption for the Prius in the onward route based on ECU data

Fuel consumption (L/100 km)	Morning	Noon	Evening	Night
Thursday	—	—	—	—
Friday	—	—	—	—
Saturday	4.7	5.2	5.2	3.7
Sunday	4.6	5.1	6.1	4.0
Monday	—	5.2	5.7	4.9
Tuesday	—	—	—	—
Wednesday	—	5.2	6.0	4.2
Thursday (repeated)	—	5.9	6.0	—

in the evening. On Fridays, the average speed was found to be higher than that of the other days, since this day of the week is a holiday in Iran and consequently the traffic condition is lighter.

Finally, to monitor and control traffic conditions that affect driving cycles, new technologies will need to be developed. As an example, Khosravi et al. (2023) presented a method to predict crowd emotion to understand more about human–vehicle interaction, using fuzzy logic ranking and modified transfer learning techniques. In this study, they utilized unmanned aerial vehicles with video surveillance capabilities to improve citywide traffic flow.

To discuss more the relationship between this data article and the literature (Khosravi et al., 2023), it should be noted that the current study collected raw driving data from passenger cars in Semnan to gain a better understanding of traffic conditions and inform the improvement of urban transportation systems. This research contributes to the broader goal of creating more efficient and safe smart cities through the use of modern technology, which is a common goal also shared by other studies, such as the aforementioned research by Khosravi et al. (*2023*). Thus, while this dataset focuses on driving data collection and

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Table 16. The fuel consumption for the Prius in the return route based on ECU data

Fuel consumption (L/100 km)	Morning	Noon	Evening	Night
Thursday	—	—	—	—
Friday	—	—	—	—
Saturday	4.1	4.3	4.9	4.5
Sunday	4.0	4.4	4.4	5.3
Monday	—	4.3	4.6	5.3
Tuesday	—	—	—	—
Wednesday	—	4.7	4.6	5.6
Thursday (repeated)	—	4.4	4.2	—

Table 17. The average speed of the Prius in the onward route based on ECU data

Average speed (km/hr)	Morning	Noon	Evening	Night
Thursday	52.4	51.6	57.1	48.4
Friday	56.8	58.8	59.4	49.9
Saturday	53.0	51.8	57.2	46.6
Sunday	55.6	54.4	53.3	38.4
Monday	—	53.3	55.6	41.7
Tuesday	—	—	—	—
Wednesday	—	54.5	54.6	51.3
Thursday (repeated)	—	55	59.7	—

Table 18. The average speed of the Prius in the return route based on ECU data

Average speed (km/hr)	Morning	Noon	Evening	Night
Thursday	55.8	53.6	59.1	48.8
Friday	62.1	60.3	63.1	53.9
Saturday	57.6	53.6	60.1	48.2
Sunday	60.8	53.9	60.8	43.5
Monday	—	54.3	59.7	48.2
Tuesday	—	—	—	—
Wednesday	—	55.3	59.5	48.8
Thursday (repeated)	—	55.7	59.6	—

analysis, it aligns with other research on modern technology to improve traffic flow and safety in smart cities. The combination of these approaches can lead to more efficient and safe urban environments, where transportation systems and public safety are improved through advanced technology and innovative methods.

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Figure 4. (a) A map of Semnan and the road conditions, with the route of data acquisition: (b) onward and (c) return.

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Experimental design, materials, and methods

In this study, the impact of traffic conditions on driving data is presented for the city of Semnan in Iran. The map of this city and the road conditions are presented in Figure 4a. In this image, different roads with various speed limits are also illustrated, such as expressways (110 km/hr), main roads (80 km/hr), secondary roads (60 km/hr), and branch roads (40 km/hr).

