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**Case Study**

# Environmental impact assessment of employing intelligent transportation systems on carbon dioxide ($CO_2$) emissions in Iran (Case Study: Karaj-Chalous axis)

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ABSTRACT

**Background and objective:** Transportation is the driving force needed to achieve the goals of economic development and create the well-being of human societies. Modern life requires growth and expansion of the movement. The present research is applied in terms of purpose-based classification. The idea of applied research is to develop applied knowledge in a particular field. This study aimed to estimate the environmental effects of reducing $CO_2$ emissions by using intelligent transportation system (ITS) in Iran.
**Materials and methods:** This research is descriptive-correlational in terms of method and nature. The statistical population of this study is the vehicles traveling during the eight busy days of September from 1 am to 00:00 in the Karaj-Chalous axis in 2019 during the study time. No other specific sampling was performed. All calculations and analyzes were performed using Excel and 10Eviews software.
**Results and conclusion:** The results revealed that the application of the intelligent transportation system had decreased travel time on the Karaj-Chalous axis and, therefore, reduced carbon dioxide ($CO_2$) emissions. The outcomes indicated that the use of the ITS during the eight days of the research had decreased 10,129 tons of carbon dioxide emissions in the Karaj-Chalous axis.

## 1. Introduction

Transportation is the driving force required to reach the goals of economic development and create the well-being of human societies. Modern life needs the growth and expansion of motion. It is often thought that the application of personal vehicles, the use of which is growing day by day, is safer and more secure. Hence, due to the increase in the number of vehicles, a heavy load is charged on the transport

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infrastructure. Despite the high cost of making new road infrastructure, traffic congestion is still increasing, and the consequences for road safety and environmental advancements are reducing. Road transport is one of the main sources of greenhouse gas emissions that lead to global warming and climate change. Promoting the decarbonisation of the sector through more efficient and greener mobility is a challenging task that can be realized by Intelligent Transport Systems (ITS) enabled by vehicular communication d'Orey & Ferreira, (2013). To manage environmental impacts, road transport emissions inventories are used by stakeholders and government researchers to track emissions reduction progress (Wu et al., 2016).

Accordingly, environmental pollution, falling and rising prices of energy resources, material and moral damages caused by increasing accidents, problems of monitoring and management in suburban transportation, rising wasted time, and the rapid growth of transportation demand, especially during peak hours in the world's metropolises, today, are among the issues and challenges facing the transportation industry.

In this respect, the intelligent transportation system has been employed as one of the tools to overcome these challenges. The intelligent transportation system is a collection of elements that work together to transport cargo and passengers and have the ability to learn to adapt to new situations. These components are defined by the use of information analysis and experience to improve operational effectiveness. In a better sense, the intelligent transportation system means "the intended use of the technologies of collecting, processing, and broadcasting information to boost safety, economic efficiency and control of environmental pollution, and to provide facilities for users and operators in association with transportation and freight and passenger." In other words, intelligent transportation systems are the application of modern and computer technologies to enhance the safety and efficiency of transportation systems and to decrease environmental pollution (Mfenjou et al., 2018; Jamali et al., 2021).

Intelligent transportation uses information technology to improve the level of safety, efficiency, and cheapness of transportation. These benefits can be generalized to different modes of transportation, such as road, rail, air, and sea. ITS has designated a fitting association between humans, vehicles, and roads. In other words, intelligent transportation systems using information technology will revolutionize the transportation industry. Optimal application of available resources, decreasing injuries and increasing safety and comfort, reducing costs and adverse environmental effects, reducing energy consumption and unwanted delays during transportation, accurate and efficient management and planning in transportation and traffic, increasing passenger satisfaction, and Traffic flow smoothing, are always the most critical benefits and objectives of using intelligent transportation systems (Rahbar et al., 2018).

Chalous Road is one of the most crucial communication axes to reach the north of the country. This road is more vital for travelers as it is a tourist attraction. This road, registered as the fourth tourist road worldwide, is toiling with many difficulties these days, and it is gradually moving towards leaving the list of the top roads in the world. In other words, the infrastructure of this road does not answer the current traffic. Therefore, this study aims to assess the environmental outcomes of decreasing carbon dioxide (CO2) emissions by using ITS on the Karaj-Chalous axis.

### *1.1. Research background*

In a study, Ghadbik and Ehsanifar (2019) have addressed the "Development and application of urban traffic management evaluation framework and intelligent transportation systems." The findings of analysis and comparison of before and after studies were presented. It was found that by prioritizing the passage of city buses and taxis on designated lines, we can decrease travel time and increase mobility. This was stated not only for the study area but also for the overall model framework for its evaluation and application.

Samavi et al. (2017), in a study, have examined the "hardware and software infrastructure in the implementation of the intelligent transportation system and urban traffic." This article considers that the realization and implementation of intelligent transportation systems require the provision of the necessary prerequisites and communication infrastructure in this field, while briefly introducing this system, will discuss the importance of communication as one of the important pillars of providing intelligent transportation systems services and introduce the types of communication and the criteria required in choosing communication technology in intelligent transportation systems. Ghanbari et al. (2015), in a study, have researched "intelligent transportation systems in urban traffic management." They have stated that in today's world, with rising population, increasing urban travel, economic development of society, and increasing car ownership, we encounter more traffic problems, particularly in cities. The growth of urban transportation is one of the central issues in solving the problems and quandaries of urban traffic.

In research, Zoghi et al. (2014) addressed the "Functional analysis of smart ERP systems in the development of the transportation industry." They have remarked that ERP stands for Electronic Road Pricing. The general mechanism of this system is that designated cameras are set in all automatic payment gateways of highways. These cameras take a photo of the license plate when the car passes through the door and then allocate the sum of tolls to the license plate according to the distance traveled on the road. If the amount in the specific internet bank account related to the license plate is enough, the sum of tolls will be deducted from the account, and the toll is paid. If the available amount is not enough, it will be allocated to the car for a given time (for instance, six months), and the vehicle will have to be paid as a violation.

