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Data-driven decarbonization: Optimizing P+R in Istanbul with machine learning energy modeling and ITS

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Due to the rapidly developing technologies, fast and practical solutions are offered to the problems encountered in daily life. Metropolitan cities are greatly affected by the ever-increasing population and migrations to big cities, the increase in production with the economy and job opportunities. At this point, with the introduction of smart transportation systems, fast and effortless solutions can be produced by saving time and space. City life can be facilitated by applying more efficient and rational solutions with smart transportation systems. In this study, it is aimed to investigate information about the Intelligent Transportation Systems and one of its applications, park and ride, which has created a significant agenda within the scope of transportation engineering in the recent past, and to provide information about the investments made by examining the application for Istanbul along with its various applications in the world. Some suggestions will be made by emphasizing the importance of the park and Ride smart city application for Istanbul. In conclusion, predictions of P + R application and energy consumption in periods of 1–24 months were made through machine learning. By obtaining energy consumption data thanks to machine learning, carbon gas emissions and its effects on greenhouse gases were also examined. It can be thought that by obtaining energy consumption data for the long term thanks to machine learning, it can make significant contributions to future investments, green environment-green world, and climate change studies.

KEYWORDS

park and ride, smart city, machine learning, carbon emission, climate change, energy research

1 Introduction

Migration to metropolises and rapid population growth, lack of infrastructure and the increasing number of vehicles on the road and rapid consumption in proportion to the increase in people's income levels; It brought along problems such as transportation problems, traffic congestion and increased carbon emissions. In Istanbul, which is a cosmopolitan city, it emerges as a priority solution area to encourage the public transportation sector in cities where the demand for the road exceeds the capacity, travel times are prolonged, delays to the desired destination are experienced, and it is difficult to find a parking space.

There is a need for smart transportation applications that work in an integrated way that combines more than one type of transportation in order to prevent traffic density, parking space, accumulation and loss of time. At this point, with the use of the "Park and Ride"

application in Istanbul, which is a metropolitan and crowded city, people can park their vehicles far from the center and continue with public transport, thus saving energy and fuel in the shortest possible way without wasting time to their destination. With the use of the park and ride smart city application and prefer public transportation instead of individual vehicles, it becomes possible to reduce the confusion and the traffic. In addition, it is necessary to encourage public transportation and facilitate access to public transportation through practices such as the park-and-ride application. With the increase in access to public transportation, smart city applications such as park-and-ride will become more functional.

In this study, firstly reviewed the existing literature on P + R systems, exploring their effectiveness in different contexts and their advantages in reducing traffic congestion and environmental impacts. Then, examined the P + R system implemented in Istanbul and discussed its conceptual definition, structure and classification with examples from around the world. It is analyzed the effectiveness of the P + R system in Istanbul as a smart city application. Then covered planning and design considerations of P + R facilities, including accessibility, safety, and integration with other modes of transportation. It is used Istanbul as a case study to demonstrate the implementation and benefits of P + R systems in a major metropolis. Finally, it is examined the application of machine learning in predicting energy consumption due to P + R usage. Data on factors such as wait times, travel times, and P + R usage patterns are analyzed to estimate potential energy savings from implementing P + R systems. In conclusion, it is showed that P + R systems and machine learning can play an important role in improving urban transport efficiency and reducing environmental impact. Future research should focus on evaluating the effectiveness of P + R systems in different cities and developing policies to encourage the adoption of these systems.

2 Literature review

The P + R application can be expressed as a temporary parking lot along public transportation roads in rural areas in the United States (Noel, 1988). According to the study of Spillar in the literature; Thanks to the Park and Go system, which includes more than one type of transportation integrated with each other, an alternative mode of transportation is provided to people who use individual vehicles by directing them to public transportation (Spillar, 1997).

Population density is increasing day by day with the increase of alternatives and developments in the hope of finding a job in İstanbul. The concept of parking in Istanbul has started to become a problem. In Istanbul, 49% of the traffic is composed of reasons such as searching for a parking space or stopping for parking (Güngör, 2017).

Park-and-ride car parks, which encourage public transportation from private vehicles used individually in İstanbul, are a highly used solution on the metrobus line. In addition, as a result of considering and projecting the park-and-ride facilities, which are built synchronously with public transportation systems, they can contribute to the minimization of traffic problems in the city center and to the regular progress of public transportation (Yalınız and ve Bilgiç, 2007; Gurbetci et al., 2014). A study was conducted on the returns of regular public transport services in addition to stable and encouraging pricing policies in park-and-ride facilities (William et al., 2001). Gurbetçi et al. conducted a study on the benefits of P + R application such as reducing carbon dioxide emissions, less waiting times, saving time and less stressful travel (Gurbetci et al., 2007). The fact that the park-and-ride applications are based on the rail system is due to the fact that it is quickly accessible and the transportation is more practical, as can be seen in the example of the cities of Toronto, Hamburg and London (Weiss and Habib, 2017).

The presence of free shuttle services from the parking area to the stations of the rail systems in some P + R applications city of Malta in Floriana, also makes the P + R system attractive (Anonymous, 2019). However, in the UK, lighter rail systems work in integration with P + R systems, due to the fact that access to the center is made by bus in historical cities. In addition, there are partially P + R areas in Australia. The main reason why rail systems are preferred in the park-and-ride system is that they go underground and do not cause traffic (Mills and White, 2018). In achieving optimum efficiency in the planning of park-and-ride areas, the location of the facility is proportional to its economic evaluation and that can meet the needs of the society (Du and Wang, 2014). Bagloee et al. studied park-and-ride systems on optimum parking capacity and economy (Bagloee et al., 2012). Hendricks et al. also conducted a study to accurately predict real-time demand by observing user behavior in park-and-ride areas (Hendricks and Outwater, 1998; Hamer, 2010). Duncan et al. conducted research on the importance of cost-effectiveness and integration of park-and-ride systems with other vehicles (Duncan and Cook, 2014). In another study, Önder et al. made a modeling on routing to park-and-go systems in seven different selected regions and the fee for vehicle entrances; they found that the tendency to public transportation increased and there was a 23% decrease in using passenger cars (Önder and ve Kaplan, 2017).

According to Şimşek, in order to encourage park and ride areas in city centers and to make it economical; It would be beneficial to make useful arrangements, make public transport more attractive and promote P + R systems (Şimşek, 2014). According to another study by Baohong, 26% of drivers in Nanjing city in China do not prefer the P + R system due to the inadequacy of transfer services, uncomfortable transportation vehicles and the lack of suitable P + R areas (Baohong et al., 2012). The most inquire about objective of the article is to recognize partners impacting the economical improvement of energy-efficient e-scooter sharing frameworks based on Clean cities and allot them to diverse bunches. The cooperation of organizations taking part within the execution of bike sharing administrations can contribute to more prominent economical advancement and security by utilizing modern modes of versatility that expend less vitality and at the same time make the city vitality productive (Macioszek et al., 2023, Macioszek and Granà, 2022, Macioszek and Kurek, 2020).

3 Materials and methods

Linear regression may be a factual learning strategy utilized to show the direct relationship between two or more factors. This strategy clarifies a subordinate variable (more often than not the variable we need to predict) by a combination of autonomous factors (more often than not factors thought to impact the subordinate variable).

FIGURE 1
Table of P + R (Arkitera, 2022).

In this study, the conceptual definition, structure, classification and some examples from around the world of park and ride facilities are given. Various informations are given about the park and ride system applied in İstanbul which is a metropolitan city, and researches have been made about the importance of the park and ride facilities in İstanbul, and the operability of the P + R system as a smart city application.

3.1 Intelligent transportation systems and their benefits

The use of technologies created by utilizing technological developments in different areas for a high-performance, safe and efficient sustainable transportation system emerging in international road transportation is expressed as Intelligent Transportation Systems. In addition, smart transportation systems can be defined as the organization of operation and management of infrastructure and superstructure on highways by using information and communication technologies. Owing to smart transportation systems, it is possible to increase road safety, ensure a regular traffic flow, systematically manage traffic and infrastructures, and thus have a higher utilization rate compared to airline and railway (KGM, 2013).

With smart transportation systems applications, economic solutions are provided, parking search times are minimized and waiting and crowding can be prevented. It is effective in directing drivers quickly and effectively owing to intelligent transportation systems, ensuring a regular traffic flow without violating traffic rules, and guiding them to P + R areas in a practical way whose signboard shows in (Figure 1). In addition, it reduces the potential for accidents and can be effective in directing the safety and health units in the fastest and most accurate way in case of an accident, monitoring the vehicles carrying heavy and dangerous goods, and providing directives quickly and accurately in case of an emergency. Apart from these, new business opportunities can arise and revive the business sector thanks to the investment of innovative smart application systems.

3.2 Systemic structure of Parking Systems before change

In İstanbul which is a metropolitan city, it is important to have smart city applications in the face of congestion and increasing population. In spite of this, it indicates the distance of parks areas from the corporate architecture because of there are non-intelligent systems such as weak system structure for any corporate project, scattered data, occupation of similar business lines in different databases, adequate technical infrastructure on a daily basis and inability to receive instant data flow.

FIGURE 2
Pre-change system structure of parking systems (Macioszek and Granà, 2022).