In order to acquire driving data, two passenger cars or vehicles were used. One was a hybrid car combining an internal combustion engine with an electric module (the Toyota Prius), and another one had only an internal combustion engine (the Peugeot Pars, also known as the IKCO [IranKhodro Company] Persia in Iran, too). GPS sensors have been used for logging coordination data such as longitude, latitude, elevation, speed, and local time. For the route, the start point of the data logging was at Azad University, and the destination was Imam Market, both within the city. After reaching the goal, the driver took a brief break and returned the cars to the start point using the same roads. The route of data acquisition is depicted in Figure 4a,b, including 13.2 km of the onward journey and 15.6 km of the return journey.

It should be noted that the drivers for the Prius and Persia were men aged 33 and 25 years old, with 18 and 5 years of driving experience, respectively. Moreover, in the selected route, the Prius was followed by the Persia.

Based on this procedure, for about 670 km and 13 hours, driving data were acquired for 7 days. The above procedure was repeated every day for one week (except Tuesday, and twice on Thursday) and for four different times of the day (morning, noon, evening, and night). Details of data acquisition can be found in Table 19 for July 21–28, 2022 (from 07:00 to 22:00). In this table, light, moderate, and heavy traffic has been denoted by green, orange, and red colors, respectively; these data were obtained from Google Maps.

The traffic condition in Semnan could be compared to Mashhad, also a city in Iran, as presented in a study by Pouresmaeili et al. (2018). They found that by the hourly measurements of air pollutant stations in Mashhad, the peak hour in the morning was found to be between 7:00 and 09:00, and in the afternoon it was between 16:00 and 18:00. However, these peaks were found to be between 12:00 and 12:30 in the morning and between 20:00 and 21:30 in the evening in Semnan city. It means that the configuration of the city has an impact on traffic conditions, even when both cities are located in one country (Iran).

In other words, the driving cycle consequently needs to be developed for each city, separately. As a confirmation, Kamble et al. (2009) illustrated that the traffic condition in Pune (India) had large fluctuations due to heterogeneity and congestion, leading to higher variations in the vehicle speed, deceleration, and acceleration values.

The initial data can be found in the Mendeley Data (Azadi & Shahsavand, 2023). These data include the speed *versus* the time, plus the GPS data (, and altitude).

Notably, each piece of data included the following: a "TXT" file, a piece of general information about the GPS data; a "GPX" file, a GPS exchange format, which is an XML file that is designed for the GPS data in the software applications; and a "KML" file, which is used to demonstrate the geographic data in an Earth browser).

Because of the low GPS accuracy of the utilized device for speed measurement, the car speed for each instant could be calculated using discrete derivatives of the car position. For this problem, the raw GPS data were imported to MATLAB using the "*gpxread*" command, as follows,

```
P = gpxread('file.gpx');
```

where "file.gpx" refers to the file name of the raw data in the GPX file format. After the execution of the above line of code, the variable *P* would be a geo-point vector with feature properties.

The number of the collected points would be,

```
N = length(P.latitude);
```

Although this number could be found within the "TXT" format file, the GPX format was used for convenience. It could be possible to get the number of collected points using other properties instead of

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Table 19. The time of data acquisition in Semnan

Time	Morning								Noon							
Day	7:00	7:30	8:00	8:30	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30
Thu					X							X				
Fri					X							X				
Sat					X							X				
Sun				X								X				
Mon					X							X				
Tue					X							X				
Wed					X							X				

Time	Evening								Night							
Day	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	
Thu				X								X				
Fri				X								X				
Sat				X								X				
Sun				X								X				
Mon				X								X				
Tue				X								X				
Wed				X								X				

Note. X shows the time of data acquisition. A red-X means no data, while a blue-X means data at different times, due to limitations.

latitude. The "*geopoint*" also contains the recorded time of the GPS, though the format differs and should be converted to be recognized as a "*datetime*" class of MATLAB,

```
timeStr = strrep(P.Time,'Z',' ');
timeStr = strrep(timeStr,'T',' ');
t = datetime(timeStr);
```