Dandala et al. (2020) said in a study that vehicles on the Internet of Vehicles (IoV) could communicate with each other to specify road and vehicle status in real-time. These parameters are employed to evaluate the average speed and identify the optimal route to reach the destination. Nonetheless, government traffic departments are unable to use this valuable traffic data. Thus, more traffic, congestion, and more road accidents happen.

Lee et al. (2020) performed a study to solve the real-world traffic problem in a large-scale factory. Autonomous Vehicle Systems (AVS) systems, designed to operate multiple vehicles to transport materials, are broadly used for transmission in the construction of semiconductors. Traffic control with AVS is an essential challenge as all vehicles must be controlled in real-time to manage uncertainties such as congestion. Empirical outcomes demonstrated that AVS performed better than the existing approach in delivery time, transfer time, and queue time. We discovered that adopting machine learning-based traffic control can enhance the performance of existing AVSs and ease the burden on the human specialists who control AVSs.

Barth et al. (2015) studied this issue in a study named "Intelligent Transportation System and Greenhouse Gas Reduction." As such, we pithily confer on how intelligent transportation systems impact greenhouse gas emissions. It then explains some recent intelligent transportation systems programs specifically designed to lower energy and environmental effects. These smart environmental transportation system applications commonly show energy savings and emissions decreases of about 5 to 15 percent.

## 2. Theoretical foundations of research

### *2.1. Traffic*

Traffic is a fact that comes from the level and type of quality of human life. This fact is affected by the kind of reason and the subject matter of human beings and is studied. But the level and type of quality of human life have always been shifting over time and similar to the continuity of time change. Consequently, the subject of traffic as an unmoving reality that always accompanies the man at any time has unique characteristics (Jamadi & Jamadi, 2019). In today's world, although the same as before, in some respects, the bitter taste of this reality overshadows its sweet taste. Insofar as when we think of the two ideas of technology and the purpose of science at the same time, we see that the technology of the car, if what is realized, is considered the goal of science, the direct and indirect effects and consequences of which not only lead to a worse life but sometimes lead to death (ibid.).

In the development plan of the developed countries of the world, having a safe and efficient transportation system has a special place as an infrastructure factor. Our country is no exception to this rule due to its unique geographical location in terms of transit and transportation of goods in the Middle East and Central Asia.

Dire casualties stemming from road accidents cause the loss of notable amounts of national resources and the concern and suffering of the families of the victims of the accident. Investigations by the Transportation Research Laboratory indicate that the number of years of work lost because of road accidents is greater than the number of years lost owing to other reasons of premature death. These studies reveal that about 70% of life lost due to accidents are work years. In developing countries, meanwhile, people are losing the most active and productive years of their lives owing to car accidents. Comparing other causes of premature death in the country, particularly malaria and infectious diseases, it is evident that deaths due to road accidents are still rising (Khodabandeh Lou et al., 2019).

Therefore, a review of the current poor traffic situation in our country indicates that social insecurities in this field, despite the limited apparent island effect on the lives of distinct individuals in a community, will have a detailed and pervasive impact on the lives and destinies of all members of society and even the nations of the world due to the dominance of nonlinear relationships between the components of social systems. It will be the life and destiny of all members of society and even the nations of the world. Hence, following a series of various measures that have been taken to reduce the rate of development of traffic tolls in our country, as well as to maintain the comprehensiveness of national macro-planning, after reviewing the historical course of traffic safety in our country and also reviewing the series of measures and interventions taken to prevent the increase of the country's road insecurity index, a measure should be considered in line with other parts of the Fifth Development Plan to provide a more credible guarantee of success in the progress of the country by using the maximum systemic ideas and approaches.

The chief roots of the country's traffic challenges include the weak understanding of the dimensions of the problem, the weak executive capacity of government institutions, lack of systemic view and approach among government elements, and lack of long-term and forward-looking view to the issue.

### *2.2. Intelligent Transportation Systems (ITS)*

ITS, which stands for Intelligent Transportation Systems, contains all information, telecommunications, control, system engineering technologies, strategies, management decisions, and coordination mechanisms. The application of ITS yields enhanced transportation and traffic parameters such as decreased travel time and fuel consumption and improved safety. There are several definitions of the intelligent transportation system. The shared concept of these definitions underlines the purposeful and coordinated use of information and communication technology and management strategies with the condition of improving the efficiency and safety of transportation systems (Möller & Vakilzadian, 2016).

ITS is a set of amazing IT advancements in transportation that have altered the quality of life of people as well as transport management in these communities. In other words, this intelligent system is one of the most critical manifestations of life in the modern economy. ITS includes the intersections, messaging of variable news signs, display and speed warning system, automatic receipt of road tolls, automatic recording of traffic violations, instant notification of urban transportation network, and in-vehicle routing of traffic parameters and the like. In these systems, there is no requirement for the continuous and simultaneous presence of manpower at the site of the operation, and the constraints of operating fixed systems with low efficiency are removed. Appropriate use of new technologies is fundamental to fulfill the above challenges. ITSs are complex, multifaceted tools created by incorporating advanced technologies and are employed to enhance transportation conditions and provide solutions to improve the quality of life (Lee & Taheri, 2017).

### *2.3. Implications of the intelligent transportation system on environment and traffic*

ITSs have generated significant enthusiasm in the transportation community owing to their potential to enhance road safety, ease traffic congestion, and improve the mobility of people and goods. In addition to safety and mobility, we now witness that intelligent transportation systems can play an essential role in decreasing emissions and greenhouse gases (emissions) as well as lowering energy consumption. It is a common perception that the transportation sector is accountable for nearly one-third of the emissions.

