Journal of Systems Thinking in Practice
JSTINP, *QUARTERLY*
Homepage: jstinp.um.ac.ir
Online ISSN: 2821-1669, Print ISSN: 2980-9460
Research Article
DOI: 10.22067/jstinp.2025.91024.1129
JSTINP 2025; Vol. 4, No. 3

Systems Dynamics Modelling of Gasoline Consumption in Iran

Mahsa Khalilabadi[a], Mohammad Mirbagherijam[a]*, Hamideh Moharrami[a]

[a] *Department of Industrial Engineering and Management, Shahrood University of Technology, Shahrood, Iran.*

How to cite this article

Khalilabadi, M., Mirbagherijam, M., Moharrami, H., 2025. Systems Dynamics Modelling of Gasoline Consumption in Iran, *Journal of Systems Thinking in Practice*, *4*(3), pp.1 -21. doi: 10.22067/jstinp.2025.91024.1129.
URL: https://jstinp.um.ac.ir/article_47058.html.

A B S T R A C T

This study presents a dynamic analysis of gasoline demand in Iran from 1978 to 2021, employing a system dynamics approach. A comprehensive model was developed to forecast gasoline consumption, incorporating key variables such as population, trip frequency, the number of gasoline-only vehicles, dual-fuel (gasoline-CNG) vehicles, the number of CNG stations, and the consumer price index (CPI). The model explicitly captures the complex and dynamic interrelationships among these variables, providing a nuanced understanding of the factors influencing gasoline consumption. Model validation was performed by comparing model predictions with actual gasoline consumption data from 2006 to 2021. The results demonstrate a satisfactory level of accuracy in simulating past gasoline consumption patterns. Following validation, the model was used to project gasoline demand from 2022 to 2031. In addition to a base scenario, three alternative scenarios were explored to assess the impact of different policy interventions aimed at reducing gasoline consumption. These scenarios involved increasing the number of dual-fuel vehicles, increasing the number of CNG stations, and a combined scenario incorporating both interventions. The projection results indicate that all three alternative scenarios lead to significant reductions in gasoline consumption compared to the base scenario. Notably, the scenario focusing on increasing the number of dual-fuel vehicles had the most substantial impact on reducing gasoline consumption. These findings underscore the importance of developing CNG infrastructure and promoting the adoption of dual-fuel vehicles as effective strategies for reducing gasoline dependence and managing fuel consumption in Iran. This research provides policymakers with a robust dynamic model for informed decision-making in fuel consumption management. Furthermore, the findings and methodology can be broadly applied to similar studies in other countries and related fields of energy and environmental research.

Keywords

Gasoline Consumption, Iran, Systems Dynamics, Energy Policy, CNG, Forecasting.

Article history

Received: 2024-12-02
Revised: 2025-07-20
Accepted: 2025-07-24
Published (Online): 2025-09-27

Number of Figures: 5 **Number of Tables: 9** **Number of Pages: 21** **Number of References:42**

****Corresponding author***
Email: m.mirbagherijam@shahroodut.ac.ir

1. Introduction

Iran faces a pressing challenge in managing its gasoline consumption, which remains among the highest globally and is increasingly unsustainable. Persistent growth in demand—driven by inefficient vehicles, an aging fleet, and extensive government subsidies—has placed mounting pressure on the energy sector. In 2024, national consumption reached 113 million liters per day, representing an 8% year-over-year increase (Iran Chamber Newsroom, 2024). This surge, coupled with limited refining capacity, has widened the gap between domestic production and demand, forcing greater reliance on imports and barter-based fuel trade.

Many studies have utilized econometric methods—primarily regression analyses—to explore the relationship between gasoline consumption and various economic factors such as price, income, and growth (e.g., Al-Ghandoor et al., 2013; An-loh, Botsas, and Monroe, 1985; Bates and Kim, 2024; Goetzke and Vance, 2021; Kilian and Zhou, 2024; Lee and Olasehinde-Williams, 2021; Rogat and Sterner, 1998; Sapnken et al., 2018). Among these, Mikayilov et al. (2020a) specifically examined gasoline price elasticity in fuel-subsidizing economies, offering insights that are especially relevant to Iran's context. These approaches often focus on price elasticity and other statistical relationships. Recently, machine learning techniques, including deep learning, have been increasingly applied for forecasting gasoline consumption (Bayat, Davoodi, and Rezaei, 2023; Ceylan, Akbulut, and Baytürk, 2024; Yang et al., 2022; Yu et al., 2021). However, while these methods provide valuable insights, they may lack in-depth explanatory power regarding causal mechanisms.

In contrast, system dynamics modeling offers a holistic approach by explicitly representing feedback loops and interactions among variables, providing deeper insights into the dynamic behavior of gasoline consumption systems over time. This approach has been effectively applied in previous studies to model urban air pollution (Vafa-Arani et al., 2014) and gasoline demand (Zareayan Mazrae Khosro and Shakouri Ganjavi, 2016). Unlike econometric models that primarily analyze static relationships or machine learning methods focused on prediction, system dynamics can elucidate how factors such as vehicle efficiency, government policies, and infrastructure developments interact to influence gasoline demand.

Unlike prior models that isolate econometric or predictive frameworks, this study offers a dynamic system model tailored to Iran's fuel infrastructure, incorporating trip frequency, CPI, and policy simulations. The innovation lies in the causal structuring and integration of policy feedback, especially in modeling the adoption of hybrid vehicles and the accessibility of CNG.

This study aims to investigate the various factors influencing gasoline consumption in Iran through a dynamic modeling approach. The unique challenges within the Iranian context—including significant energy subsidies, fluctuating gasoline prices, and an increasing reliance on personal vehicles—complicate the dynamics of fuel demand. Prior research has established links between travel behavior and fuel consumption, but a comprehensive analysis that effectively integrates these multiple influencing factors remains limited.

To address this gap, the study poses the following research questions:

- What are the key factors influencing gasoline consumption in Iran?
- How do economic conditions, such as GDP and inflation, affect gasoline demand?
- What role do vehicle types—specifically dual-fuel and hybrid vehicles—play in shaping gasoline consumption patterns?
- How effective are policy interventions aimed at promoting alternative fuels and reducing gasoline dependency?

Based on these questions, the study hypothesizes that increased trip frequency will correlate with higher gasoline consumption and that the expansion of CNG infrastructure and the adoption of dual-fuel vehicles will significantly mitigate gasoline demand.

The findings of this study will provide valuable insights into the determinants of gasoline consumption in Iran, offering a robust framework for policymakers to develop targeted interventions that promote sustainable energy use and reduce environmental impacts. The paper is structured as follows: Section 1 provides the background on Iran's gasoline consumption challenges and justifies the use of system dynamics modeling. Section 2 details the methodology, including the model structure, data sources, and calibration/validation techniques. Section 3 presents the results from the simulation experiments, analyzing the impacts of key factors and policy scenarios. Section 4 discusses the policy implications derived from the model's outputs, offering recommendations for sustainable transportation strategies in Iran. Finally, Section 5 concludes the study, highlighting its contributions, limitations, and potential avenues for future research.