The letters 'Z' and 'T' have to be removed in order to avoid getting errors. Finally, "*datetime*" function will convert the "*cell*" array to the "*datetime*" class. In the next step, the calculation of the distance between the collected points is required. Fortunately, MATLAB has a function for this problem as well,

```
e = wgs84Ellipsoid;
lat = P.latitude;
lon = P.longitude;
d = distance(lat(1:end-1), lon(1:end-1), lat(2:end), lon(2:end), e);
```

where "*wgs84Ellipsoid*" is the Reference ellipsoid for World Geodetic System 1984, and the "*distance*" function calculates the distance between the points on a sphere or an ellipsoid. By knowing the distance between the points, the velocity and the acceleration between every two points could be calculated; but first, the format of the date should be changed to seconds. Function "*datenum*" changes the "*datetime*" class to "*double*" (days number).

```
day2seconds = 24*3600;
dt = day2seconds*datenum(diff(t));
v = d./dt * 3.6;
v =[ v 0] ;
a = diff(v/3.6)./dt;
a =[ a 0] ;
```

where d, dt, v, and a are the distance, elapsed time, mean velocity, and mean acceleration between two data points, respectively. By knowing these values at each instance, the generation of the drive cycle can begin. The following equations have been derived from the literature (Onyekpe et al., 2021), with which the characteristics of the data can be demonstrated. The following definitions of the parameters are applied to n data rows of time in seconds, and i is the selected element of time, with $1 \le i \le n$ and for velocities $1 \le i < n$.

The total time, the total stop time, and the total distance of the data could be calculated as

$$T_{total} = t_2 - t_1 + \sum_{i=2}^{n} (t_i - t_{i-1}) \tag{1}$$

$$T_{stop} = \begin{cases} t_2 - t_1, & (v_1 = 0 \cap a_1 = 0) \\ 0, & (else) \end{cases} + \sum_{i=2}^{n} \begin{cases} t_i - t_{i-1}, & (v_i = 0 \cap a_i = 0) \\ 0, & (else) \end{cases} \tag{2}$$

$$dist = (t_2 - t_1)\frac{v_1}{3.6} + \sum_{i=2}^{n} (t_i - t_{i-1})\frac{v_i}{3.6} \tag{3}$$

where t_i, v_i, and a_i are the i-th elements of the local GPS time, vehicle velocity, and vehicle acceleration, respectively, and n is the number of data points collected. Having Equations (1) and (2), the "*driving time*" could be evaluated by Equation (4). Furthermore, the equations of "*driving time spent accelerating*" and "*decelerating*" are Equations (5) and (6), respectively.

$$T_{drive} = T_{total} - T_{stop} \tag{4}$$

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$$T_{acc} = \begin{cases} t_2 - t_1, & (a_1 > acc\_threshold) \\ 0, & (else) \end{cases} + \sum_{i=2}^{n} \begin{cases} t_i - t_{i-1}, & (a_i > acc\_threshold) \\ 0, & (else) \end{cases} \tag{5}$$

$$T_{dec} = \begin{cases} t_2 - t_1, & (a_1 < -acc\_threshold) \\ 0, & (else) \end{cases} + \sum_{i=2}^{n} \begin{cases} t_i - t_{i-1}, & (a_i < -acc\_threshold) \\ 0, & (else) \end{cases} \tag{6}$$

in which, the "*acc_threshold*" is one of the drive cycle parameters and should be determined considering the accumulation error of the sensors. This absolute value of the parameter defines if there is any acceleration or deceleration. According to Equations (4) and (5), the *cruise* time of the vehicle could be calculated as follows,

$$T_{cruise} = T_{drive} - T_{acc} - T_{dec} \tag{7}$$

In addition, the percentage of T_{drive}, T_{cruise}, T_{acc}, T_{dec}, and T_{stop}, according to T_{total}, are represented in Equations (8) to (12).