The complex structure of camera, barrier and handheld terminal systems is shown in Figure 2. Because the data obtained from the field is stored locally and cannot be reported practically when requested, directing people towards different solutions. At this point, authorities has put into use applications in terms of smart transportation systems in Istanbul. By choosing information technology solutions for Istanbul card application, it has transformed from the classical corporate tradition into a brand new modern corporate identity equipped with technology. A forward-looking infrastructure has been created with applications such as big data and data mining for merging databases, and the equipment used in the field has been equipped with NFC-enabled systems, and the basis for the creation of the necessary infrastructure for the implementation of the Istanbul card has been prepared. Innovative solutions and technological developments have been provided with central management and data storage cloud technologies (İ.B.B. Faaliyet Raporu, 2015).

4 P + R systems and the sample of İstanbul city

4.1 P + R facilities planning

Park-and-ride areas are based on parking individual vehicles and then switching to public transport and ending the journey. The rest of the journey can be carried out by ferry and air vehicles, as well as by metro, tram or buses from public transportation vehicles. Park-and-ride facilities can be classified under two main headings according to their functions and distance from the destination (Özdemir, 2006).

Accessibility means that all facilities in the city are open and accessible without interruption. On the other hand, access from the surrounding areas can also be described as accessibility between

FIGURE 3
Söğütlüçeşme Park and Ride (ISPARK, 2022c).

FIGURE 4
Ünalan Metro Park and Ride (ISPARK, 2022a).

different types of transportation and for people with disabilities (Kuntay, 1990).

The security issue for park and ride can arise from physical and psychological needs, as well as to protect against physical attacks and theft. Developing solutions for security in the design of P + R facilities and positioning them accordingly can also be beneficial in terms of encouraging the facilities. In some countries, even the presence of official security officers was considered (Saraçoğlu, 2012).

It can be said that during the design and integration phase of P + R facilities, access to the facility with multiple alternatives and giving the necessary importance to pedestrian circulation may lead to a reduction in costs, low risks and low operating costs. Constructing high-rise buildings nearby together with park-and-ride facilities can increase the sense of security. This creates a sense that the facility is safer and has increased traceability, and adjacent areas and commercial activities can also increase the potential to attract more customers. Aesthetic designs that arise visibility can increase orientation and incentives for park-and-ride facilities. The fact that the facility can be an alternative to all accessible vehicles, giving importance to pedestrians and bicycles, can be conducive to the use of the facility with multiple modes of transportation. Rising accessibility can increase in direct proportion to the centralization of transportation services. Ways to increase that involves prioritizing bicycle and pedestrian access in and around the P + R facility and locating the P + R facility in the center of the development area (Bos, 2004).

In order for the park-and-ride facilities to operate efficiently and intensively, they must be designed in such a way that all design components such as pedestrians, bicycles and cars can easily, comfortably and safely transfer from the vehicles they use to public transportation systems.

4.2 Park and ride areas

P + R areas can be named as transfer areas from motor vehicles used individually to public transportation (AASHTO, 2004). İstanbul Metropolitan Municipality operates a system that is preferred by approximately 3.5 million İstanbul residents annually, considering to expand it and foresees public transportation, with its park-and-ride car parks with fourteen thousand vehicles capacity at approximately forty-four points in İstanbul. Thus, the intensity of traffic is reduced to a certain extent thanks to the park-and-ride facilities. Approximately three and a half million people in İstanbul continue their journeys by parking their cars in the park and ride car parks such as Söğütlüçeşme Park and Ride in Figure 3, after a short walking distance, by being transferred to alternative public transportations such as metro, tramway, marmaray, ferry or bus, and they can reach their desired

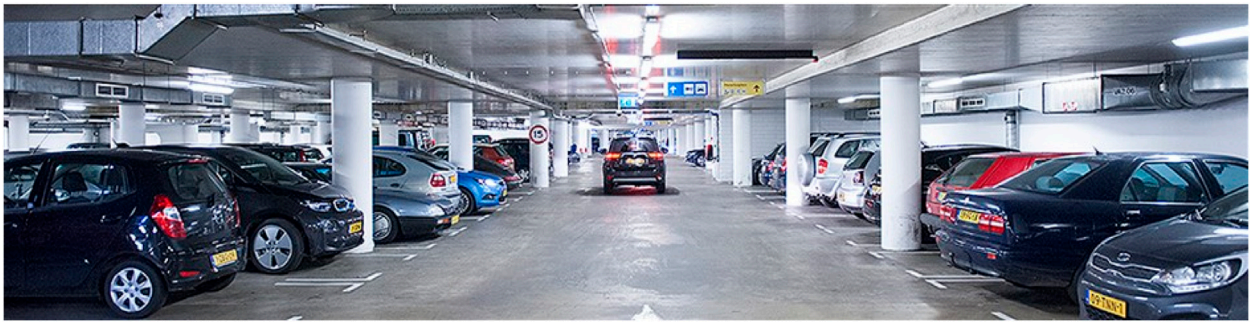

FIGURE 5
The city of Amsterdam Park and ride.

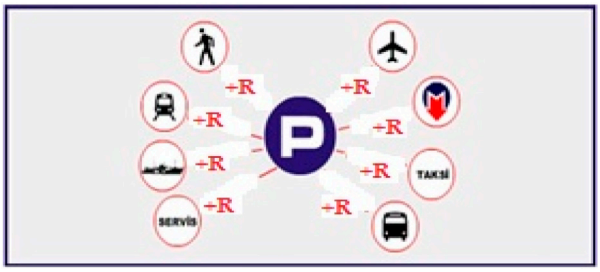

FIGURE 6
P + R System Elements (Arkitera, 2022).

destination on time, effortlessly and economically. With the park-and-ride application, it is estimated that approximately thirty-five thousand kilometers of vehicle convoys are withdrawn from the traffic every day. For example, the person who parks his vehicle in Kadıköy Ayrılıkçeşme car park can reach Yenikapı via Marmaray, to the airport via Aksaray Metro, or to Beylikdüzü as an alternative, via Metrobus, without any traffic stress. In addition to this, some incentive applications such as free ring service and discounts can also be directed to park-and-ride systems.

The park-and-ride car park at Ünalan stop, which is a very important transfer center in İstanbul, is shown in Figure 4. Owing to this P + R area, they can contribute to the reduction of traffic jam. Authorities whom has the park and continue with the metro project, is located on the Üsküdar-Ümraniye Metro line and started with the

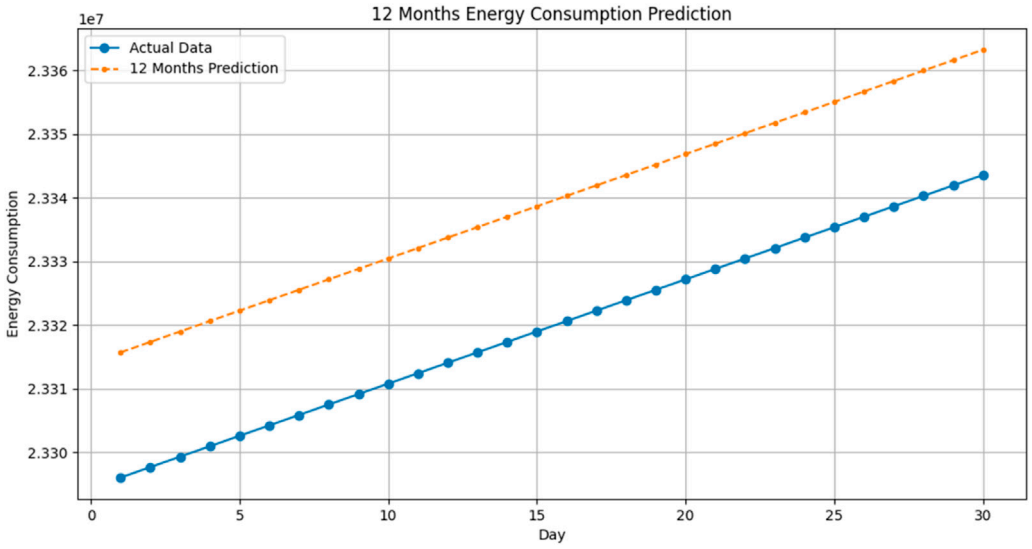

FIGURE 7
12 Months energy consumption prediction.

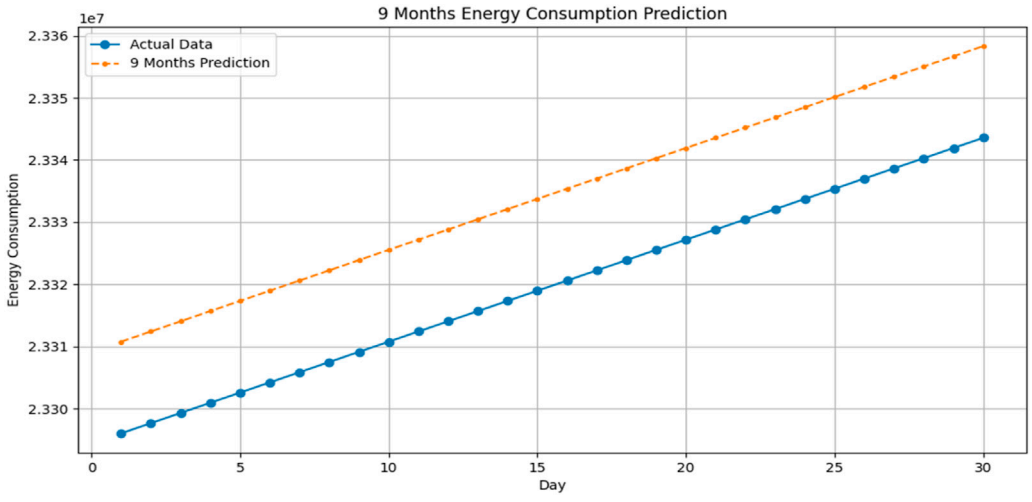

FIGURE 8
9 Months energy consumption prediction.