2. Literature review

2.1. Methodological approaches to gasoline consumption modeling

Numerous studies have employed diverse methodologies to model and forecast gasoline consumption, each with its strengths and limitations. Traditional econometric techniques—such as linear regression—have been widely used to establish relationships between gasoline demand and variables like price, income, and vehicle ownership (e.g., Sapnken et al., 2018; Al-

Ghandoor et al., 2013; An-loh et al., 1985; Rogat and Sterner, 1998). However, these approaches often assume linearity and struggle to account for the system's dynamic and multifaceted nature (Chang, 2016).

More advanced econometric frameworks, including correlated random coefficient models (Bates and Kim, 2024) and time-varying coefficient approaches (Lee and Olasehinde-Williams, 2021), have been adopted to address these shortcomings, offering improved estimation of demand elasticities. Mikayilov et al. (2020b) analyzed price and income elasticities in petroleum-dependent economies, providing insights into their temporal fluctuations—an issue particularly relevant to Iran's subsidy-laden fuel market. Other studies have revealed that elasticity estimates can vary significantly across different national and socioeconomic contexts (Goetzke and Vance, 2021; Kilian and Zhou, 2024).

In parallel, machine learning (ML) algorithms have emerged as powerful forecasting tools, capable of capturing non-linear patterns and complex interdependencies within consumption data (e.g., Ayyıldız and Murat, 2024; Ceylan et al., 2024; Bayat et al., 2023; Yang et al., 2022; Yu et al., 2021). For instance, Yang et al. (2022) and Bayat et al. (2023) demonstrated the efficacy of ML models—particularly deep learning and big data integration—in short-term fuel consumption prediction using multidimensional inputs and on-board diagnostics. Despite their predictive strength, such models often operate as "black boxes," limiting interpretability and hinders their suitability for policy analysis, where causal understanding is crucial. More recently, hybrid approaches have emerged that integrate data mining techniques with system dynamics to model energy policies and fuel demand (Roudbaraki et al., 2025).

In contrast to these predominantly static or predictive approaches, system dynamics modeling offers a unique framework for analyzing the complex dynamics of gasoline consumption (Akbari et al., 2020; Shamsapour et al., 2021; Zareayan Mazrae Khosro and Shakouri Ganjavi, 2016; Vafa-Arani et al., 2014; Mosleh Shirazi and Sotodeh, 2015). This approach explicitly represents the feedback loops and interactions between various factors, allowing for a more comprehensive understanding of the system's behavior over time. Studies have used system dynamics to model the impact of policies such as fuel subsidies (Mosleh Shirazi and Sotodeh, 2015) and vehicle hybridization (Norouzi et al., 2022) on energy consumption and emissions. Houri Jafari and Baratimalayeri (2008) highlighted the crisis in Iran's transportation sector, setting the stage for a system dynamics approach capable of analyzing such a complex problem. While some studies have explored specific aspects using system dynamics, this research proposes a comprehensive model capturing a wider range of influential factors, offering potentially richer insights for policymaking in the context of Iran's specific challenges, including its unique energy policy landscape (Raei et al., 2024; Saryazdi and Tavangar, 2023; Samavi et al., 2024; Ansarinasab and Manzari Tavakoli, 2020). The model will build upon the foundation laid by previous system dynamics work, addressing the gaps in understanding the complete interplay of factors influencing Iranian gasoline consumption. Moshiri (2020) and Moshiri and Aliyev (2017) provide relevant context on consumer behavior and rebound effects, which will be considered in the development of the model. Salimi et al. (2022) provide valuable insights into gasoline supply and demand modeling, informing the structure of the proposed system dynamics model. Heidari et al. (2023) and Pourmatin et al. (2024) demonstrate the applicability of system dynamics in modeling related aspects, such as CO2 emissions and low-carbon vehicle transitions, thereby further supporting the chosen methodology. Finally, the work by Ghoddusi et al. (2019) on foreign exchange shocks provides an additional important context for the Iranian case.

2.2. Challenges of gasoline consumption in iran and their policy implications

Gasoline consumption in Iran presents significant challenges that impact the economy, environment, and social stability. The consumption breakdown reveals that 61% of gasoline is used by passenger cars, 8% by taxis, 21% by vans, 4% by trucks and light trucks, and 6% by motorcycles, indicating the dominance of personal vehicles in overall consumption patterns.

Historically, Iran's refining capacity has fluctuated, reaching a low of 751,000 barrels per day during the Iran-Iraq War and climbing to over 2.3 million barrels per day by December 2019, reflecting substantial investments in new and upgraded refineries. Despite this increased capacity, current gasoline consumption levels continue to pose significant challenges as illustrated in Figure 1.

Iran's per capita energy consumption, particularly of gasoline, significantly exceeds the global average. Coupled with low energy prices and substantial energy subsidies—approximately 90% of hidden subsidies reported in 2020—Iran is one of the leading international providers of energy subsidies. Notably, its gasoline consumption is about ten times higher than that of Turkey, despite similar population sizes.

Historically, a positive correlation has existed between population growth, increasing motor vehicle ownership, and gasoline consumption. Until 2006, gasoline consumption exhibited a continuous upward trend. The introduction of Compressed Natural Gas (CNG) as a gasoline

 DOI: 10.22067/jstinp.2025.91024.1129

substitute in 2004 and the implementation of fuel rationing through the "fuel card" system in 2006 led to a temporary decline in gasoline consumption, which lasted until 2011.

However, this downward trend reversed in 2011 with the removal of gasoline rationing and the implementation of a single-price system in 2015. This resurgence is largely attributed to Iran's growing young population and the subsequent increase in vehicle ownership, with the number of passenger vehicles rising from approximately 11,179,681 in 2011 to nearly 24 million by 2021. Although the reintroduction of rationing in 2019 temporarily curtailed consumption for a single year, the long-term trajectory remains concerning.