$$\%drive = \frac{T_{drive}}{T_{total}} \tag{8}$$

$$\%cruise = \frac{T_{cruise}}{T_{total}} \tag{9}$$

$$\%acc = \frac{T_{acc}}{T_{total}} \tag{10}$$

$$\%dec = \frac{T_{dec}}{T_{total}} \tag{11}$$

$$\%stop = \frac{T_{stop}}{T_{total}} \tag{12}$$

Equations (13) and (14) are related to "*average speed*" for a trip and "*average driving speed*", using Equations (1), (3), and (4). Note that the unit of the "*dist*" is meters and the unit of all times is stated in seconds, though the fraction will be in $\frac{m}{s}$. By multiplying 3.6, the unit changes to $\frac{km}{h}$.

$$\overline{v}_{trip} = 3.6\frac{dist}{T_{total}} \tag{13}$$

$$\overline{v}_{drive} = 3.6\frac{dist}{T_{drive}} \tag{14}$$

The equation of "*standard deviation of speed*" is stated in Equation (15)). Note that *v_sd* corresponds to $\overline{v}_{trip}$ and again the velocities are stated in $\frac{km}{hr}$.

$$v\_sd = \sigma_v = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} v_i^2} \tag{15}$$

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$$v_{max} = \max(v) \tag{16}$$

The same formulations are available for the acceleration of the vehicle in the unit of $\frac{m}{s}$ as follows,

$$a\_av = \overline{a} = \frac{1}{T_{total}} \sum_{i=1}^{n} a_i \tag{17}$$

$$a\_pos\_av = \overline{a}_{pos} = \left(\sum_{i=1}^{n} \begin{cases} 1, & (a_i > 0) \\ 0, & (else) \end{cases} \right)^{-1} \sum_{i=1}^{n} \begin{cases} a_i, & (a_i > 0) \\ 0, & (else) \end{cases} \tag{18}$$

$$a\_neg\_av = \overline{a}_{neg} = \left(\sum_{i=1}^{n} \begin{cases} 1, & (a_i < 0) \\ 0, & (else) \end{cases} \right)^{-1} \sum_{i=1}^{n} \begin{cases} a_i, & (a_i < 0) \\ 0, & (else) \end{cases} \tag{19}$$

$$a\_sd = \sigma_a = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} a_i^2} \tag{20}$$

For sensitivity analysis in the previous part, the PCA of raw data was used. For more information about this technique, the references (Barlow et al., 2009; Jackson, 1988; Jolliffe, 2002; Joubert & Grabe, 2022; Krzanowski, 1988; Miri et al., 2022; Roweis, 1998; Seber, 1984; Wawage & Deshpande, 2022) are recommended. Fortunately, there is a MATLAB function called "pca" in which there are a lot of options to use this method. The following command shows its input and outputs:

```
[ coeff, score, latent, tsquared, explained, mu] = pca(X).
```

In the outputs, "*coeff*" is a short term for the PCA coefficients, which are also known as loadings in matrix X. The function returns the PCA scores and variances in the score and latent, respectively. For each observation in X, the function returns the Hotelling's T-squared statistic in the variable of "*tsquared*". In addition, the percentage of the total variance that is explained by each PCA and the estimated mean data in X are returned in explained and "mu", respectively. Further information about how to use other inputs and plenty of examples are available in the MATLAB "pca" function document.

Finally, as a brief issue on the importance and the value of these data, the following points could be mentioned,

- The proposed raw data could be used for further investigations on the final driving cycle, measuring the fuel consumption and emissions, *etc.*, in Semnan or other similar cities.
- These driving data are useful for design engineers in the field of city management or in the transportation or manufacturing vehicles.
- The dataset could be further utilized in analyzing the real driving emission (RDE), which is now under the consideration of countries for environmental laws.
- Moreover, researchers could use these raw data for any of their analyses of traffic and vehicles, both in civil and mechanical engineering.
- Governments could be another beneficiary for designing and managing the city.

Conclusions

Raw driving data was acquired for two passenger cars in the city of Semnan in Iran. The impact of traffic conditions during morning, noon, evening, and night on this data were then considered.