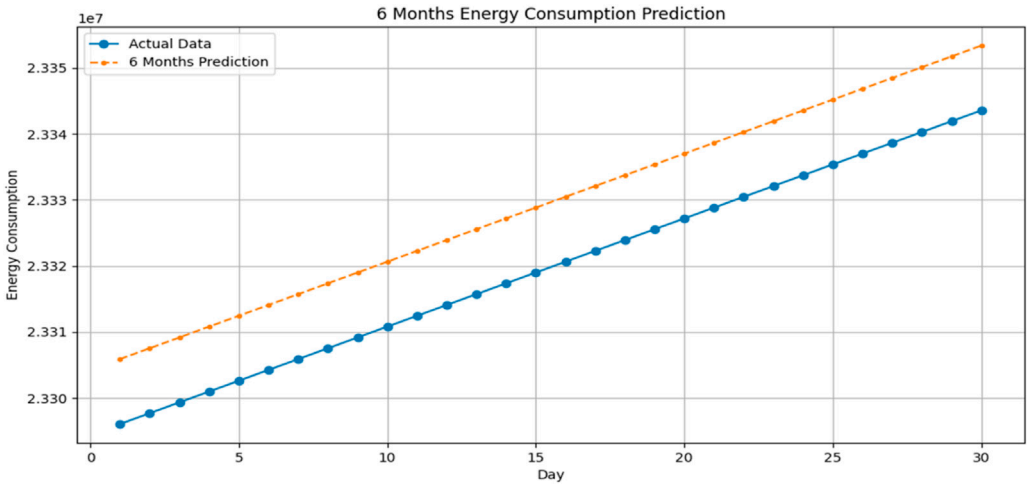

FIGURE 9
6 Months energy consumption prediction.

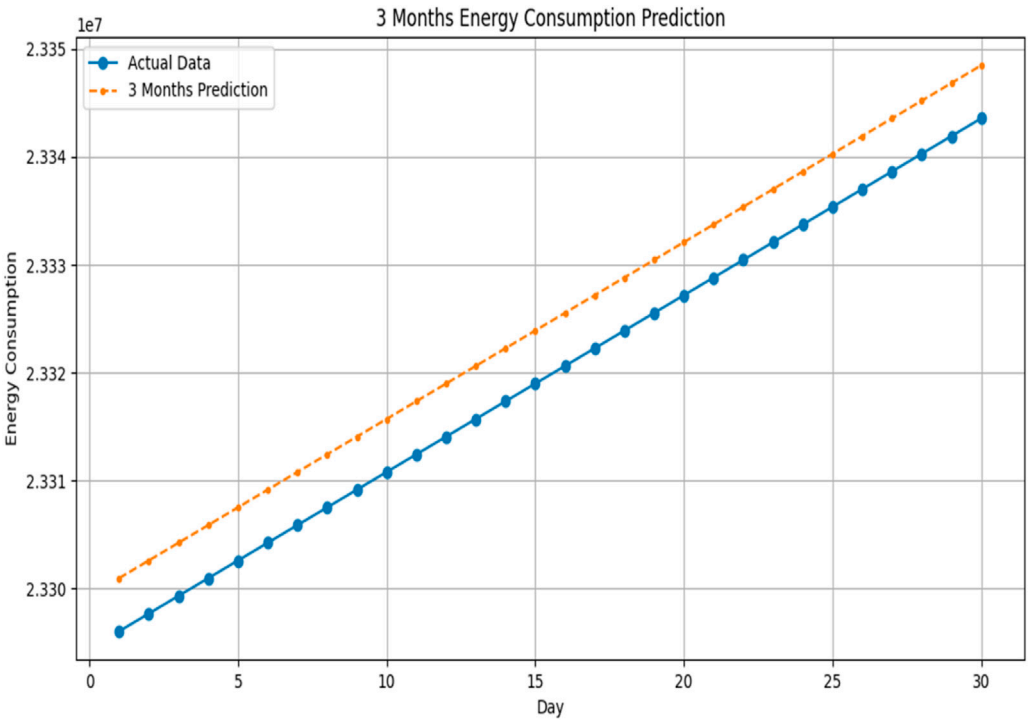

FIGURE 10
3 Months energy consumption prediction.

Haldun Alagaş Multi-Storey Car Park for the first time in Turkey, and Ümraniye Multi-Storey Central Open Car Park, Bağlarbaşı Multi-Storey Car Park, Altunizade Outdoor Car Park, Marmara Theology Car Park serves drivers with Üsküdar Municipality Multi-Storey Car Parks. In addition to these, Figure 5 was also shown abroad at the Amsterdam Park and Ride. Drivers who park their vehicles in car parks with a capacity of approximately 2,500 vehicles on this line can make the journey between Ümraniye and Üsküdar in a short time of 15 minutes without getting busy. In addition, they can continue their journey to Yenikapı route by using Marmaray or from Kadıköy to Kartal route by metro transfer center (ISPARK, 2022b).

Figure 6 shows the elements of the park-and-ride system operating in İstanbul. Here, it is seen that the individual vehicle can continue its journey with different alternatives after being parked in the park-and-ride car park and benefit from this system in a comfortable, safe and economical way. Additionally, graphs containing energy consumption predictions are shown in Figures 7–21.

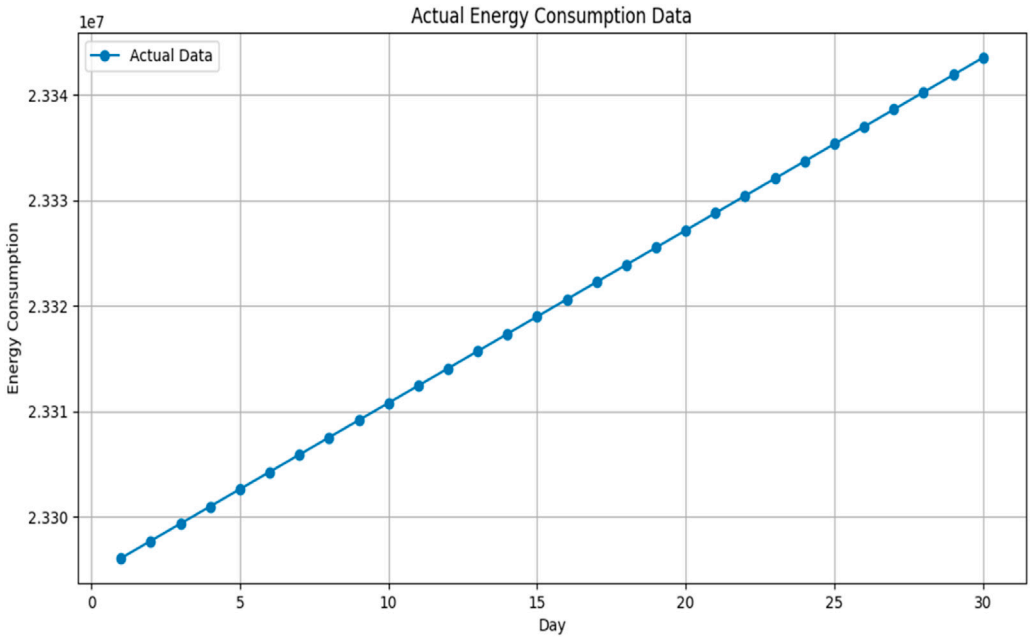

FIGURE 11
Actual energy consumption data and energy consumption.

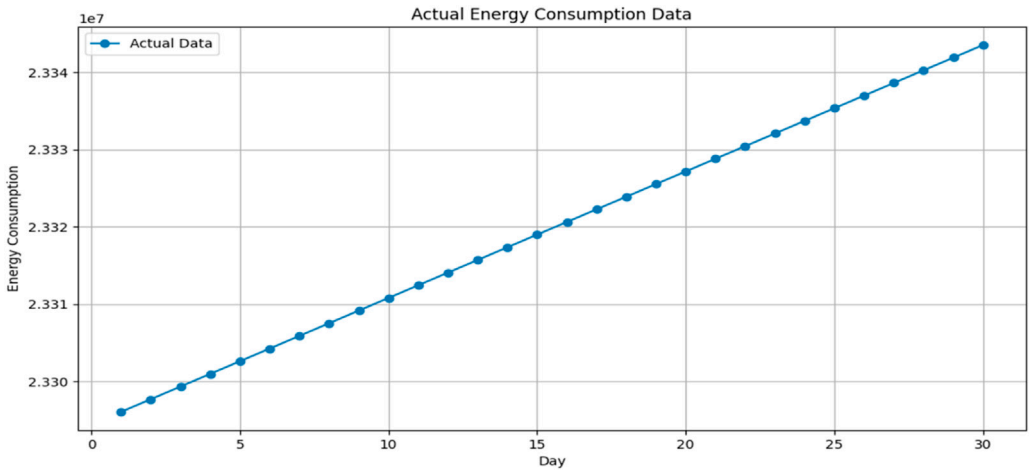

FIGURE 12
Actual energy consumption data.