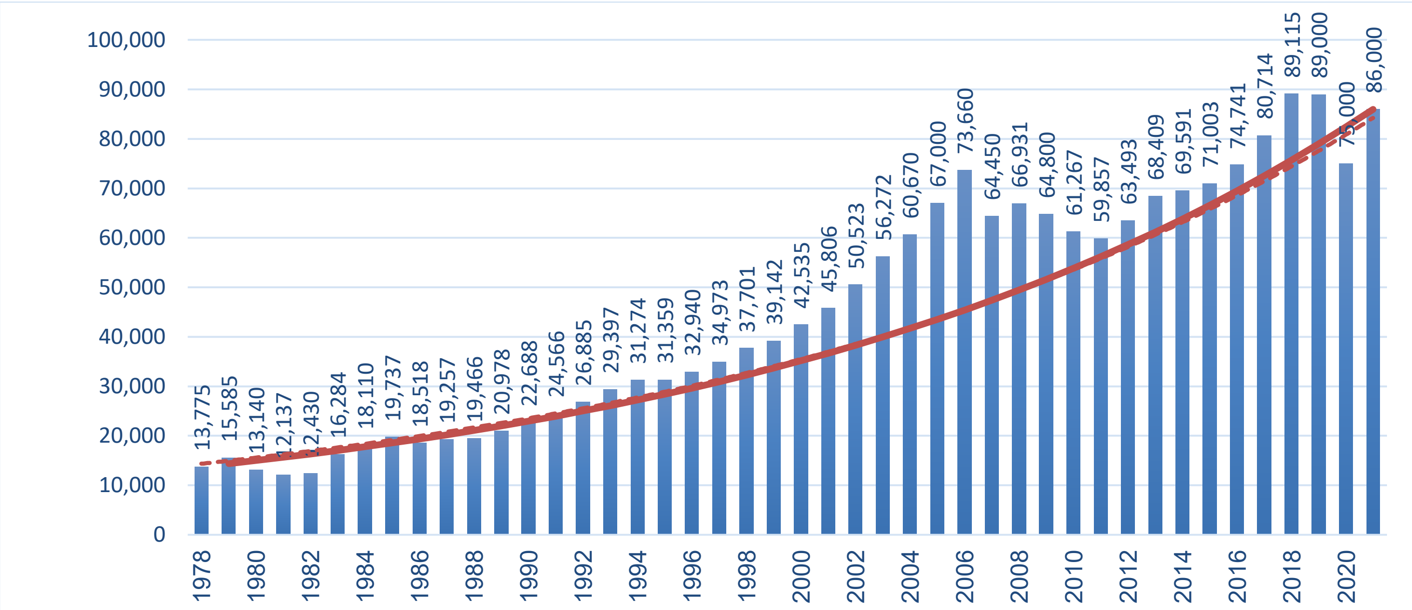

Figure 1. Daily gasoline consumption (thousands of litters) 1978-2021.

2.3. The multifaceted nature of gasoline consumption

As presented in Table 1, the adverse consequences of excessive gasoline consumption in Iran span environmental, economic, and social domains. This multidimensional challenge highlights the need for coordinated interventions, including strengthening fuel efficiency standards, investing in public transportation infrastructure, expanding access to CNG and electric vehicles, and implementing gradual fuel pricing reforms.

Table 1. Impacts of gasoline consumption and policy responses

Impact domain	Negative effects	Policy interventions	System dynamics feedback loop
Air pollution and public health	Elevated CO_2 and PM emissions contribute to the development of respiratory and cardiovascular diseases, particularly in urban areas.	Strengthen fuel efficiency standards; phase out old vehicles; encourage electric and hybrid cars.	Pollution ↑ → Healthcare costs ↑ → Budget pressure ↑ → Subsidy reform → Fuel consumption ↓
Economic burden	Budget pressure from subsidies (>$50 billion/year), fuel smuggling, and underpricing of gasoline.	Implement gradual fuel pricing reforms; redesign subsidies; allocate smart fuel quotas per person.	Subsidies ↑ → Consumption ↑ → Budget deficit ↑ → Policy reform → Price adjustment → Behavior change
Social impacts	Price volatility can spark public protests and worsen inequality; low-income households face disproportionate burdens.	Provide targeted cash transfers; increase subsidy transparency; design inclusive fuel policies.	Price shocks → Social unrest ↑ → Compensatory policies → Infrastructure development → Demand shift
Environmental degradation	Soil and water contamination from poor-quality fuels; loss of biodiversity and increasing climate risks.	Expand clean fuel infrastructure (CNG, EV); prohibit harmful additives; upgrade refinery standards.	Fossil fuel use ↑ → Environmental damage ↑ → Restoration costs ↑ → Environmental taxes ↑ → Demand ↓

The table further highlights how these policies interact with system dynamics feedback loops, offering a comprehensive framework for mitigating fuel demand through strategic policy design.

2.4. Determinants of gasoline demand

The factors influencing gasoline demand in Iran are complex and interconnected, spanning economic, social, environmental, technological, political, cultural, and demographic aspects. Table 2 summarizes the multidimensional factors influencing gasoline consumption, adapted from comparative fuel demand studies (Newman and Kenworthy, 2021; Romero et al., 2024).

Table 2. Determinants of gasoline consumption

Factor category	Sub-Factor	Impact on gasoline consumption	Description
Economic factors	Gasoline Price (Government-set)	Positive (subsidies); Negative (higher prices)	Consumer behavior is directly impacted; subsidies increase consumption.
	Per Capita Income	Positive	Higher income leads to more vehicles and higher consumption
	Fuel Taxes	Negative (if effectively implemented)	Influences consumption, effectiveness varies with tax levels and enforcement.
Social factors	Number of Vehicles	Positive	Directly proportional to gasoline consumption.
	Public Transportation	Negative	Reduces reliance on personal vehicles and fuel use.
	Consumer Behavior (Fuel Efficiency Attitudes)	Positive (if fuel-efficient)	Fuel efficiency habits and attitudes significantly influence consumption.
Environmental factors	Environmental Concerns	Negative	Growing awareness promotes fuel-efficient choices and alternatives
	Climate Change Policies	Negative	Government regulations indirectly reduce gasoline demand.
Technological factors	Vehicle Technology (Fuel Efficiency)	Negative	Fuel-efficient vehicles reduce gasoline demand.
	Fuel Efficiency Improvements	Negative	Technological advancements lower consumption rates
	Consumption Management Software/Apps	Negative	Positive influence on consumer behavior.
Political factors	Energy Policies	Varies (depending on policy)	Significantly impacts consumption patterns.
	Regulations (Fuel Production and Consumption)	Varies (depending on regulation)	Influences fuel production, consumption, and renewable energy use.
	Financial Incentives (Fuel-Efficient Vehicles)	Negative	Subsidies encourage fuel-efficient choices
Cultural factors	Cultural and Social Habits	Varies (depending on habits)	Travel patterns affect gasoline demand.
	Desire for Modernization	Positive	Preference for new vehicles increases consumption.
Demographic factors	Population Size and Distribution	Positive	Larger populations consume more gasoline
	Age and Gender	Varies (depending on demographic)	Consumption varies across different groups.
Other factors	Availability of Alternative Fuels (e.g., CNG)	Negative	Increased availability reduces gasoline demand
	Access to Fuel Stations (Alternative Fuels)	Negative	Convenient access promotes alternative fuel use.

3. Methodology

3.1. Conceptualization of the gasoline consumption dynamic system

3.1.1. Model components: Stocks, flows, and auxiliary variables

The research variables are detailed in the following table:

Table 3. Research variables

No.	Variable name	Period available	Min	Max	Growth rate	Variable type
1	Petrol consumption	1957-2021	12137	89115	0.0435	Flow
2	Petrol production	1957-2021	15187	106000	0.0473	Flow
3	Petrol price	1957-2021	1	1500	0.1854	Stock
4	Number of petrol stations	1976-2021	995	3937	0.056559	Stock
5	Number of petrol cars	1985-2021	6019008	19415351	0.081204941	Stock
6	Petrol export	1985-2021	0	1.9		Flow
7	Petrol import	1957-2021	0	27.5		Flow
8	Consumable petrol	1957-2021	12743	93370	0.043514186	Stock
9	CNG Consumption	1983-2021	0.4	23.32	0.2702	Flow
10	CNG Production		0.44	25.652	0.270173	Flow
11	CNG Price	1984-2021	80	657	0.13186	Stock
12	Number of CNG stations	1957-2021	3	2500	0.1693	Stock
13	Number of hybrid cars	NA	NA	NA	NA	Stock
14	Traffic congestion index	1957-2021	0.26	113.35	NA	Auxiliary
15	Welfare index	1957-2021	0.42	0.89	NA	Auxiliary

Table 3 compiles key variables influencing gasoline and CNG consumption, based on national datasets and previous modeling frameworks (Salimi et al., 2022; Heidari et al., 2023).