To decrease the share of pollutants and greenhouse gas emissions, the focus has been on three items. (1) enhancing vehicle fuel efficiency (e.g., using innovative methods and reducing weight while maintaining safety), (2) using low-carbon fuels (such as ethanol, electricity), and (3) managing travel demand (e.g., road tolls) and switching travel to non-motorized modes. Plus, we now see that intelligent transportation systems can be employed as the fourth critical element: to improve the efficiency of the transportation system. As such, it decreased the overall emission of greenhouse gases (Ebrahimi and Fatemi, 2019).

## 3. Material and Methods

The present study is descriptive. Descriptive research strives to answer its questions by analyzing the associations between variables. In this method, the explicit content of the messages is systematically and quantitatively explained. The basic concept of content analysis is to put the components of a text (words, sentences, paragraphs, and the like) according to the units picked in some predefined categories. This method can be considered a way of converting qualitative data into quantitative data. Content analysis is a fantastic way to answer questions about the content of a message. To do the study, preliminary and theoretical studies were performed first to determine the variables being measured. Plus, using the proposed theories, the theoretical framework used was extracted, and then the chief component was defined operationally. Next, using the scientific relations of physics and chemistry, the quantities related to each of the variables were determined.

### *3.1. Hypotheses*

Research hypotheses include:

Hypothesis 1: Exit and entry vehicles to the case study area (Karaj-Chalous) from villages and side roads have been ignored.

Hypothesis 2: Fuel consumption is counted based on travel time, not engine speed.

Hypothesis 3: Stopping and moving cars again along the studied route (Karaj-Chalous) for any reason - including tourism, accidents, how drivers drive, etc. - has been neglected.

Hypothesis 4: Road construction and other factors influencing the speed of vehicles along the route are considered the same (such as slope, tunnel, road width, traffic signs, light, etc.).

Hypothesis 5: Cars are considered to be the same type.

Hypothesis 6: Natural disasters such as snow, rain, landslides, floods, etc., have been ignored.

Hypothesis 7: C8H18 octane is considered the chemical formula of gasoline.

Since the statistical population refers to the whole group of people, events, or things that the researcher wants to investigate and are the variables that are studied, the statistical population of the present study is vehicles that traveled on the busy days of the tenth, twelfth, thirteenth, fourteenth, fifteenth, seventeenth, twenty-fourth, and thirty-first of Shahrivar 2018 on the way from Karaj to Chalous. No other specific sampling has been done in this regard. To measure the impacts of using intelligent transportation on the control of road traffic and the amount of greenhouse gas emissions, the following method is used. Location and some remote sensing related maps were produced (Jamali et al., 2020; Ghane Ezabadi et al., 2021) (Fig. 1).

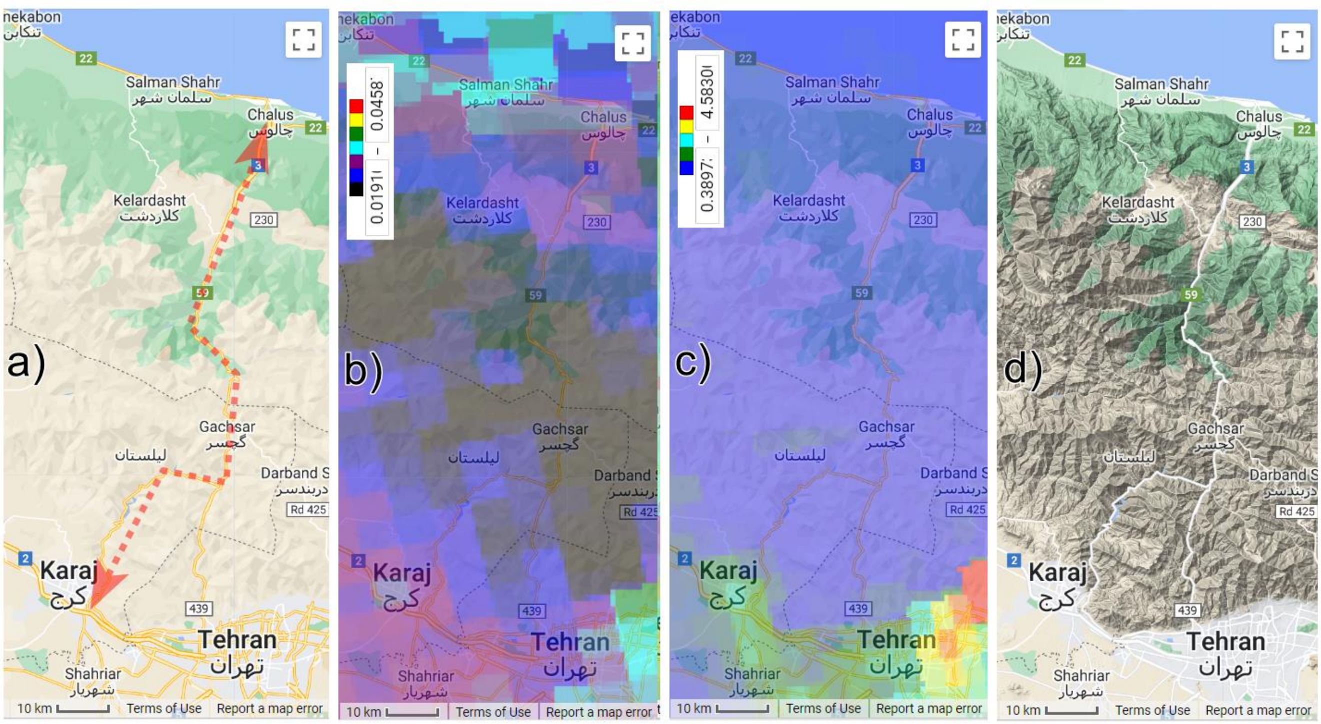


**Fig. 1-Study area a) Karaj-Chalous road b) CO mol/m2 Sentinel 5P map c) NO2 mol/m2 Sentinel 5P map extracted from Google Earth Engine (GEE) in Sep 2019 d) terrain map**

Step 1: First, we figure the amount of carbon dioxide emissions in the study area (time and place) before employing information technology (current situation) with the following formula. Having information regarding travel time and the number of cars in the study area, we calculate the weight of carbon dioxide created by a vehicle using equation 1.

$$w_{co2} = \bar{t}_r . \overline{W_r\ co}_2 \qquad (1)$$

Where: $\overline{w_r\ co}$ is the average weight of carbon dioxide produced by a car in kilograms per hour.