4.3 Informal park and ride areas

Informal P + R area is the type of parking where users always leave their vehicles on the side of the road. This inappropriate park-and-ride mode of parking demonstrates the need for a safer and more organized facility for customers.

4.4 Opportunistic or shared areas

Opportunistic or shared areas; It can be defined as sharing the facility with other attractions such as private activity centers, cinemas, shopping centers or religious facilities. The park-and-ride activity may be a secondary use of the attraction, depending on the required direction and opportunity provided. Shared areas can be built at a lower cost proportionally and it may be possible to develop them in the future.

4.5 Shared car meeting points

Shared car meeting points are the parking spaces that individuals use as a transfer point before they agree to travel with a single vehicle, by paying the necessary expenses for the

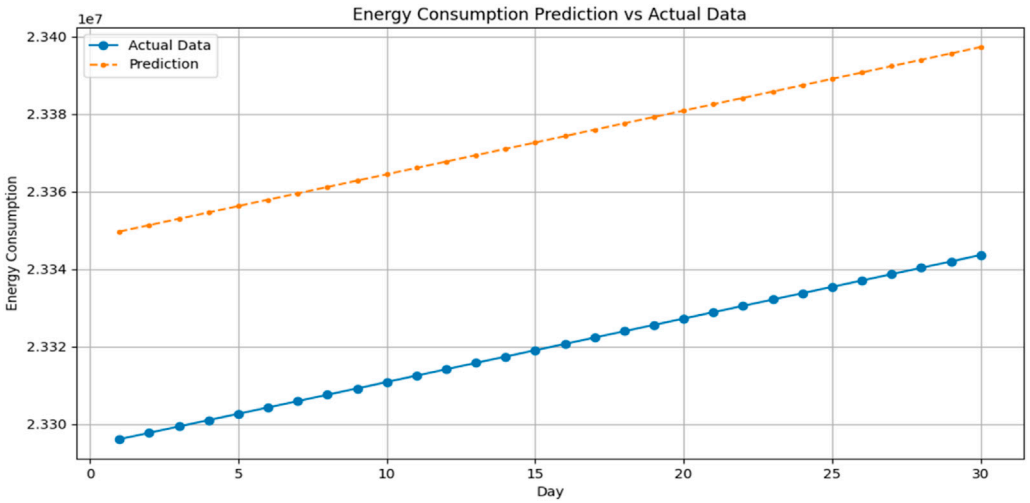

FIGURE 13
Energy consumption prediction and actual data.

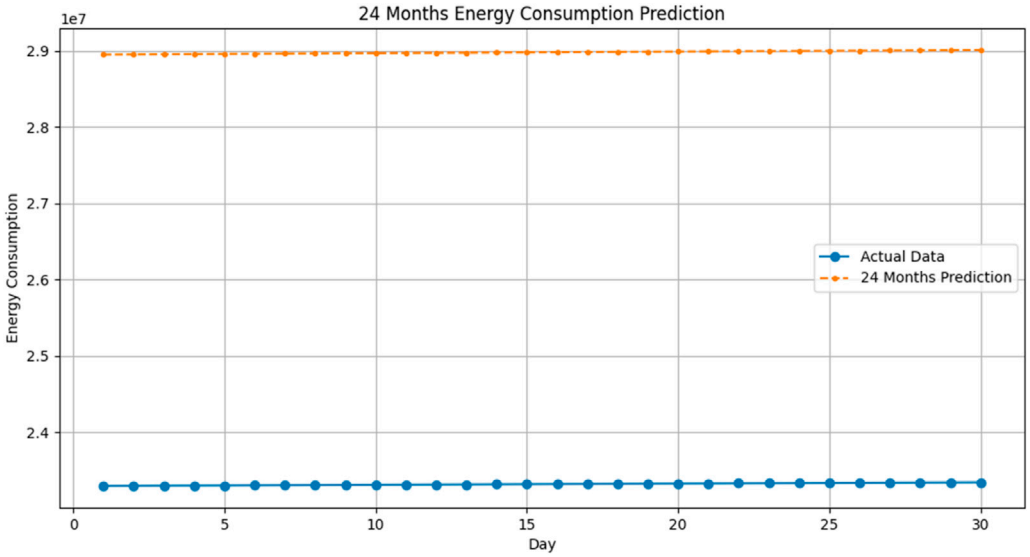

FIGURE 14
24 Months energy consumption prediction.

journey. Comparative travel may be a transportation elective based on the rule of individuals with comparative travel routes traveling together in a single vehicle, instead of utilizing person vehicles. In this way, activity blockage and discuss contamination are decreased, and travelers spare cash by sharing travel costs.

In meet-and-greet ride administrations, assembly focuses are assigned areas where clients come together, arrange their travel plans, and meet some time recently beginning their travel. These focuses can regularly be stopping parcels, tram stations, transport stops or other open ranges. Meeting points are basic to the operation of the travel administrations to be experienced. These hotspots permit clients to put through with each other and arrange travel plans. It too permits travelers to securely meet drivers and start the travel.

4.6 Rural P + R areas

Rural park-and-ride areas, as the name suggests, are traditional parking spaces typically located at the outer edges of urban area boundaries. Rural park-and-ride car parks are generally defined as car parks between 6 and 50 km from business centers that allow switching between different modes of transport. The main function of these areas is to collect potential public transport passengers as

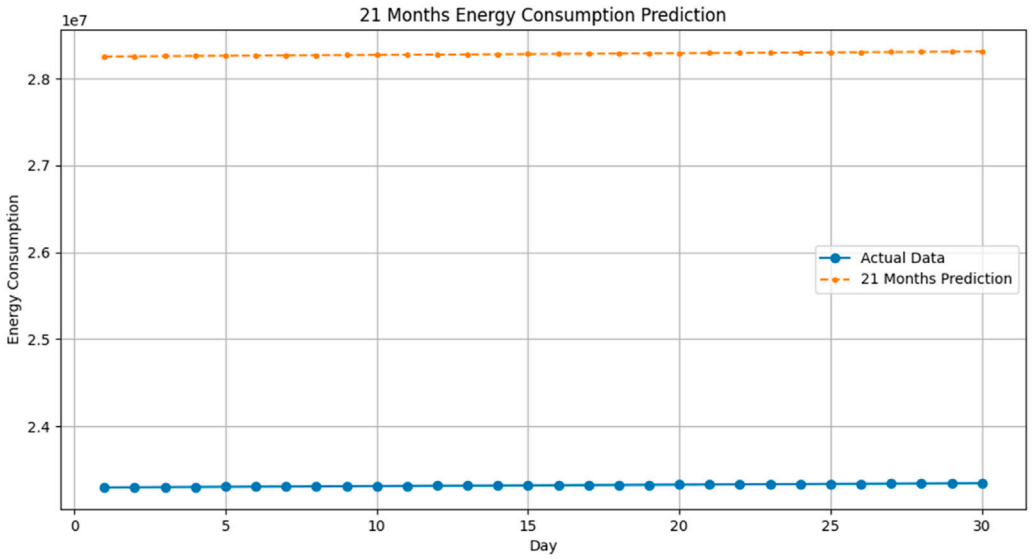

FIGURE 15
21 Months energy consumption prediction.

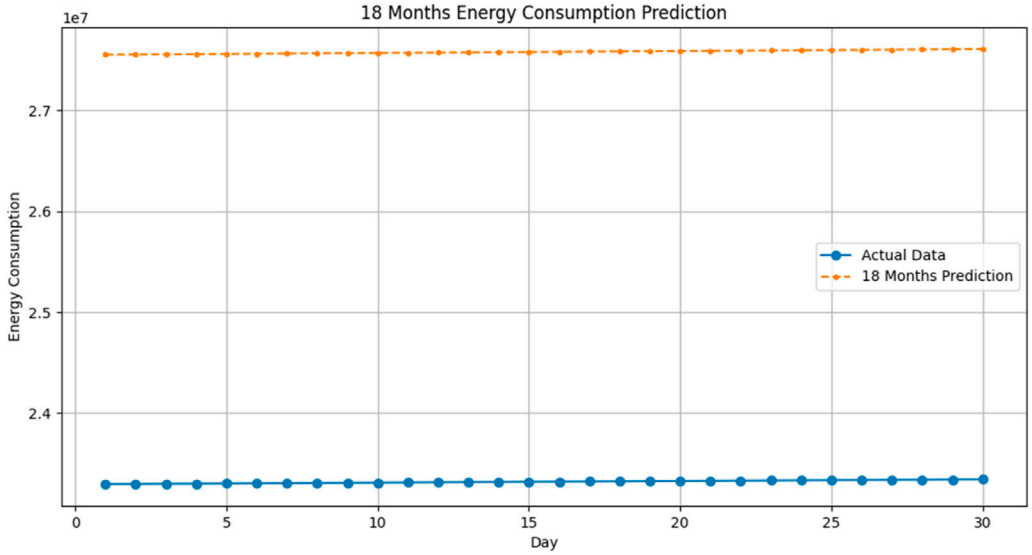

FIGURE 16
18 Months energy consumption prediction.

close to their homes as possible, and to provide direct access to the destination without stopping until the destination.