3.1.2. Causal loop diagram

A causal loop diagram (Figure 2) visually represents the relationships between variables, using "+" to denote positive relationships and "-" to denote negative relationships.

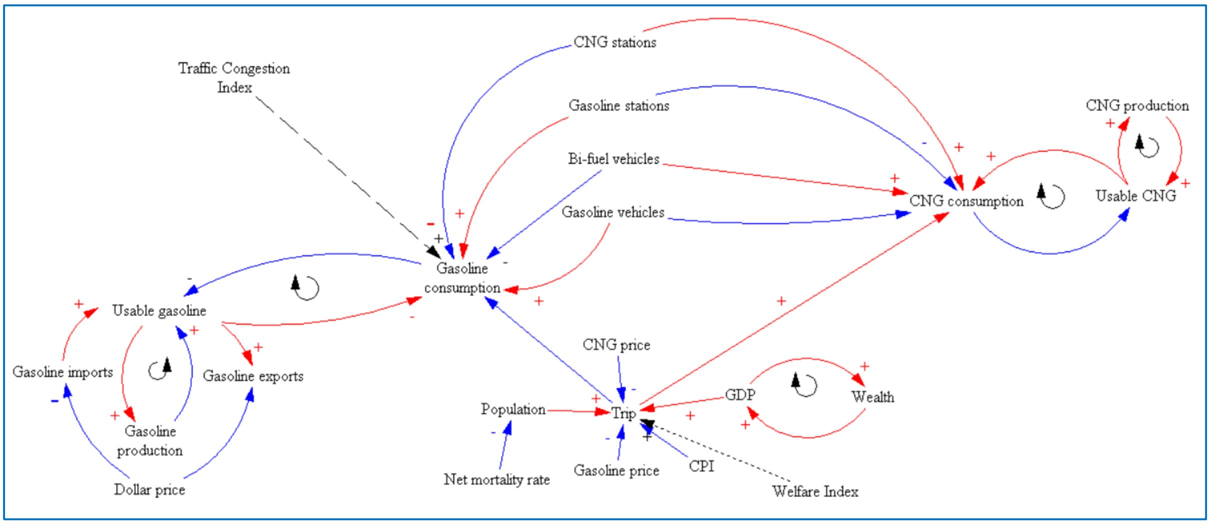

Figure 2. Causal loop diagram of gasoline consumption system

 DOI: 10.22067/jstinp.2025.91024.1129

To enhance model realism, qualitative inputs such as traffic congestion and welfare indicators were incorporated as auxiliary variables that impact trip frequency and fuel choice (Allen and Arkolakis, 2022; Nitoiu et al., 2025).

3.1.3. Stock and flow diagram

This diagram (Figure 3) translates the causal loop diagram into a stock and flow model, focusing on the key variables of gasoline consumption, CNG consumption, and the number of trips. Trips are treated as a constant, influenced by population, GDP, CPI, gasoline price, and CNG price. Policy parameters (Policy Parameter 1 and 2) are introduced to model policy interventions on the number of hybrid cars and CNG stations.

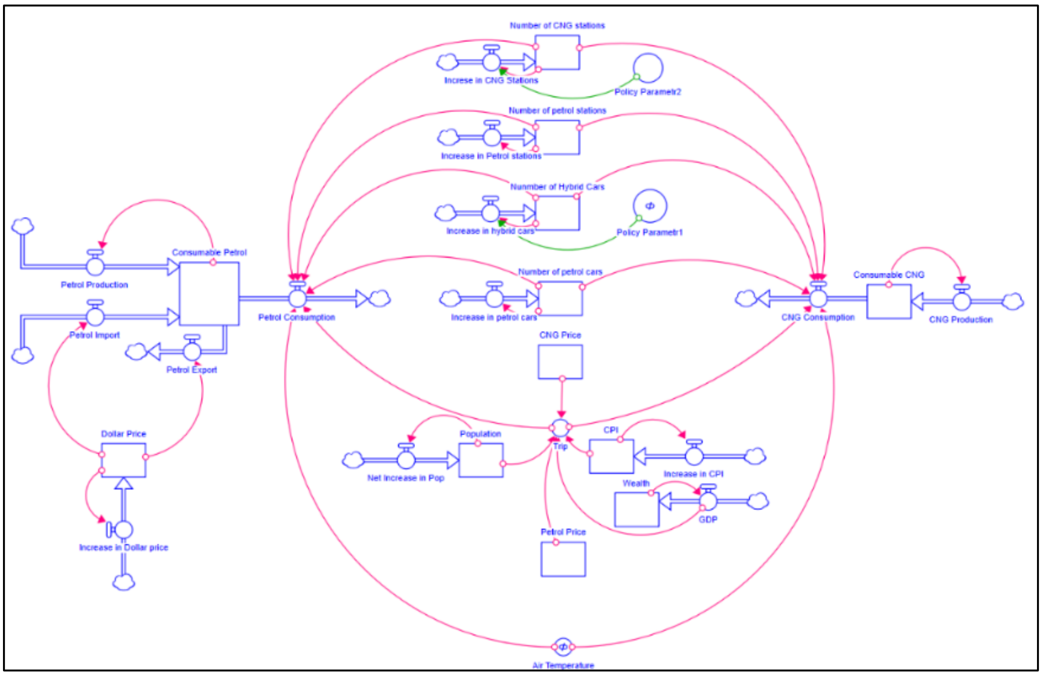

Figure 3. Stock and flow diagram of gasoline consumption

3.1.4. Regression analysis of trips and fuel consumption

In this section, we employ regression analysis using EViews to examine the relationships between various factors influencing trips and fuel consumption in Iran. Three distinct regression models were developed: one to predict the number of trips, another to predict gasoline consumption, and a third to predict CNG consumption. The results, including estimated coefficients and p-values, are presented in Tables 4, 5, and 6. Notably, we observe a strong positive correlation between trips and gasoline consumption, with a p-value of 0.000, indicating statistical significance.

The findings from each regression model are summarized below:

1. Trips model (Table 4)

This model predicts the number of trips based on several variables, including population, Consumer Price Index (CPI), Gross Domestic Product (GDP), gasoline prices, CNG prices, and trips from the prior period.

Table 4. Regression analysis of trips model

Variable	Coefficient	p-value	Interpretation
Population	1.673	0.0169	Positive and statistically significant; higher population increases the number of trips.
CPI	-2.103	0.0540	Negative and marginally significant; higher CPI may slightly reduce trips.
GDP	-0.000271	0.6429	No statistically significant relationship.
Gasoline Price	-6.3962	0.6782	No statistically significant relationship.
CNG Price	-10.168	0.2210	No statistically significant relationship.
Previous Period Trips	0.3249	0.3769	No statistically significant relationship.