Hence, considering the number of samples (N), the total weight of carbon dioxide emitted in the current situation (before the use of information technology) in the study area (temporal and spatial) is calculated by equation 2. Where $n_{rc}$ is the number of vehicles on the road.

$$w_{tco2} = \sum_{n=1}^{N} n_{rc}\, \overline{t_{rn}}\, \overline{w_{co_2}} \qquad (2)$$

Step 2: To estimate the amount of carbon dioxide emissions if information technology is used (the situation desired by the researcher) in the study area (time and place), we do the following.

### 3.2. Speed of any car on the road depends on the following factors

$N_{rc}$: number of cars on the road, $V_z$: Speed of other cars, IN: Number of vehicles entering the road, EX: Off-road vehicles, $C_k$: Type of vehicles, $R_m$: Road construction (slopes, turns, and other physical factors of the road), S: Stop other vehicles (rotation, breakdown, service, etc.), $H_a$: Accidents, W: Weather conditions, $C_c$: Driving culture, ND: Natural disasters (mountain falls, tunnels, landslides, floods, etc.), L: The amount of road lighting.

So based on equation 3 we can say $\overline{v_r}$ (average vehicle speed along the route) is a function of:

$$Vr=f\,(Nrc, Vz, IN, EX, Ck, Rm, S, Ha, W, Cc, ND, L) \quad (3)$$

If, according to the research hypotheses, other factors are fixed, and only the number of cars on the road is variable, then it can be said equation 4:

$$Vr=f\,(N) \quad (4)$$

Now to obtain the relationship between the number and speed of vehicles in the research area, we estimate the following pattern equation 5:

$$\overline{v_r} = a - bn_{rc} \quad (5)$$

Where $\overline{(Vr)}$ is the average vehicle speed obtained from $\overline{v_r} = \frac{x}{\bar{t}}$ where x is the length of the study path (160 km) and $\bar{t}$ is the average travel time according to the real data available of the study area that is to be calculated. Then, the values of *a* and *b* will be estimated using *Eviews* software. In the above relation, $n_{rc}$ is the real number of vehicles (the real data of the study area). Road efficiency is maximized when cars can cross the road at the highest speed.

For this goal, using the relation $v''_r=\frac{x}{t''_r}$, the average speed value of each car was obtained.

Then, using the relation $v''_r=a-bn''_{rc}$, the desired optimal vehicle value was figured, at which time the travel reaches the desired range.

Then, the total weight of carbon dioxide created in the study area is calculated after the application of information technology (control of the number of vehicles using intelligent transportation systems) equation 6.

$$Wt'co2 = w'_t co_2 \sum_{n=1}^{N} n''_{rc} \overline{t'_r} \overline{wco_2} \quad (6)$$

Where:

$t''_r$ is the average time of vehicles in the study area (Karaj-Chalous) after the use of information technology in terms of hours. $N''_{rc}$ is the number of optimal vehicles in the study area (Karaj-Chalous) after the use of information technology. $W_t'co_2$ is the total weight of carbon dioxide produced in the study area (time and place) after the application of information technology.

Or one can write equation 7:

$$W'tco2 = N n''_{rc} \overline{t'_r}\, \overline{wco_2} \quad (7)$$

Step 3: Calculation of the difference between the amount of carbon dioxide emissions obtained from the first and second steps by equation 8.

$$\Delta w_t co_2 = \left( \overline{wco_2} \sum_{n=1}^{N} n_{rcn} \overline{t_r} \right) - N n''_{rc} \overline{t'_r}\, \overline{wco_2}$$

$$(8)$$

$$=> \Delta w_t co_2 = \overline{wco_2} [\left( \sum_{n=1}^{N} c_{rn} \overline{t_n} \right) - N c'_r \overline{t'_r}]$$

Where $\Delta w_t co_2$ is the difference in the total weight of carbon dioxide produced before and after the use of information technology. In order to perform research calculations, Excel statistical software, as well as Eviews10 econometric software are used.

## 4. Results and discussion

### 4.1. Findings

In this research, by merging and using the information on the number and duration of traffic per day, the average travel time per hour was calculated from the average travel time set per 5 minutes for one hour.

Given the average travel time per hour, we calculate the average speed in meters per second and kilometers per hour using the formula v = x / t. At this stage, according to the research hypotheses, the fuel consumption of each car is 6 liters per hour, and we calculate the fuel consumption of each vehicle. Gasoline can be chemically considered to be C8H18 octane with a molecular weight of 114 grams of octane per mole:

$$C_8H_{18}=8(12)+18(1)=114$$

The weight of carbon dioxide is 44 grams per mole.