4.7 Public transport centers

A transit hub is often thought of as a place with only local and express service transfers. The fact that these centers provide park-and-ride facility services is often overlooked. In fact, public transport hubs play a vital role in the park-and-ride network. Public transport P + R facilities are built to places with higher transfer demand than rural park-and-ride facilities. They often provide travelers with a much higher degree of travel service, route options, and destination alternatives than can be found at the next.

4.8 Satellite parking facilities

Satellite parking areas are located at the edge of an event center as an alternative to roadside parking and to provide a proportionally cheaper alternative to reduce congestion within the event center itself.

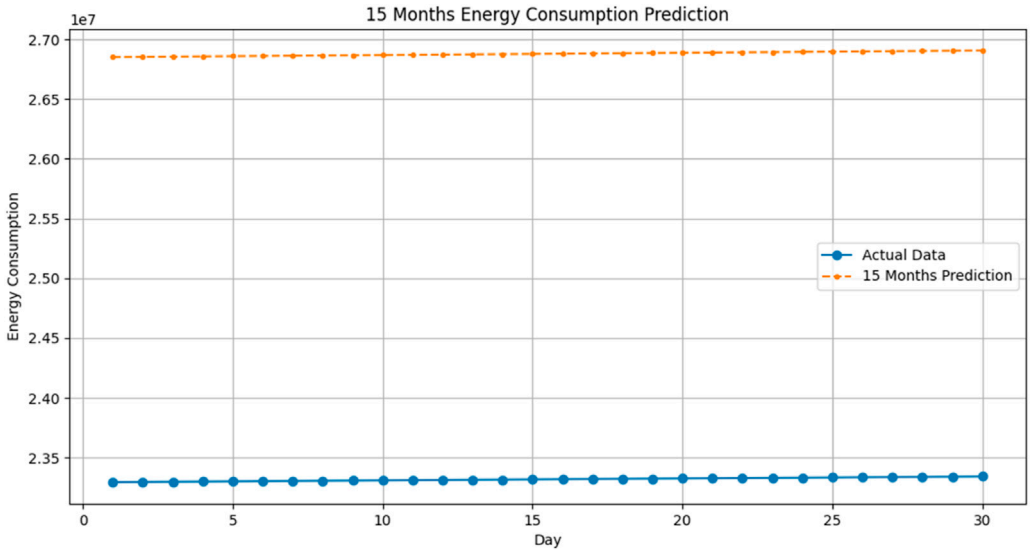

FIGURE 17
15 Months energy consumption prediction.

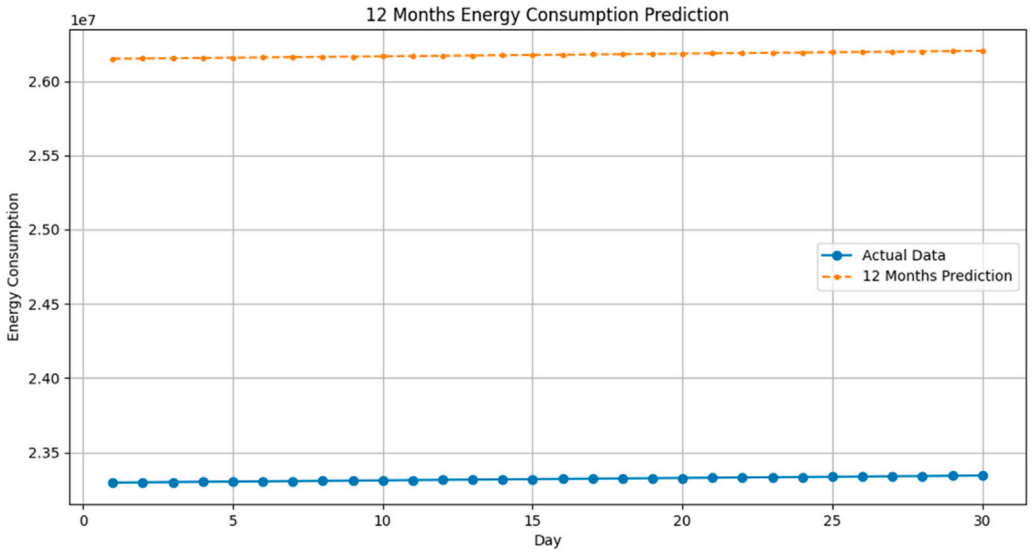

FIGURE 18
12 Months energy consumption prediction.

4.9 Long-distance park areas

Long-distance parking lots are similar to rural park-and-ride facilities and offer convenient transfer facilities. Typically, however, these areas are located further away from the destination and serve as a secondary service to the center located within the city area.

4.10 Local city park and ride facilities

Local city parking facilities are areas that fills the gap between the metropolitan area and the inner-city market. They are located between 2 and 7 km from the activity center and are often informal, shared or opportunistic parking areas.

4.11 Environmental P + R areas

Environmental P + R areas are facilities established at the edge or outer of a business area to provide additional parking spaces. The main purpose of environmental parking areas is to catch travelers before the city center, to enable them to take their vehicles to areas where parking costs are low or there is sufficient space.

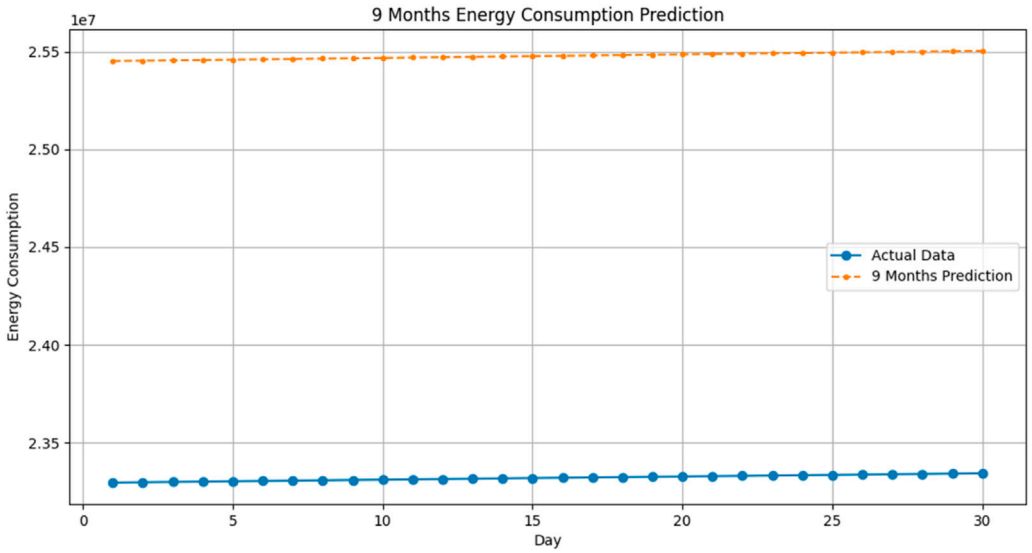

FIGURE 19
9 Months energy consumption prediction.

5 Results and discussions

5.1 Machine learning and energy modelling

When EPDK data is examined, the impact of the COVID-19 pandemic is seen on the consumption values of petroleum products in April and May 2020. Consumption of petroleum products, which increased by 5.2% in the first quarter of 2020 compared to the average of the first quarter of 2017–2019, decreased by 27% in April and 27.3% in May. In June 2020, the 2-month negative growth turned positive and an increase of 2.6% was observed compared to the 2017–2019 averages. While the consumption of petroleum products in 2017–2019 was 2,353,444-tons for April, this amount was 1,717,105-tons in 2020, and while the average for May 2017–2019 was 2,510,319-tons, it was 1,825,667-tons in May 2020 has been realised. In June, the consumption amount of 2020 again exceeded the average of 2017–2019. While the average consumption of petroleum products in 2017–2019 was 2,417,293-tons for June, this amount became 2,480,680-tons in 2020. When import amounts are examined, a decrease of over 40% is seen in April and May. When the January-March period of 2020 is compared with the average of the same period of 2017–2019, a decrease of 29.4% is observed, while a decrease of 48.1% was observed in April and 41.4% in May. As EPDK data confirms, there was a serious decrease in fuel consumption in April and May as a result of the measures taken to prevent the spread of the COVID-19 pandemic. Within the framework of the normalization steps that started in June, consumption and imports appear to have increased to their levels in previous years. However, the fuel distribution sector suffered serious revenue losses as both individual and industrial usage dropped very sharply in April and May. If the mentioned declines are repeated or continue, it is considered that workforce losses and forced handovers may come to the fore in parallel with the loss of income in the dealer network. Considering the current global trend, it is thought that the impact of the pandemic on oil demand poses a risk not only for 2020 in general but also for 2021. Energy Consumption data is shown in Table 1.