2. Gasoline consumption model (Table 5)

This model evaluates gasoline consumption based on the number of CNG stations, dual-fuel vehicles, gasoline-only vehicles, gasoline stations, the number of trips, and previous gasoline consumption.

Table 5. Regression analysis of gasoline consumption

Variable	Coefficient	p-value	Interpretation
CNG Stations	-1.9757	0.0043	A negative and statistically significant correlation exists between the increase in CNG stations and reduced gasoline consumption.
Dual-Fuel Vehicles	-1.840	0.0302	Negative and statistically significant; a higher number of dual-fuel vehicles corresponds to lower gasoline consumption.
Gasoline-Only Vehicles	0.830	0.0580	Positive and marginally significant; an increase in gasoline-only vehicles leads to higher gasoline consumption.
Gasoline Stations	-0.3020	0.5165	No statistically significant relationship.
Trips	1.015	0.0000	Positive and highly statistically significant; increased trips lead to greater gasoline consumption.
Previous Period Gasoline Consumption	-0.0012	0.9627	No statistically significant relationship.

3. CNG consumption model (Table 6)

This model focuses on predicting CNG consumption, taking into account the number of CNG stations, dual-fuel vehicles, gasoline-only vehicles, gasoline stations, and the frequency of trips.

Table 6. Regression of CNG consumption

Variable	Coefficient	p-value	Interpretation
CNG Stations	0.0097	0.0000	Positive and highly statistically significant; more CNG stations lead to increased CNG consumption.
Dual-Fuel Vehicles	2.003	0.0412	Positive and statistically significant; higher numbers of dual-fuel vehicles correlate with increased CNG consumption.
Gasoline-Only Vehicles	-3.26e-7	0.3066	No statistically significant relationship.
Gasoline Stations	0.0019	0.1062	No statistically significant relationship.
Trips	8.03e-5	0.4585	No statistically significant relationship.

The regression analyses indicate a robust positive relationship between the number of trips and gasoline consumption, thereby confirming our initial hypothesis. Additionally, the presence of CNG stations and the prevalence of dual-fuel vehicles significantly influence gasoline and CNG consumption patterns, as anticipated. However, several variables showed no statistically significant correlations, suggesting a need for further analysis or refinement of the model.

3.2. Data analysis and software utilization

The analysis for this study was performed using a combination of software tools tailored for various aspects of the research. Initially, descriptive data analysis was conducted using Microsoft Excel to calculate average growth rates for key variables, including gasoline production, gasoline consumption, and the prices of gasoline and CNG. The growth rates were computed using the following formula:

$$X_t = X_0(1+g)^{t-0} \qquad (1)$$

Where g represents the annual growth rate of the variable Xt.

For the quantitative and statistical analysis aimed at estimating the coefficients of the dynamic model, EViews was utilized to implement multivariate regression analysis, which facilitated a thorough examination of the relationships among the variables influencing gasoline consumption.

Moreover, dynamic systems analysis of gasoline consumption was performed using Stella software. This approach allowed us to develop causal loop diagrams and stock-flow diagrams, along with their corresponding formulations, to illustrate and analyze the feedback mechanisms within the gasoline consumption system.

Ultimately, the outputs generated by Stella were instrumental in conducting comprehensive research analyses, providing valuable insights into the system's dynamics and enabling a thorough understanding of the factors influencing gasoline consumption in Iran.

3.3. Validation of the dynamic model

The model was validated using complementary methods:

1. **Comparison with historical data** (2006-2021): We compared model outputs with actual consumption data from the National Iranian Oil Products Distribution Company (NIOPDC). The model demonstrated:

- ✓ Excellent predictive accuracy ($R^2 = 0.93$)
- ✓ Mean absolute error of 4.7%
- ✓ Root mean square error of 6.2%

Notably, the model successfully replicated the 15% reduction in consumption following the 2019 fuel rationing policy (Fig. 5a).

2. **Sensitivity analysis:** Parameter sensitivity was tested through Monte Carlo simulations (±20% variation):

- ✓ Gasoline price elasticity showed the greatest impact (±18% consumption change)
- ✓ CNG infrastructure expansion potential (±12%)
- ✓ Dual-fuel vehicle adoption rate (±15%)

All parameters were statistically significant ($p<0.01$) using Sobol's sensitivity indices.

3. **Cross-Validation:** We employed k-fold cross-validation (k=5):

- ✓ Training period: 2006-2017 (80% of data)
- ✓ Testing period: 2018-2021 (20% of data)

Model performance remained consistent across all folds:

- ✓ MAE range: 4.2-5.1%
- ✓ RMSE range: 5.8-6.5%

In conclusion, these validation methods confirmed that the model effectively predicts fuel consumption dynamics, establishing it as a valuable tool for energy policy analysis in Iran.

4. Results

4.1. Simulation outcomes of the dynamic model

The final stock and flow model (see Figure 4) integrates the regression results, illustrating the interconnectedness of various factors influencing gasoline consumption. In this diagram, thicker arrows indicate stronger and more direct relationships among the variables.