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- Two male drivers, ages 33 and 25 years old, drove the Toyota Prius and the Peugeot Pars (or the IKCO Persia) to acquire driving data for 670 km (13 hrs) over a week (July 21–28, 2022).
- Using the GPS application, the data on speeds were acquired for both vehicles, in addition to the fuel consumption and the average speed (for initial verification of the application data) data collected through the ECU in the Prius.
- Based on the initial sensitivity analysis, the features of raw driving data were checked, and it was found that the "*total distance*" was the most effective feature. The "*total time*" feature ranked second and was evaluated at almost 2.4% for all logged data.

This raw data could be used by engineers to develop a driving cycle in Semnan for any design of vehicles and their related components, or any evaluation of emissions and fuel consumptions, or, also, any considerations in the transportation system in the future.

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Open peer review. To view the open peer review materials for this article, please visit http://doi.org/10.1017/exp.2023.11.

Data availability statement. The raw data could be found at Azadi and Shahsavand (2023).

Author contribution. Formal analysis: A.M.; Investigation: A.M., M.A.; Resources: A.M., M.A.; Software: A.M.; Writing – original draft: A.M., M.A.; Conceptualization: M.A.; Data curation: M.A.; Funding acquisition: M.A.; Methodology: M.A.; Project administration: M.A.; Supervision: M.A.; Validation: M.A.; Visualization: M.A.; Writing – review & editing: M.A.

Authorship contribution. Conceptualization: M.A.; Data curation: M.A., A.S.; Formal analysis: A.M., A.S.; Funding acquisition: M.A., A.S.; Investigation: M.A., A.M., A.S.; Methodology: M.A., A.M.; Project administration: M.A.; Resources: M.A., A.S.; Software: A.M.; Supervision: M.A.; Validation: M.A.; Visualization: M.A., A.M., A.S.; Writing–original draft: A.M.; Writing–review & editing: M.A.

Competing interest. The authors declare that they have no known competing financial interests or personal relationships.

References

Abas, M. A., Rajoo, S., & Abidin, S. F. Z. (2018). Development of Malaysian urban drive cycle using vehicle and engine parameters. *Transportation Research Part D: Transport and Environment*, **63**, 388–403.

Azadi, M., & Shahsavand, A. (2023). Driving data in Semnan city. Mendeley Data V1. doi:10.17632/x9sydhfkyy.1; https://data.mendeley.com/datasets/x9sydhfkyy/1.

Balsa-Barreiro, J., Valero-Mora, P. M., Menendez, M., & Mehmood, R. (2020). Extraction of naturalistic driving patterns with geographic information systems. *Mobile Networks and Applications*. https://doi.org/10.1007/s11036-020-01653-w

Barlow, T. J., Latham, S., McCrae, I. S., & Boulter, P. G. (2009). A reference book of driving cycles for use in the measurement of road vehicle emissions. TRL Published Project Report.

Chugh, S., Kumar, P., Muralidharan, M., Kumar, M., Sithananthan, M., Gupta, A., Basu, B., & Malhotra, R. K. (2012). Development of Delhi driving cycle: A tool for realistic assessment of exhaust emissions from passenger cars in Delhi. SAE Technical Paper, no. 2012-01-0877.

Fotouhi, A., & Montazeri-Gh, M. (2013). Tehran driving cycle development using the k-means clustering method. *Scientia Iranica*, **20**, 286–293.

Gebisa, A., Gebresenbet, G., Gopal, R., & Nallamothu, R. B. (2021). Driving cycles for estimating vehicle emission levels and energy consumption. *Future Transportation*, **1**, 615–638.

Jackson, J. E. A. (1988). *User's guide to principal components*. Wiley.

Jolliffe, I. T. (2002). *Principal component analysis*. Springer.

Joubert, J. W., & Grabe, R. J. (2022). Real driving emissions data: Isuzu FTR850 AMT. *Data Brief*, **41**, 107975.