According to Table 1, the energy consumption values of a car depending on the waiting time at the red light, waiting time at the junctions, waiting time in traffic, travel time and P + R times are presented in the table in unit of liters. Accordingly, the consumption data of 3,328,008 vehicles in Istanbul that can perform P + R and the energy consumption data created according to the ever-increasing number of vehicles are seen in table 1, created by machine learning.

After machine learning, energy consumption data for 3-6-9-12 month periods are estimated in Table 2. Additionally, the resulting data was visualized and made more detailed.

Here is some of the coding:

```
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.linear_model import LinearRegression
import numpy as np

# Importing the data
data = {
   'Gun': list(range(1, 31)),
    …
…
…
…
…
# Visualization - Prediction vs Actual
plt.figure(figsize=(12, 6))
plt.plot(df['Gun'], df['Energy_Consumption'], label='Actual Data', marker='o')
plt.plot(df['Gun'], df['Predicted_Energy'], label='Prediction', linestyle='--', marker='.')
plt.title('Energy Consumption Prediction vs Actual Data')
plt.xlabel('Day')
plt.ylabel('Energy Consumption')
plt.legend()
plt.grid(True)
plt.show()

# Visualization - 3, 6, 9, 12 Months Predictions
for i in [3, 6, 9, 12]:
    plt.figure(figsize=(12, 6))
    plt.plot(df['Gun'], df['Energy_Consumption'], label='Actual Data', marker='o')
    plt.plot(df['Gun'], df[f'{i}_Months_Prediction'], label=f'{i} Months Prediction', linestyle='--
', marker='.')
    plt.title(f'{i} Months Energy Consumption Prediction')
    plt.xlabel('Day')
    plt.ylabel('Energy Consumption')
    plt.legend()
    plt.grid(True)
    plt.show()
```

The values of energy consumption data obtained after machine learning in 3-6-9-12 month periods are shown in Table 2 together

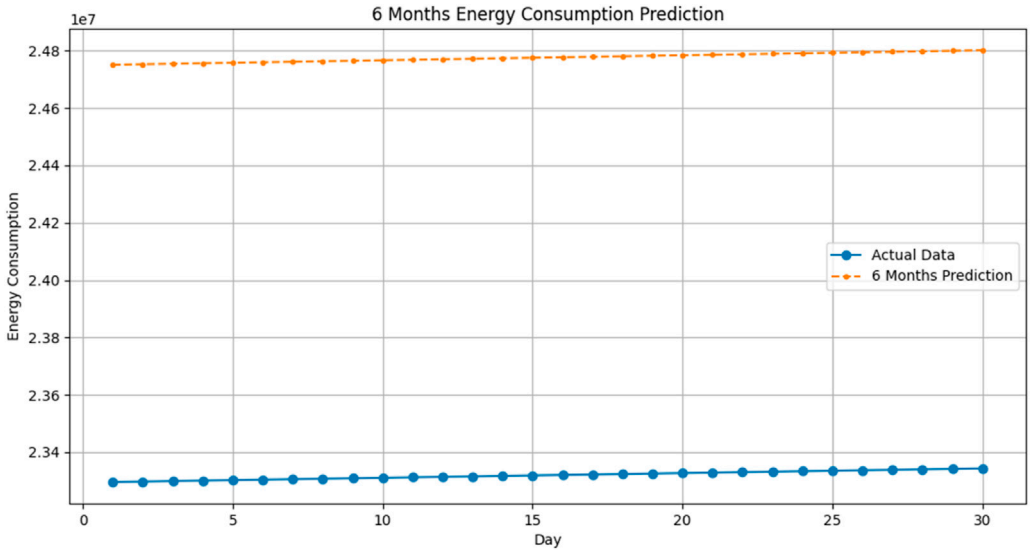

FIGURE 20
6 Months energy consumption prediction.

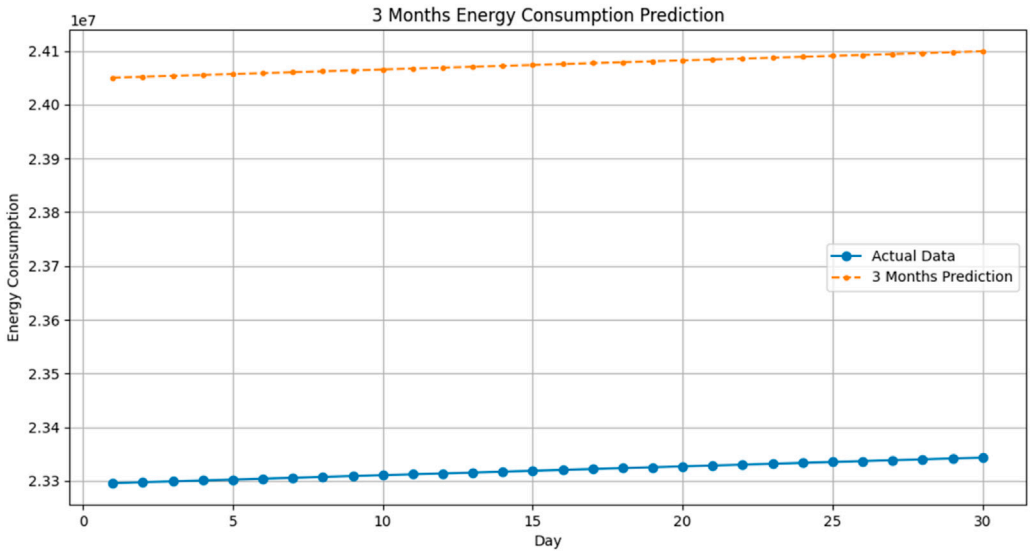

FIGURE 21
3 Months energy consumption prediction.

with the number of cars. The first day in the day column represents the first day of the month. Energy consumption data starting from the first day of the month until the thirtieth day are presented in Table 2.

As a result of the 3-6-9-12 months energy consumption data obtained by machine learning, it can be seen that the energy consumption values increase with the change of time period from each other. The data received can provide significantly effective solutions in future actions and planning, investments and growth, and forward-looking transactions.

The 'Distance to P + R′ parameter is an important parameter in terms of its effect on energy consumption data. Because as the distance to the P + R area increases, consumption data increases and its effect on the table can be observed with changes. The results and changes when the 'Distance to P + R′ parameter is added to the variable parameters are shown in Table 3.

It can be seen in Table 4 that as a result of 3-6-9-12 months energy consumption data obtained by machine learning, the energy consumption values increase with the change of time period. Here, by adding the distance to P + R parameter, the results of energy

TABLE 1 Machine learning energy modeling.

Day	Car numbers [piece]	Waiting at red light [min]	Waiting at junctions [min]	Waiting at traffic [min]	Time of journey [min]	P + R time [min]	Energy consumption [lt]
1	3.328.008	39.936.096	26.624.064	106.496.256	226.304.544	316.160.760	23,296,056
2	3.328.242	39.938.904	26.625.936	106.503.744	226.320.456	316.182.990	23,297,694
3	3.328.476	39.941.712	26.627.808	106.511.232	226.336.368	316.205.220	23,299,332
4	3.328.710	39.944.520	26.629.680	106.518.720	226.352.280	316.227.450	23,300,970
5	3.328.944	39.947.328	26.631.552	106.526.208	226.368.192	316.249.680	23,302,608
6	3.329.178	39.950.136	26.633.424	106.533.696	226.384.104	316.271.910	23,304,246
7	3.329.412	39.952.944	26.635.296	106.541.184	226.400.016	316.294.140	23,305,884
8	3.329.646	39.955.752	26.637.168	106.548.672	226.415.928	316.316.370	23,307,522
9	3.329.880	39.958.560	26.639.040	106.556.160	226.431.840	316.338.600	23,309,160
10	3.330.114	39.961.368	26.640.912	106.563.648	226.447.752	316.360.830	23,310,798
11	3.330.348	39.964.176	26.642.784	106.571.136	226.463.664	316.383.060	23,312,436
12	3.330.582	39.966.984	26.644.656	106.578.624	226.479.576	316.405.290	23,314,074
13	3.330.816	39.969.792	26.646.528	106.586.112	226.495.488	316.427.520	23,315,712
14	3.331.050	39.972.600	26.648.400	106.593.600	226.511.400	316.449.750	23,317,350
15	3.331.284	39.975.408	26.650.272	106.601.088	226.527.312	316.471.980	23,318,988
16	3.331.518	39.978.216	26.652.144	106.608.576	226.543.224	316.494.210	23,320,626
17	3.331.752	39.981.024	26.654.016	106.616.064	226.559.136	316.516.440	23,322,264
18	3.331.986	39.983.832	26.655.888	106.623.552	226.575.048	316.538.670	23,323,902
19	3.332.220	39.986.640	26.657.760	106.631.040	226.590.960	316.560.900	23,325,540
20	3.332.454	39.989.448	26.659.632	106.638.528	226.606.872	316.583.130	23,327,178
21	3.332.688	39.992.256	26.661.504	106.646.016	226.622.784	316.605.360	23,328,816
22	3.332.922	39.995.064	26.663.376	106.653.504	226.638.696	316.627.590	23,330,454
23	3.333.156	39.997.872	26.665.248	106.660.992	226.654.608	316.649.820	23,332,092
24	3.333.390	40.000.680	26.667.120	106.668.480	226.670.520	316.672.050	23,333,730
25	3.333.624	40.003.488	26.668.992	106.675.968	226.686.432	316.694.280	23,335,368
26	3.333.858	40.006.296	26.670.864	106.683.456	226.702.344	316.716.510	23,337,006
27	3.334.092	40.009.104	26.672.736	106.690.944	226.718.256	316.738.740	23,338,644
28	3.334.326	40.011.912	26.674.608	106.698.432	226.734.168	316.760.970	23,340,282
29	3.334.560	40.014.720	26.676.480	106.705.920	226.750.080	316.783.200	23,341,920
30	3.334.794	40.017.528	26.678.352	106.713.408	226.765.992	316.805.430	23,343,558

consumption data can be obtained as different energy consumption data. Energy consumption data estimates for long-term investments between 12 and 24 months are also obtained in Table 4.