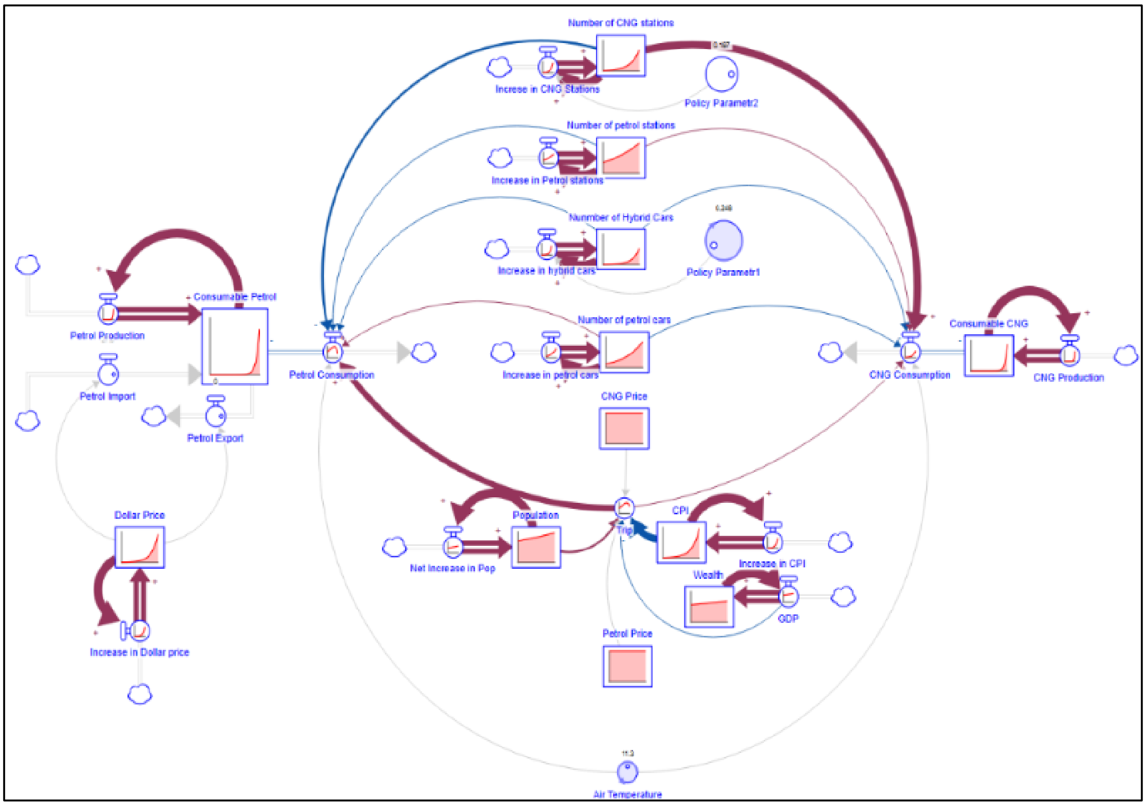

Figure 4. Stock and flow diagram of the simulated dynamic model for gasoline consumption

The analysis reveals a strong positive correlation between the number of trips and gasoline consumption. Other factors—such as population, GDP, CPI, gasoline and CNG prices, the number of CNG stations, and the prevalence of hybrid vehicles—primarily impact gasoline consumption through their influence on the number of trips. Notably, the policy interventions (designated as Policy Parameters 1 and 2) are designed to affect gasoline consumption indirectly by influencing the growth of hybrid vehicles and the establishment of CNG stations. While Figure 4 captures key dynamic relationships, Variables such as population death rate and foreign exchange trends were excluded due to their indirect temporal impact on gasoline consumption. These may be considered in future iterations for macroeconomic expansion.

4.2. Forecasting results

Following the initial design of the dynamic model, validation is essential for its practical application. To this end, gasoline consumption data from Iran (2006-2021), along with other relevant model variables, were integrated into the dynamic model. The simulated data were then compared against actual historical consumption data as presented in Table 7.

Table 7. Comparison of actual and simulated gasoline consumption (2006-2021)

Year	Actual Consumption (k liters)	Simulated consumption (k liters)
2006	73,660	48,800
2007	64,450	51,900
2008	66,931	55,000
2009	64,800	58,200
2010	61,267	61,300
2011	59,857	64,300
2012	63,493	67,400
2013	68,409	70,400
2014	69,591	73,300
2015	71,003	76,100
2016	74,741	78,700
2017	80,714	81,200
2018	89,115	83,500
2019	89,000	85,500
2020	75,000	87,100
2021	86,000	88,300

Table 8. Gasoline consumption forecast (2022-2031)

Year	Forecasted consumption (thousands of liters)
2022	89,000
2023	89,000
2024	88,100
2025	86,200
2026	83,100
2027	78,500
2028	71,900
2029	63,100
2030	51,400
2031	36,200

The model projects gasoline consumption to decrease to 36,200,000 liters by 2031 as shown in Table 8. In contrast, a simple extrapolation based on the average annual growth rate of 4.35% would suggest consumption could reach 131,666,000 liters. This predicted downward trend from 2023 to 2031 can be attributed to several factors, including significant inflation that reduces purchasing power, shifting priorities regarding travel expenditures, technological advancements that yield more fuel-efficient vehicles, and the growing prevalence of online shopping and remote work. The dynamic model's forecast suggests a more conservative outlook than the simple extrapolation, reflecting the model's incorporation of complex, non-linear interrelationships among the various influencing factors, which may result in more accurate predictions.

4.3. Sensitivity analysis

This section presents a sensitivity analysis of the dynamic model used to predict gasoline consumption in Iran. The base model incorporates coefficients of 0.17295 and 0.18702, corresponding to the average annual growth rates of dual-fuel vehicles and CNG stations, respectively, from 2006 to 2020. Three scenarios were simulated to assess model sensitivity to variations in these parameters (see Table 9):

Scenario 1: Increased annual growth rate of dual-fuel vehicles from 0.17295 to 0.35.

Scenario 2: Increased annual growth rate of CNG stations from 0.18702 to 0.22.

Scenario 3: Simultaneous increase of both parameters (Scenario 1 and Scenario 2 combined)

Table 9. Gasoline consumption forecast (2022-2031) under different scenarios

Year	Forecasted consumption (thousands of liters)-base mode	Scenario 1	Scenario 2	Scenario 3
2022	89,000	88	87	86
2023	89,000	87	87	86
2024	88,100	86	86	84
2025	86,200	80	84	81
2026	83,100	76	80	77
2027	78,500	68	74	70
2028	71,900	58	67	62
2029	63,100	45	57	50
2030	51,400	42	44	35
2031	36,200	24	27	15

- Scenario 1 (Increased Dual-Fuel Vehicles): This scenario indicates a significant reduction in gasoline consumption by 2031, decreasing from 36,200,000 liters to 24,000,000 liters, underscoring the strong influence of dual-fuel vehicle adoption on gasoline demand. The effect becomes increasingly pronounced in the later years.
- Scenario 2 (Increased CNG Stations): This scenario reflects a less dramatic reduction in gasoline consumption, with projected consumption reaching 27,000,000 liters by 2031. The impact is notably less substantial during the earlier years of the forecast period.
- Scenario 3 (Combined Effect): This scenario demonstrates the most significant decrease in gasoline consumption, projecting a reduction to 15,000,000 liters by 2031. This highlights the synergistic effect of enhancing both dual-fuel vehicle and CNG station accessibility.

The sensitivity analysis indicates that policy initiatives targeting the promotion of dual-fuel vehicles and the expansion of CNG infrastructure could significantly reduce gasoline consumption in Iran. Among the scenarios, Scenario 3, which represents an integrated policy approach, proves to be the most effective. However, the reliability of the model's forecasts depends on the accuracy of the growth rate estimates and the consideration of other relevant factors. Figure 5 illustrates the comparison of predicted gasoline consumption outcomes across the different scenarios.

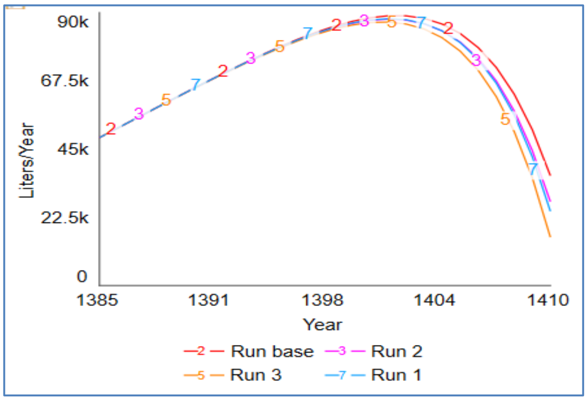

Figure 5. Comparison of predicted gasoline consumption under different scenarios

5. Discussion

This study aimed to explore the dynamics of gasoline consumption in Iran through a comprehensive dynamic model that incorporates various influencing factors, such as economic conditions, vehicle types, and policy interventions. The simulation results indicate a robust positive correlation between the number of trips and gasoline consumption, suggesting that travel behavior is a critical driver of fuel demand. This finding aligns with previous research indicating that increases in mobility are closely linked to rising fuel consumption.