$CO_2=1(12)+2(16)=44$

And the molar weight of water is 18:

$$H_2O= 2(1) + 16 =18$$

Plus, the reaction equation of octane combustion is:

$$C_8H_{18} + 25O_2 \rightarrow 16\ CO_2 + 18\ H_2O + Energy$$

Therefore, the mass of carbon dioxide (CO2) released per mole of octane burned is 352 grams:

$$352\ g_r=\frac{16\times 44}{2}$$

The mass of water (H2O) released per mole of octane burned is 162 grams.

$$162g_r=\frac{18[2(1)+16]}{2}$$

Also, the ratio of carbon dioxide emissions due to gasoline-burning is equal to 3.0877.

$$3/0877=\frac{352}{114}$$A

nd the ratio of water production due to burning gasoline is 1.421.

$$1/421=\frac{162}{114}$$

Considering that each liter of gasoline is equal to 0.74 kg, having a carbon dioxide emission ratio due to burning gasoline which is equal to 3.0877. It is concluded that by burning one gram of gasoline, 3.09 grams of CO2 and 1.42 grams of water are produced.

$$\frac{1\ gr_{Gasoline}}{740}=\frac{3.09\ gr_{Co_2}}{x}$$

$$X=3.09\times 740=2286.6\ gr$$

So it can be concluded that one liter of gasoline after combustion produces 2.23 kg of CO2. Thus, having the amount of fuel consumption, we calculate the amount of carbon dioxide produced in kilograms for each car.

Having the amount of gasoline and carbon dioxide produced for each car and the number of cars, we calculate the amount of gasoline and carbon dioxide produced per hour by multiplying the above two amounts. Next, by summing the amount of gasoline consumed and carbon dioxide produced per hour, we calculate the amount of gasoline consumed and carbon dioxide produced in one day.

Then, by summing the gasoline consumed and the carbon dioxide produced per day, we calculate the total amount of gasoline consumed and carbon dioxide produced at the time and place studied in the current situation: 4403943 liters of gasoline and 10129069 kg of carbon dioxide Table 1.

**Table 1 - Total amount of gasoline consumed and carbon dioxide produced**

| | Studied days | Sum of the gasoline consumed per day | Gasoline and carbon dioxide produced per day | The number of total cars during the study day |
|---|---|---|---|---|
| 1 | $10^{th}$ | 356910 | 820892 | 16798 |
| 2 | $12^{th}$ | 432768 | 995367 | 21021 |
| 3 | $13^{th}$ | 719972 | 1655937 | 26340 |
| 4 | $14^{th}$ | 779838 | 1793628 | 24227 |
| 5 | $15^{th}$ | 684424 | 1574175 | 25049 |
| 6 | $17^{th}$ | 449686 | 1034277 | 14095 |
| 7 | $24^{th}$ | 488829 | 1124308 | 21185 |
| 8 | $31^{st}$ | 491516 | 1130486 | 20907 |
| | Total sum | 4403943 | 10129069 | 169622 |

On the other hand, having the values of travel time and the total number of vehicles, the average speed per trip is calculated for each day, and for each day (24 hours), 5 to 7 travel groups are extracted. Now to estimate the model of extracted information, we consider Table 2 and Fig. 1 as the main data (statistical population) of the research.

**Table 2 - Total number of vehicles - Average speed per trip**

| Total number of vehicles through the path | Average speed of the vehicles through the path |
|---|---|
| 2180 | 47.0035 |
| 1323 | 50.4226 |
| 2609 | 50.6839 |
| 2748 | 49.3205 |
| 3618 | 41.9538 |
| 2242 | 40.6045 |
| 2078 | 42.0691 |
| 1238 | 50.1800 |
| 700 | 50.1332 |
| 2284 | 51.2521 |
| 2619 | 50.5437 |
| 4265 | 45.9386 |
| 4450 | 41.5671 |
| 5465 | 39.6831 |
| 4559 | 42.0395 |
| 4062 | 44.4630 |
| 3709 | 35.7534 |
| 5236 | 25.1209 |
| 5504 | 36.2709 |
| 3270 | 42.2806 |
| 3209 | 41.6419 |
| 3818 | 35.6402 |
| 6921 | 24.5096 |
| 6788 | 27.1412 |
| 3491 | 39.6952 |
| 3650 | 41.9210 |
| 3965 | 41.6699 |
| 4725 | 31.9661 |
| 5879 | 27.0698 |
| 4280 | 40.9141 |
| 2550 | 44.3350 |
| 993 | 47.9452 |
| 803 | 45.8181 |
| 1794 | 43.3797 |
| 2251 | 41.1843 |
| 4657 | 22.4849 |

| | |
|---|---|
| 3597 | 31.9439 |
| 2482 | 44.4809 |
| 1759 | 47.5806 |
| 2844 | 49.1916 |
| 3601 | 40.0500 |
| 4098 | 37.8746 |
| 3749 | 38.8774 |
| 2652 | 43.7196 |
| 2349 | 43.0848 |
| 1983 | 49.1589 |
| 2986 | 46.5153 |
| 3763 | 36.8404 |
| 3496 | 37.2156 |
| 3620 | 37.9029 |
| 2750 | 46.5464 |