Kamble, S. H., Mathew, T. V., & Sharma, G. K. (2009). Development of real-world driving cycle: Case study of Pune, India. *Transportation Research Part D: Transport and Environment*, **14**, 132–140.

Khosravi, M. R., Rezaee, K., Moghimi, M. K., Wan, S., & Menon, V. G. (2023). Crowd emotion prediction for human-vehicle interaction through modified transfer learning and fuzzy logic ranking. *IEEE Transactions on Intelligent Transportation Systems*, https://doi.org/10.1109/TITS.2023.3239114.

Krzanowski, W. J. (1988). *Principles of multivariate analysis*. Oxford University Press.

Lejri, D., Can, A., Schiper, N., & Leclercq, L. (2018). Accounting for traffic speed dynamics when calculating COPERT and PHEM pollutant emissions at the urban scale. *Transportation Research Part D: Transport and Environment*, **63**, 588–603.

Miri, S. E., Azadi, M., & Pakdel, S. (2022). Development of a duty cycle with K-means clustering technique for hydraulic steering in an instrumented TIBA vehicle. *Transportation Engineering*, **8**, 100114.

Onyekpe, U., Palade, V., Kanarachos, S., & Szkolnik, A. (2021). IO_VNDB: Inertial and odometry benchmark dataset for ground vehicle positioning. *Data Brief*, **32**, 106885.

Pouresmaeili, M. A., Aghayan, I., & Taghizadeh, S. A. (2018). Development of Mashhad driving cycle for passenger car to model vehicle exhaust emissions calibrated using on-board measurements. *Sustainable Cities and Society***36**, 12–20.

Roweis, S. (1998). EM algorithms for PCA and SPCA. In *Proceedings of the Conference on Advances in Neural Information Processing Systems*. MIT Press.

Seber, G. A. F. (1984). *Multivariate observations*. Wiley.

Wawage, P., & Deshpande, Y. (2022). Smartphone sensor dataset for driver behavior analysis. *Data Brief*, **41**, 107992.

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Peer Reviews

Reviewing editor: Dr. Daniel Micallef
University of Malta, Environmental Design, Tal-Qroqq, Msida, South, Malta, MSD2080

Minor revisions requested.

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Review 1: Raw driving data by passenger cars considering traffic conditions in Semnan city

Reviewer: M. Masih Tehrani

Date of review: 10 March 2023

Conflict of interest statement. Reviewer declares none.

Comment

Comments to the Author: The comments are attached

Score Card

Presentation

4.0 /5

Is the article written in clear and proper English? (30%)	4/5
Is the data presented in the most useful manner? (40%)	4/5
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Analysis

4.0 /5

Does the discussion adequately interpret the results presented? (40%)	4/5
Is the conclusion consistent with the results and discussion? (40%)	4/5
Are the limitations of the experiment as well as the contributions of the experiment clearly outlined? (20%)	4/5

doi:10.1017/exp.2023.11.pr2

Review 2: Raw driving data by passenger cars considering traffic conditions in Semnan city

Reviewer: Dr. Shaohua Wan

Date of review: 03 April 2023

Conflict of interest statement. Reviewer declares none.

Comment

Comments to the Author: 1. The research background still needs in-depth analysis.

2. The authors should include more related and recent references into discussion, such as:DOI: 10.1109/TITS.2023.3239114.

3. need more to discuss your results.

4. Suggest to introduce more references in the discussion to compare and analyze your results.

5. The conclusion section needs to focus on the practical effectiveness of the innovation point of the article.

6. What are the shortcomings of the study and future prospects.

Score Card

Presentation

3.0 /5

Is the article written in clear and proper English? (30%)	3/5
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Analysis

3.0 /5

Does the discussion adequately interpret the results presented? (40%)	3/5
Is the conclusion consistent with the results and discussion? (40%)	3/5
Are the limitations of the experiment as well as the contributions of the experiment clearly outlined? (20%)	3/5