The impact of policies aimed at promoting dual-fuel vehicles and expanding CNG stations was particularly noteworthy. This outcome aligns with findings from Raei et al. (2024), who evaluated the effects of energy policy reforms on fuel consumption and emissions in Iran, as well as Maleki et al. (2024), who highlighted the strategic role of transitioning toward clean energy in national policy frameworks.

The sensitivity analysis revealed that both interventions could significantly mitigate gasoline demand, with Scenario 3—combining increased adoption of dual-fuel vehicles and expansion of CNG infrastructure—demonstrating the most substantial reduction in projected consumption. These results underscore the effectiveness of integrated policy approaches. They also reflect a growing global consensus that multi-pronged strategies are essential for achieving meaningful energy transitions and reducing fuel dependency.

Furthermore, the forecasting results indicate a marked decline in gasoline consumption over the next decade, with predictions stabilizing at levels considerably lower than those extrapolated from historical growth rates. This divergence suggests the importance of accounting for structural changes within the economy, such as technological advancements and shifts in consumer behavior, which simple extrapolation methods may not capture. Key factors identified, including inflation, increased fuel efficiency, and trends toward online shopping and

 DOI: 10.22067/jstinp.2025.91024.1129

remote work, highlight the need for policymakers to consider broader economic shifts when developing strategies to manage fuel consumption. Additionally, the proposed system dynamics model was benchmarked against reference frameworks such as the C-ROADS climate simulator and Ford's energy policy dynamics (Ford, 2020). Compared to these models, our framework offers greater granularity in fuel infrastructure and vehicle segmentation, making it better suited for national-level policy analysis.

6. Conclusion

In conclusion, this study provides valuable insights into the determinants of gasoline consumption in Iran, highlighting the roles of trip frequency and vehicle type in shaping fuel demand patterns. The dynamic model developed herein offers a nuanced understanding of how various factors interact within the fuel consumption system, providing a platform for informed decision-making.

The findings underscore the importance of implementing policies that do not merely aim to increase fuel availability but also encourage shifts toward more sustainable vehicle technologies. By promoting the adoption of dual-fuel vehicles and expanding CNG infrastructure, Iran can potentially reduce its reliance on gasoline, alleviate environmental pressures, and enhance energy security.

Future research should seek to refine the model further by incorporating additional variables, such as changes in consumer behavior in response to economic shocks, policies targeting public transportation, and the impact of renewable energy adoption. Additionally, longitudinal studies could provide deeper insights into how these factors evolve and their implications for Iran's long-term energy policy.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Abediasl, H., Ansari, A., Hosseini, V., Koch, C.R. and Shahbakhti, M., 2024. Real-time vehicular fuel consumption estimation using machine learning and on-board diagnostics data. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, *238*(12), pp.3779-3793. https://doi.org/10.1177/09544070231185609.

Akbari, F., Mahpour, A. and Ahadi, M.R., 2020. Evaluation of energy consumption and CO2 emission reduction policies for urban transport with system dynamics approach. *Environmental Modeling & Assessment*, *25*(4), pp.505-520. https://doi.org/10.1007/s10666-020-09695-w.

Al-Ghandoor, A., Jaber, J., Al-Hinti, I. and Abdallat, Y., 2013. Statistical assessment and analyses of the determinants of transportation sector gasoline demand in Jordan. *Transportation Research Part A: Policy and Practice*, *50*, pp.129-138. https://doi.org/10.1016/j.tra.2013.01.022.

Allen, T. and Arkolakis, C., 2022. The welfare effects of transportation infrastructure improvements. *The Review of Economic Studies*, *89*(6), pp.2911-2957. https://doi.org/10.1093/restud/rdac001.

An-loh, L., Botsas, E.N. and Monroe, S.A., 1985. State gasoline consumption in the USA: an econometric analysis. *Energy Economics*, *7*(1), pp.29-36. https://doi.org/10.1016/0140-9883(85)90036-2.

Ansarinasab, M. and Manzari Tavakoli, Z., 2020. Modeling Gasoline Consumption Behaviors in Iran Based on Long Memory and Regime Change. *Quarterly Energy Economics Review*, *16*(64), pp.125-149. URL: http://iiesj.ir/article-1-1145-en.html. [in Persian].

Ayyıldız, E. and Murat, M., 2024. A lasso regression-based forecasting model for daily gasoline consumption: Türkiye Case. *Turkish Journal of Engineering*, *8*(1), pp.162-174. https://doi.org/10.31127/tuje.1354501.

Bates, M. and Kim, S., 2024. Estimating the price elasticity of gasoline demand in correlated random coefficient models with endogeneity. *Journal of Applied Econometrics*, *39*(4), pp.679-696. https://doi.org/10.1002/jae.3042.

Bayat, N., Davoodi, M.M. and Rezaei, A., 2023. Forecasting Gasoline Consumption in Iran using Deep Learning Approaches. *Iranian Economic Review*, *27*(2), pp.347-376. 10.22059/ier.2023.317681.1007087.

Ceylan, Z., Akbulut, D. and Baytürk, E., 2024. Forecasting gasoline consumption using machine learning algorithms during COVID-19 pandemic. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *46*(1), pp.16623-16641. https://doi.org/10.1080/15567036.2021.2024919

Chang, C.C., 2016. Causal analysis of carbon emissions, deadweight tonnage of global shipping fleet, fuel oil consumption, and economic activities in marine transportation. *Energy Sources, Part B: Economics, Planning, and Policy*, *11*(4), pp.303-308. https://doi.org/10.1080/15567249.2011.607884.

Ford, A., 2018. System dynamics models of environment, energy, and climate change. In *Encyclopedia of complexity and systems science* (pp. 1-25). Springer, Berlin, Heidelberg.

Ghoddusi, H., Morovati, M. and Rafizadeh, N., 2019. Foreign exchange shocks and gasoline consumption. *Energy Economics*, *84*, p.104472. https://doi.org/10.1016/j.eneco.2019.08.005.

Goetzke, F. and Vance, C., 2021. An increasing gasoline price elasticity in the United States?. *Energy economics*, *95*, p.104982. https://doi.org/10.1016/j.eneco.2020.104982.

Heidari, E., Bikdeli, S. and Daneshvar, M.R.M., 2023. A dynamic model for CO2 emissions induced by urban transportation during 2005–2030, a case study of Mashhad, Iran. *Environment, Development and Sustainability*, *25*(5), pp.4217-4236. https://doi.org/10.1007/s10668-022-02240-7.

Iran Chamber Newsroom, 2024. *Iran's average daily gasoline consumption reaches 113m liters.* Available at: https://en.otaghiranonline.ir/news/45254.

Jafari, H.H. and Baratimalayeri, A., 2008. The crisis of gasoline consumption in the Iran's transportation sector. *Energy Policy*, *36*(7), pp.2536-2543. https://doi.org/10.1016/j.enpol.2008.03.014.