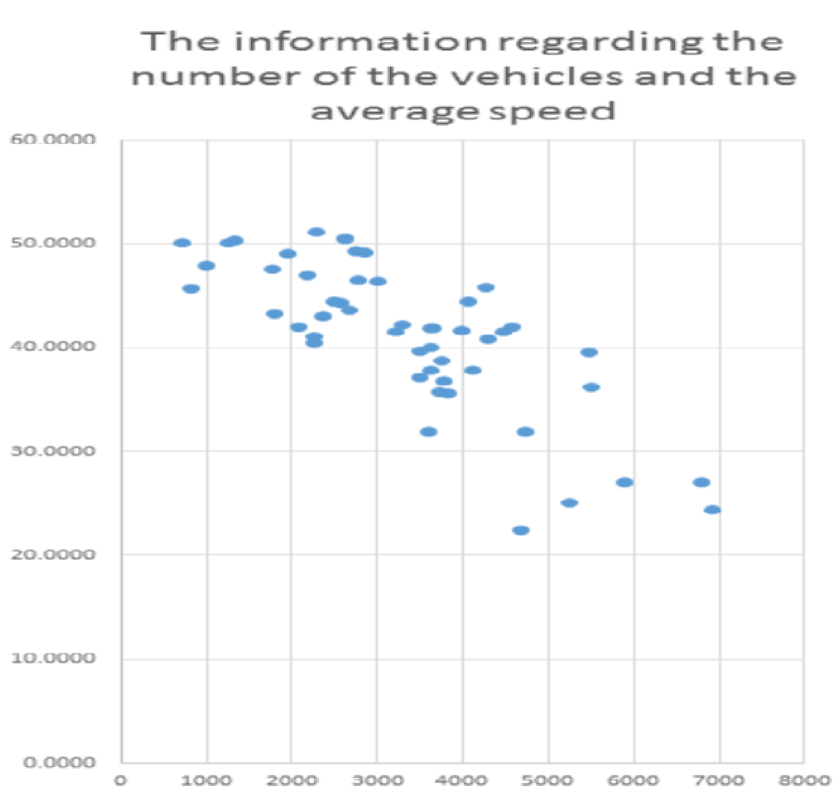

**Fig. 1- Total number of vehicles - Average speed per trip**

To better grasp the essence of the statistical population that has been studied in the research and become more acquainted with the research variables, before analyzing the statistical data, it is required to describe these data. The statistical description of data is also a step towards determining the pattern governing them and a basis for describing the connections between variables used in research. Table 3 displays the descriptive statistics of the research variables. Descriptive statistics of research variables include the mean, median, variance, standard deviation, minimum, and maximum.

As can be inferred from the Table of descriptive statistics, the mean, median, maximum, minimum, standard deviation, skewness, and elongation of the research variables are exhibited from top to bottom, respectively. In this research, 51 data or observations have been used to test the research model hypothesis.

**Table 3 - Descriptive statistics of research variables**

| | V | N |
|---|---|---|
| Mean | 41.28594 | 3325.922 |
| Median | 41.95380 | 3491.000 |
| Maximum | 51.25210 | 6921.000 |
| Minimum | 22.48490 | 700.0000 |
| Std. Dev. | 7.205903 | 1416.556 |
| Skewness | -0.865954 | 0.416578 |
| Kurtosis | 3.296514 | 3.051186 |
| Observations | 51 | 51 |

### *4.2. Matrix of correlation coefficients of model variables (detection of alignment test of independent variables)*

One of the simple criteria for identifying a line is the use of correlation coefficients between explanatory variables. If the correlation coefficients between the explanatory variables are relatively large, the alignment is relatively strong. But if the correlation coefficients are small, there is no alignment. As seen in Table 4, there is no alignment between the model variables.

**Table 4. Matrix of correlation coefficients of model variables**

| | V | N |
|---|---|---|
| **V** | 1 | -0.7820410026362861 |
| **N** | -0.7820410026362861 | 1 |

### 4.3. Results of normal distribution of disturbance elements (Jarque-Bera statistic)

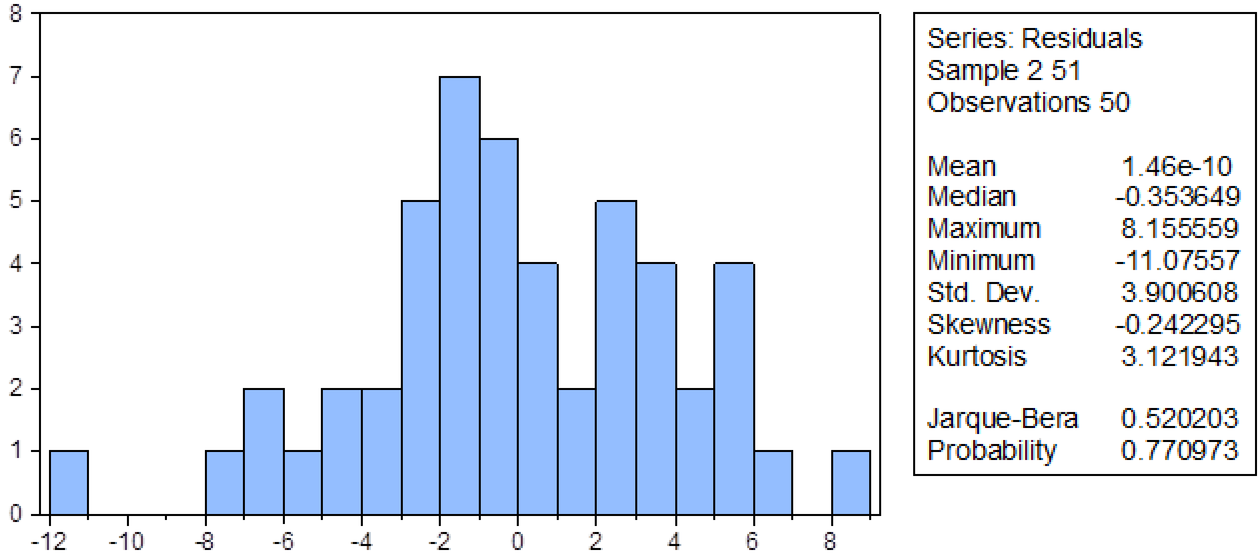


**Fig. 2 - Jarque-Bera test statistics of model**

Hypothesis zero and opposite hypothesis in this test:

$H_0$: Normal distribution of perturbation component

$H_1$**:** Abnormal distribution of disturbance components

According to the results, the probability of Jarque-Bera test statistics in the model is more than 5%. Therefore, in this model, the null hypothesis (normality of the distribution of perturbation components) is not rejected. In the research model, the variable of the total number of vehicles along the route (n) is entered as the main independent variable, and the average variable of vehicle speed along the route (V) is entered as a dependent variable (Fig. 2).