Energy consumption values of the car depending on the waiting time at the red light, waiting time at the intersection, waiting time in traffic, travel time, P + R time, Distance to P + R times are visualized in figures in unit of liters. Accordingly, the consumption data of 3,328,008 vehicles in Istanbul that can perform P + R and the energy consumption data created according to the ever-increasing number of vehicles, figures created by machine learning, are detailed below.

6 Conclusion

The emergence of a new global world order in the light of gradually developing technologies can be expressed as an indication that the development of metropolitan and densely populated cities and the progress in the transportation sector are in the hands of Intelligent Transportation Systems.

Within the scope of Turkey's 15-year transportation vision and planning, it is aimed to meet the commercial, economic and social needs of air, land, sea transportation and infrastructure services of all

TABLE 2 Obtaining 3-6-9-12 monthly energy consumption data with machine learning.

Day	Car numbers [piece]	Energy Consumption [lt]	3_Months Prediction [lt]	6_Months Prediction [lt]	9_Months Prediction [lt]	12_Months Prediction [lt]
1	3,328,008	23,296,056	23,300,970	23,305,884	23,310,798	23,315,712
2	3,328,242	23,297,694	23,302,608	23,307,522	23,312,436	23,317,350
3	3,328,476	23,299,332	23,304,246	23,309,160	23,314,074	23,318,988
4	3,328,710	23,300,970	23,305,884	23,310,798	23,315,712	23,320,626
5	3,328,944	23,302,608	23,307,522	23,312,436	23,317,350	23,322,264
6	3,329,178	23,304,246	23,309,160	23,314,074	23,318,988	23,323,902
7	3,329,412	23,305,884	23,310,798	23,315,712	23,320,626	23,325,540
8	3,329,646	23,307,522	23,312,436	23,317,350	23,322,264	23,327,178
9	3,329,880	23,309,160	23,314,074	23,318,988	23,323,902	23,328,816
10	3,330,114	23,310,798	23,315,712	23,320,626	23,325,540	23,330,454
11	3,330,348	23,312,436	23,317,350	23,322,264	23,327,178	23,332,092
12	3,330,582	23,314,074	23,318,988	23,323,902	23,328,816	23,333,730
13	3,330,816	23,315,712	23,320,626	23,325,540	23,330,454	23,335,368
14	3,331,050	23,317,350	23,322,264	23,327,178	23,332,092	23,337,006
15	3,331,284	23,318,988	23,323,902	23,328,816	23,333,730	23,338,644
16	3,331,518	23,320,626	23,325,540	23,330,454	23,335,368	23,340,282
17	3,331,752	23,322,264	23,327,178	23,332,092	23,337,006	23,341,920
18	3,331,986	23,323,902	23,328,816	23,333,730	23,338,644	23,343,558
19	3,332,220	23,325,540	23,330,454	23,335,368	23,340,282	23,345,196
20	3,332,454	23,327,178	23,332,092	23,337,006	23,341,920	23,346,834
21	3,332,688	23,328,816	23,333,730	23,338,644	23,343,558	23,348,472
22	3,332,922	23,330,454	23,335,368	23,340,282	23,345,196	23,350,110
23	3,333,156	23,332,092	23,337,006	23,341,920	23,346,834	23,351,748
24	3,333,390	23,333,730	23,338,644	23,343,558	23,348,472	23,353,386
25	3,333,624	23,335,368	23,340,282	23,345,196	23,350,110	23,355,024
26	3,333,858	23,337,006	23,341,920	23,346,834	23,351,748	23,356,662
27	3,334,092	23,338,644	23,343,558	23,348,472	23,353,386	23,358,300
28	3,334,326	23,340,282	23,345,196	23,350,110	23,355,024	23,359,938
29	3,334,560	23,341,920	23,346,834	23,351,748	23,356,662	23,361,576
30	3,334,794	23,343,558	23,348,472	23,353,386	23,358,300	23,363,214

transportation types. In addition, it is aimed to expand ITS practices in order to contribute to the reduction of costs by increasing the quality of the services provided in order to create and plan policies that can be applied in every sector that is stable and suitable for technological innovations.

Consumption of individual vehicles in developing countries is increasing day by day, thus causing problems such as health problems, environmental pollution, insufficient parking space, traffic jams, accidents and restricted pedestrian movement. There is a need for smart transportation system applications, especially in a metropolitan city where the capacity is exceeded and the roads are insufficient. On the basis of this, the curative effects of park-and-ride facilities directing public transport in this direction are inevitable. Although it is often based on rail systems in the world, park-and-ride (P + R) parking lots have been put into operation on the metrobus line for İstanbul which is a metropolitan city.

On the subject of awareness, it can be said that the awareness of Intelligent Transportation Systems has reached a significant level and the studies have accelerated with the tendency of Intelligent Transportation Systems stakeholders to act together. Therefore, thanks to the ideas of the Intelligent Transportation System partners and the planning of the relevant ministries, Turkey needs to implement

TABLE 3 'Distance to P + R'parameter and its effect on energy consumption.

Day	Car numbers [piece]	Waiting at red light [min]	Waiting at junctions [min]	Waiting at traffic [min]	Time of journey [min]	P + R time [min]	Distance to P + R [m]	Predicted_ Energy [lt]
1	3.328.008	39.936.096	26.624.064	106.496.256	226.304.544	316.160.760	8.975	23,349,637
2	3.328.242	39.938.904	26.625.936	106.503.744	226.320.456	316.182.990	8.998	23,351,279
3	3.328.476	39.941.712	26.627.808	106.511.232	226.336.368	316.205.220	9.021	23,352,920
4	3.328.710	39.944.520	26.629.680	106.518.720	226.352.280	316.227.450	9.044	23,354,562
5	3.328.944	39.947.328	26.631.552	106.526.208	226.368.192	316.249.680	9.067	23,356,204
6	3.329.178	39.950.136	26.633.424	106.533.696	226.384.104	316.271.910	9.090	23,357,846
7	3.329.412	39.952.944	26.635.296	106.541.184	226.400.016	316.294.140	9.113	23,359,488
8	3.329.646	39.955.752	26.637.168	106.548.672	226.415.928	316.316.370	9.136	23,361,129
9	3.329.880	39.958.560	26.639.040	106.556.160	226.431.840	316.338.600	9.159	23,362,771
10	3.330.114	39.961.368	26.640.912	106.563.648	226.447.752	316.360.830	9.182	23,364,413
11	3.330.348	39.964.176	26.642.784	106.571.136	226.463.664	316.383.060	9.205	23,366,055
12	3.330.582	39.966.984	26.644.656	106.578.624	226.479.576	316.405.290	9.228	23,367,696
13	3.330.816	39.969.792	26.646.528	106.586.112	226.495.488	316.427.520	9.251	23,369,338
14	3.331.050	39.972.600	26.648.400	106.593.600	226.511.400	316.449.750	9.274	23,370,980
15	3.331.284	39.975.408	26.650.272	106.601.088	226.527.312	316.471.980	9.297	23,372,622
16	3.331.518	39.978.216	26.652.144	106.608.576	226.543.224	316.494.210	9.320	23,374,263
17	3.331.752	39.981.024	26.654.016	106.616.064	226.559.136	316.516.440	9.343	23,375,905
18	3.331.986	39.983.832	26.655.888	106.623.552	226.575.048	316.538.670	9.366	23,377,547
19	3.332.220	39.986.640	26.657.760	106.631.040	226.590.960	316.560.900	9.389	23,379,189
20	3.332.454	39.989.448	26.659.632	106.638.528	226.606.872	316.583.130	9.412	23,380,831
21	3.332.688	39.992.256	26.661.504	106.646.016	226.622.784	316.605.360	9.435	23,382,472
22	3.332.922	39.995.064	26.663.376	106.653.504	226.638.696	316.627.590	9.458	23,384,114
23	3.333.156	39.997.872	26.665.248	106.660.992	226.654.608	316.649.820	9.481	23,385,756
24	3.333.390	40.000.680	26.667.120	106.668.480	226.670.520	316.672.050	9.504	23,387,398
25	3.333.624	40.003.488	26.668.992	106.675.968	226.686.432	316.694.280	9.527	23,389,039
26	3.333.858	40.006.296	26.670.864	106.683.456	226.702.344	316.716.510	9.550	23,390,681
27	3.334.092	40.009.104	26.672.736	106.690.944	226.718.256	316.738.740	9.573	23,392,323
28	3.334.326	40.011.912	26.674.608	106.698.432	226.734.168	316.760.970	9.596	23,393,965
29	3.334.560	40.014.720	26.676.480	106.705.920	226.750.080	316.783.200	9.619	23,395,606
30	3.334.794	40.017.528	26.678.352	106.713.408	226.765.992	316.805.430	9.642	23,397,248

the Intelligent Transportation System architecture in a safe, economic, environment-friendly, solution-centered and user-friendly manner.