Kilian, L. and Zhou, X., 2024. Heterogeneity in the pass-through from oil to gasoline prices: A new instrument for estimating the price elasticity of gasoline demand. *Journal of Public Economics*, *232*, p.105099. https://doi.org/10.1016/j.jpubeco.2024.105099.

Lee, C.C. and Olasehinde-Williams, G., 2021. Gasoline demand elasticities in the world's energy gluttons: a time-varying coefficient approach. *Environmental Science and Pollution Research*, *28*(45), pp.64830-64847. https://doi.org/10.1007/s11356-021-15615-6.

Maleki, A., Ashrafi, M.H. and Raei, H., 2024. Overview of energy policy in Iran: the proper path to clean energy. *Academia Green Energy*, *1*(2). https://doi.org/10.20935/AcadEnergy7316.

Mikayilov, J.I., Joutz, F.L. and Hasanov, F.J., 2020a. Gasoline demand in Saudi Arabia: are the price and income elasticities constant?. *Energy Sources, Part B: Economics, Planning, and Policy*, *15*(4), pp.211-229. https://doi.org/10.1080/15567249.2020.1775325.

Mikayilov, J.I., Mukhtarov, S. and Mammadov, J., 2020b. Gasoline demand elasticities at the backdrop of lower oil prices: Fuel-subsidizing country case. *Energies*, *13*(24), p.6752. https://doi.org/10.3390/en13246752.

Moshiri, S. and Aliyev, K., 2017. Rebound effect of efficiency improvement in passenger cars on gasoline consumption in Canada. *Ecological economics*, *131*, pp.330-341. https://doi.org/10.1016/j.ecolecon.2016.09.018.

Moshiri, S., 2020. Consumer responses to gasoline price and non-price policies. *Energy Policy*, *137*, p.111078. https://doi.org/10.1016/j.enpol.2019.111078.

Mosleh Shirazi, A.N. and Sotodeh, F., 2015. Simulating the role of subsidies reform in fuel consumption by system dynamics approach. *Journal of Applied Economics Studies in Iran*, *4*(13), pp.107-125. URL:https://aes.basu.ac.ir/article_1036_en.html. [in Persian].

Newman, P. and Kenworthy, J., 2021. Gasoline consumption and cities revisited: what have we learnt?. *Current Urban Studies*, *9*(3), pp.532-553. https://doi.org/10.4236/cus.2021.93032.

Nitoiu, C., Cofaru, C. & Popescu, M., 2025. Influence of road and traffic conditions on emissions and fuel consumption of light vehicles in a real urban driving cycle. *Environmental Science and Pollution Research* 32, pp. 15050–15065. https://doi.org/10.1007/s11356-025-36573-3.

Norouzi, N., Majedi, S. and Abbasi, V., 2022. Dynamic modeling of the effect of Vehicle Hybridization policy on carbon emission and energy consumption. *Journal of Chemistry Letters*, *3*(2), pp.99-107. https://doi.org/10.22034/jchemlett.2022.352806.1078.

Pourmatin, M., Moeini-Aghtaie, M., Hassannayebi, E. and Hewitt, E., 2024. Transition to Low-Carbon Vehicle Market: Characterization, System Dynamics Modeling, and Forecasting. *Energies*, *17*(14), p.3525. https://doi.org/10.3390/en17143525.

Raei, H., Maleki, A. and Farajzadeh, Z., 2024. Analysis of energy policy reform in Iran: Energy and emission intensity changes. *Economic Analysis and Policy*, *81*, pp.1535-1557. https://doi.org/10.1016/j.eap.2024.02.023.

Rogat, J. and Sterner, T., 1998. The determinants of gasoline demand in some Latin American countries. *International Journal of Global Energy Issues*, *11*(1-4), pp.162-170. https://doi.org/10.1504/IJGEI.1998.071441.

Romero, C.A., Correa, P., Ariza Echeverri, E.A. and Vergara, D., 2024. Strategies for reducing automobile fuel consumption. *Applied Sciences*, *14*(2), p.910. https://doi.org/10.3390/app14020910.

Roudbaraki, M., Valipour, M.S., Khorasani, A.F. and Salehi, G.R., 2025. Integrating Data Mining and System Dynamics to Model Energy Policy Development and Sustainability Assessment. *Petroleum Business Review (PBR)*, *9*(1). https://doi.org/10.22050/pbr.2025.475979.1348.

Salimi, M., Moradi, M.A. and Amidpour, M., 2022. Modeling and outlook analysis of gasoline supply and demand and sensitivity analysis of main economic and social drivers. *Energy*, *256*, p.124686. https://doi.org/10.1016/j.energy.2022.124686.

Samavi, M., Panahi, M., Abedi, Z. and Ahmadian, M., 2024. Assessing the Economic Impact of Using ITSs (Intelligent Transportation Systems) on Gasoline Consumption in Iran (Case Study of Karaj-Chalous Axis). *Road*, *32*(120), pp.331-348. https://doi.org/10.22034/road.2023.367900.2107. [in Persian].

Sapnken, E.F., Tamba, J.G., Essiane, S.N., Koffi, F.D. and Njomo, D., 2018. Modeling and forecasting gasoline consumption in Cameroon using linear regression models. *International Journal of Energy Economics and Policy*, *8*(2), pp.111-120. URL: https://www.econjournals.com/index.php/ijeep/article/view/5985.

Saryazdi, A.H.G. and Tavangar, L., 2023. Dynamics of Gasoline Price Changes; The Effects of Pricing Policies in Iran. https://doi.org/10.21203/rs.3.rs-3394892/v1.

Shamsapour, N., Hajinezhad, A. and Noorollahi, Y., 2021. Developing a system dynamics approach for CNG vehicles for low-carbon urban transport: a case study. *International journal of low-carbon technologies*, *16*(2), pp.577-591. https://doi.org/10.1093/ijlct/ctaa085.

Vafa-Arani, H., Jahani, S., Dashti, H., Heydari, J. and Moazen, S., 2014. A system dynamics modeling for urban air pollution: A case study of Tehran, Iran. *Transportation Research Part D: Transport and Environment*, *31*, pp.21-36. https://doi.org/10.1016/j.trd.2014.05.016.

Yang, Y., Gong, N., Xie, K. and Liu, Q., 2022. Predicting gasoline vehicle fuel consumption in energy and environmental impact based on machine learning and multidimensional big data. *Energies*, *15*(5), p.1602. https://doi.org/10.3390/en15051602.

Yu, L., Ma, Y. and Ma, M., 2021. An effective rolling decomposition-ensemble model for gasoline consumption forecasting. *Energy*, *222*, p.119869. https://doi.org/10.1016/j.energy.2021.119869.

Zareayan Mazrae Khosro, R. and Shakouri Ganjavi, H., 2016. System Analysis Gasoline Demand and Estimating the Price Elasticity in the Province of Tehran, *Iranian Energy Economics*, *5*(18), pp. 61–98. https://doi.org/10.22054/jiee.2016.7193. [in Persian]