Programs initiated for the improvements of innovative developments and applications in the world should be carefully examined in order to expand and prefer smart systems in the field of transportation, and their samples should be implemented in our country. It is also important that projects with a center-oriented and totalitarian approach to dissemination begin to be used in practice by making use of the ability to reach rural areas held by the central administration.

In the planning of the park-and-ride system chosen by the transportation planner, city-specific data such as the city's current transportation problems, the desire to usage private vehicles, pedestrian and bicycle usage should be taken into account. The planning and implementation process of park-and-ride facilities should be aligned with the needs of the public, the public transport system administrator, local or Metropolitan municipalities and the expectations of other affected entities, with existing regulations and plans. It should be designed in such a way that the negative effects on the local traffic circulation, the damage to the environment and the

TABLE 4 12–24 months energy consumption data forecasts.

Day	All parameters Predicted_ Energy	3_Months_ Prediction	6_Months_ Prediction	9_Months_ Prediction	12_Months_ Prediction	15_Months_ Prediction	18_Months_ Prediction	21_Months_ Prediction	24_Months_ Prediction
1	23.349.637	24.050.126	24.750.615	25.451.104	26.151.593	26.852.082	27.552.572	28.253.061	28.953.550
2	23.351.279	24.051.817	24.752.355	25.452.894	26.153.432	26.853.971	27.554.509	28.255.047	28.955.586
3	23.352.920	24.053.508	24.754.096	25.454.683	26.155.271	26.855.859	27.556.446	28.257.034	28.957.621
4	23.354.562	24.055.199	24.755.836	25.456.473	26.157.110	26.857.747	27.558.383	28.259.020	28.959.657
5	23.356.204	24.056.890	24.757.576	25.458.262	26.158.948	26.859.635	27.560.321	28.261.007	28.961.693
6	23.357.846	24.058.581	24.759.317	25.460.052	26.160.787	26.861.523	27.562.258	28.262.993	28.963.729
7	23.359.488	24.060.272	24.761.057	25.461.841	26.162.626	26.863.411	27.564.195	28.264.980	28.965.765
8	23.361.129	24.061.963	24.762.797	25.463.631	26.164.465	26.865.299	27.566.133	28.266.966	28.967.800
9	23.362.771	24.063.654	24.764.537	25.465.420	26.166.304	26.867.187	27.568.070	28.268.953	28.969.836
10	23.364.413	24.065.345	24.766.278	25.467.210	26.168.142	26.869.075	27.570.007	28.270.940	28.971.872
11	23.366.055	24.067.036	24.768.018	25.469.000	26.169.981	26.870.963	27.571.944	28.272.926	28.973.908
12	23.367.696	24.068.727	24.769.758	25.470.789	26.171.820	26.872.851	27.573.882	28.274.913	28.975.944
13	23.369.338	24.070.418	24.771.498	25.472.579	26.173.659	26.874.739	27.575.819	28.276.899	28.977.979
14	23.370.980	24.072.109	24.773.239	25.474.368	26.175.497	26.876.627	27.577.756	28.278.886	28.980.015
15	23.372.622	24.073.800	24.774.979	25.476.158	26.177.336	26.878.515	27.579.694	28.280.872	28.982.051
16	23.374.263	24.075.491	24.776.719	25.477.947	26.179.175	26.880.403	27.581.631	28.282.859	28.984.087
17	23.375.905	24.077.182	24.778.460	25.479.737	26.181.014	26.882.291	27.583.568	28.284.845	28.986.122
18	23.377.547	24.078.873	24.780.200	25.481.526	26.182.853	26.884.179	27.585.505	28.286.832	28.988.158
19	23.379.189	24.080.564	24.781.940	25.483.316	26.184.691	26.886.067	27.587.443	28.288.818	28.990.194
20	23.380.831	24.082.255	24.783.680	25.485.105	26.186.530	26.887.955	27.589.380	28.290.805	28.992.230
21	23.382.472	24.083.946	24.785.421	25.486.895	26.188.369	26.889.843	27.591.317	28.292.791	28.994.266
22	23.384.114	24.085.637	24.787.161	25.488.684	26.190.208	26.891.731	27.593.255	28.294.778	28.996.301
23	23.385.756	24.087.328	24.788.901	25.490.474	26.192.047	26.893.619	27.595.192	28.296.765	28.998.337
24	23.387.398	24.089.020	24.790.641	25.492.263	26.193.885	26.895.507	27.597.129	28.298.751	29.000.373
25	23.389.039	24.090.711	24.792.382	25.494.053	26.195.724	26.897.395	27.599.066	28.300.738	29.002.409
26	23.390.681	24.092.402	24.794.122	25.495.842	26.197.563	26.899.283	27.601.004	28.302.724	29.004.445

(Continued on following page)

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TABLE 4 (*Continued*) 12–24 months energy consumption data forecasts.

Day	All parameters Predicted_Energy	3_Months_Prediction	6_Months_Prediction	9_Months_Prediction	12_Months_Prediction	15_Months_Prediction	18_Months_Prediction	21_Months_Prediction	24_Months_Prediction
27	23.392.323	24.094.093	24.795.862	25.497.632	26.199.402	26.901.171	27.602.941	28.304.711	29.006.480
28	23.393.965	24.095.784	24.797.603	25.499.421	26.201.240	26.903.059	27.604.878	28.306.697	29.008.516
29	23.395.606	24.097.475	24.799.343	25.501.211	26.203.079	26.904.947	27.606.816	28.308.684	29.010.552
30	23.397.248	24.099.166	24.801.083	25.503.001	26.204.918	26.906.835	27.608.753	28.310.670	29.012.588

[a]All Parameters: Includes the car's waiting time at the red light, waiting time at the intersection, waiting time in traffic, travel time, P + R time and Distance_to_P + R parameters.

noise effects are minimal. It should be manufactured in such a way that the walking distance inside the facility is minimum. The users should be positioned in such a way that the access time to the facility with their private vehicles is minimal. Park-and-ride facilities should be placed in front of traffic jams areas. Places close to public transportation corridors should be chosen for the placement of park-and-ride facilities, and city centers or event areas with high crowds should be located in areas closest to regional highways or main arteries. In addition, P + R facilities; The number of transfer trips should be rapid and sufficient, they should be economical because they are encouraging, the transfer and transitions should be equipped in a practical and comfortable way, bicycle and pedestrian routes should be considered intensively, and they should be planned prospectively to allow capacity increases.

As a result, it can be said that the architecture of P + R facilities should be established on the basis of general planning elements such as comprehensive, high performance, innovative, future-oriented, inclusive, logical, elastic, totalitarian, informative and transparent, but there are some criteria specific to the P + R facility.

On the other hand, it is stated that elements such as accessibility, information, security, visibility, aesthetics and image should be determined as the basic principle during the establishment of the architecture of P + R facilities, but a P + R facility should be integrated with its environment, pedestrian-bike and public transportation design requirements should be met. It can be stated that there are also some special design principles to meet the design requirements of automobiles.

In the city center of Istanbul which is our study area, the daily commute time of a citizen to work, school, shopping or other activities has reached unacceptable levels due to the traffic congestion in certain areas. However, the population of the central city is increasing every year. In order to reduce this situation to a reasonable level and to solve the probable problems that may arise with the development of the city with a proactive attitude, it is remarkable that the existing public transportation system will be improved and the transportation transfer centers and park-and-ride facilities that will work integrated with this system can be further increased and then the traffic will be relieved. As an effect, it will be able to return to Istanbulites as an added value.

The findings were found by performing analyzes specific to the city of Istanbul. Urban structure; differences in city density, layout, and public transportation infrastructure and transportation needs; Factors such as different car usage levels, dependence on public transportation and dominant transportation modes can also be taken into account and compared with other cities. On the other hand, the long-term sustainability of the P + R system depends on the stability of the factors mentioned in the article and situations such as demand management and financial sustainability.

As a result of 3-6-9-12-15-18-21-24 monthly energy consumption data obtained through machine learning, it can be seen that the energy consumption values increase with the change of time period from each other. It can be said that 3-month and 6-month energy consumption data can be effective in short-term investments. It can be said that 12–24-month energy consumption data can play an important role in long-term investments and growth targets. It is an undeniable fact that the energy consumption data obtained directly affects carbon gas emissions and greenhouse gases. It is obvious that smart solutions will be

produced regarding the energy consumption data obtained and their reduction in targeting carbon emissions, greenhouse gas effects and green environment green transformation actions. It can be stated that the data obtained can provide significant effective solutions in future actions and plans, investments and growth, and forward-looking green environment-green transformation processes.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

MK: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing–original draft, Writing–review and editing.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Nomenclature

EPDK	Energy market regulatory authority
P + R	Park and ride
UK	United kingdom
ITS	Intelligent transportation system