### *4.4. Results of detecting the independence of the distribution of the disturbance components of the model (Autocorrelation test)*

**Table 5 - Breusch-Godfrey Serial Correlation LM Test**

| | | | |
|---|---|---|---|
| F-statistic | 0.672820 | Prob. F(2,45) | 0.5153 |
| Obs*R-squared | 1.451743 | Prob. Chi-Square(2) | 0.4839 |

**Test Equation:**

Dependent Variable: RESID

Method: Least Squares

Date: 09/23/21 Time: 21:41

Sample: 2 51

Included observations: 50

Presample missing value lagged residuals set to zero.

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.710952 | 2.221825 | -0.319985 | 0.7505 |
| N | 0.000211 | 0.000565 | 0.373358 | 0.7106 |
| AR(1) | -0.065383 | 0.495851 | -0.131860 | 0.8957 |
| RESID(-1) | 0.161371 | 0.507684 | 0.317857 | 0.7521 |
| RESID(-2) | -0.126326 | 0.292419 | -0.432004 | 0.6678 |

| | | | |
|---|---|---|---|
| R-squared | 0.029035 | Mean dependent var | 1.46E-10 |
| Adjusted R-squared | -0.057273 | S.D. dependent var | 3.900608 |
| S.E. of regression | 4.010753 | Akaike info criterion | 5.710475 |
| Sum squared resid | 723.8763 | Schwarz criterion | 5.901677 |
| Log-likelihood | -137.7619 | Hannan-Quinn criter. | 5.783286 |
| F-statistic | 0.336410 | Durbin-Watson stat | 1.984240 |
| Prob(F-statistic) | 0.851980 | | |

Hypothesis zero and opposite hypothesis in this test:

$H_0$: Independence of distribution of disturbance components (lack of autocorrelation)

$H_1$**:** Lack of independence of distribution of disruption components (lack of autocorrelation)

According to the results obtained from the LM test, the probability of F test statistics in the model is more than 5% Table 5. Therefore, in this model, the null hypothesis based on the independence of the distribution of perturbation components is not rejected, and there is no problem of correlation between the perturbation components with more than one interrupt.

### *4.5. Results of detecting equality of variances between disruptive components of the model (Heterogeneity variance test)*

**Table 6 - Heteroskedasticity Test: Breusch-Pagan-Godfrey**

| | | | |
|---|---|---|---|
| F-statistic | 1.739073 | Prob. F(1,48) | 0.1935 |
| Obs*R-squared | 1.748196 | Prob. Chi-Square(1) | 0.1861 |
| Scaled explained SS | 1.638889 | Prob. Chi-Square(1) | 0.2005 |

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 09/23/21 Time: 21:50
Sample: 2 51
Included observations: 50

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 5.244452 | 7.950437 | 0.659643 | 0.5126 |
| N | 0.002886 | 0.002189 | 1.318739 | 0.1935 |

| | | | |
|---|---|---|---|
| R-squared | 0.034964 | Mean dependent var | 14.91045 |
| Adjusted R-squared | 0.014859 | S.D. dependent var | 21.94040 |
| S.E. of regression | 21.77678 | Akaike info criterion | 9.038744 |
| Sum squared resid | 22762.95 | Schwarz criterion | 9.115225 |
| Log-likelihood | -223.9686 | Hannan-Quinn criter. | 9.067868 |
| F-statistic | 1.739073 | Durbin-Watson stat | 2.098159 |
| Prob(F-statistic) | 0.193514 | | |

Hypothesis zero and opposite hypothesis in this test:
$H_0$: Absence of heterogeneity variance
$H_1$**:** Existence of heterogeneity variance

According to the obtained results, the probability of F test statistics in the model is more than 5% Table 6. Therefore, in this model, the null hypothesis that there is no heterogeneity of variance is not rejected. Therefore, there is no problem of variance of inequality between the components of the disorder.

### 4.6. Specification error test results of the model (Ramsey reset)

Hypothesis zero and opposite hypothesis in this test:

$H_0$: No specification error

$H_1$**:** Existence of specification error

According to the obtained results, the probability value of F and t-test statistics in the model is more than 5% Table 7. Therefore, in this model, the null hypothesis that there is no specification error is not rejected, so there is no problem of specification error in the model.

### 4.7. Final results of the estimation of the research pattern

V=62.88127- 0.004082N

**Table 7 - Estimation of the research pattern**

**Ramsey RESET Test**

Equation: FINALEQ01

Specification: V C N AR(1)

Omitted Variables: Squares of fitted values

| | Value | df | Probability |
|---|---|---|---|
| t-statistic | 0.234781 | 46 | 0.8154 |
| F-statistic | 0.055122 | (1, 46) | 0.8154 |
| Likelihood ratio | 0.059880 | 1 | 0.8067 |

**F-test summary:**

| | Sum of Sq. | df | Mean Squares |
|---|---|---|---|
| Test SSR | 0.892297 | 1 | 0.892297 |
| Restricted SSR | 745.5224 | 47 | 15.86218 |
| Unrestricted SSR | 744.6301 | 46 | 16.18761 |
| Unrestricted SSR | 744.6301 | 46 | 16.18761 |

**LR test summary:**

| | Value | df |
|---|---|---|
| Restricted LogL | -138.4985 | 47 |
| Unrestricted LogL | -138.4685 | 46 |

Unrestricted Test Equation:

Dependent Variable: V

Method: Least Squares

Date: 09/23/21 Time: 22:05

Sample: 2 51

Included observations: 50

Convergence achieved after ten iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 50.69162 | 20.85924 | 2.430176 | 0.0191 |
| N | -0.003585 | 0.002491 | -1.439406 | 0.1568 |
| FITTED^2 | 0.001458 | 0.007271 | 0.200555 | 0.8419 |
| AR(1) | 0.472743 | 0.254413 | 1.858170 | 0.0696 |
| R-squared | 0.709459 | Mean dependent var | | 41.17159 |
| Adjusted R-squared | 0.690510 | S.D. dependent var | | 7.232166 |
| S.E. of regression | 4.023383 | Akaike info criterion | | 5.698742 |
| Sum squared resid | 744.6301 | Schwarz criterion | | 5.851704 |
| Log-likelihood | -138.4685 | Hannan-Quinn criter. | | 5.756990 |
| F-statistic | 37.44174 | Durbin-Watson stat | | 1.860647 |
| Prob(F-statistic) | 0.000000 | | | |
| Inverted AR Roots | | .47 | | |

## 4.8. Hypothesis test result of the model

One of the regression assumptions is the independence of the disruptive components. Regression cannot be used if the hypothesis of the independence of the perturbation components is rejected and the perturbation components are correlated with each other. The Durbin-Watson statistic is used to examine the independence of perturbation components from each other. If the value of the Durbin-Watson statistic is close to 2, the hypothesis of correlation between the perturbation components is rejected, and regression can be used. According to the Table above, the Durbin-Watson statistic is 1.83. This shows that the components of the disorder are independent of each other, and there is no correlation between the components of the disorder itself, and the assumption of correlation between the components of the disorder is rejected. So regression can be used.

After testing the regression assumptions and ensuring that they are established, the results of fitting the above regression equation are presented in the mentioned Table. The value of the F statistic (57.28673) also demonstrates the significance of the whole regression model. As illustrated in the lower part of the Table, the values of the determination coefficient and the adjusted coefficient of determination of the above model are 70.91% and 69.67%, respectively. Accordingly, the above results show that in the regression equation, the variable of the total number of vehicles along the route explains 69.67% of the average changes in vehicle speed along the route.

According to the above Table, the significance level of the variable of the total number of vehicles along the route (n) is equal to 0.000, which is less than 5%; Also, the absolute value of the computational statistic t related to this variable (7.808823) is greater than the t-statistic obtained from the Table with the same degree of freedom (1.96). This indicates the significance of the variable coefficient of the total number of vehicles along the route at a 95% confidence level. The results confirm that in the first model, the total number of vehicles along the route has a negative and significant effect on the average speed of vehicles along the route. That is, an increase of 1 unit in the variable of the total number of vehicles along the route will reduce the average speed of vehicles along the route by 0.004082 units.

### *4.9. Calculation of total gasoline consumption and carbon dioxide production after using information technology and the difference between the two modes from the estimated model*

V=62.88127-0.004082N

When we intend to increase the travel time to 3.25 hours (three hours and fifteen minutes), the average speed will be:

$V=\frac{160km}{3.25} \rightarrow v=49.23 \rightarrow 49.23=62.88127-0.004082N$

N=3344

Hence, 3344 vehicles should be controlled for every 25.2 hours (three hours and fifteen minutes) when cars enter the road. If we consider each trip as 3.25 hours, for 24 hours, 7.385 trips can be designated. In this case, if we consider seven trips for 24 hours, the total number of vehicles that can travel the route with a time of 3.25 hours under the management of the demand side will be 23,408 vehicles per day. This pattern will cover the existing demand even in travel demand peaks.

$$\text{Total time of trips at the time and place studied} = \text{Total vehicle number} \times 3.25$$

$$\text{T} = 169622 \times 3.25 = 551271.5$$

$$\text{Total gasoline consumption at the time and place studied} =$$

$$\text{Total time} \times 6 = 55127.1 \times 6 = 33007629 \text{ l}$$

$$\text{Total carbon dioxide produced} = \text{Total consumed gasoline} \times 2.3$$

$$\text{Total carbon dioxide produced} = 3307629 \times 2.3 = 7607546.7 \text{ Kg}$$

Differences in gasoline consumption and carbon dioxide production between before and after the use of information technology in the time and place studied:

$$\text{Differences in carbon dioxide production} = 10129069 - 7607546.7 = 2521522.3 \text{ Kg}$$

$$\text{Differences in gasoline consumption} = 4403943 - 3307629 = 1096314\ l$$

## 5. Conclusion

This study aims to assess the environmental effects of reducing carbon dioxide (CO2) emissions based on using the ITSs (intelligent transportation systems) in the Karaj-Chalous axis. Intelligent systems, if operated properly, improve people's trust in the smart transport network and, by optimizing the transportation grid, form a notable amount of economic savings for the people and the government annually. Intelligent transportation employs information technology to enhance safety and boost the cheap efficiency of transport. This system can be generalized to different modes of transportation such as road, rail, air, and sea.

The outcomes indicated that the use of the intelligent transportation system has decreased travel time on the Karaj-Chalous axis and therefore has lowered carbon dioxide (CO2) emissions. The results revealed that the intelligent transportation system (ITS) during the studied eight days have yielded a reduction of 2521522 kg of carbon dioxide emissions in the Karaj-Chalous axis.

Therefore, traffic management system solutions using intelligent transportation systems (ITSs) can help decrease fuel consumption and greenhouse gas emissions. Traffic monitoring systems using information technology can also render new data processing techniques for assessing traffic flow, density, and speed, as well as other traffic parameters to increase transportation system efficiency. This real-time information can be employed to better manage the transportation system and drivers and thus optimize the transport system.

Previous endeavors regarding the emissions from the transportation sector-focused more on enhancing vehicle fuel efficiency (for instance, using innovative methods, reducing weight while maintaining safety). The focus has also been on the use of low-carbon fuels (e.g., ethanol, electricity), travel demand management (e.g., tolls), and shifting to non-motorized modes. But now we see that intelligent transportation systems can be used as a fourth key component: improving the efficiency of transportation system performance. In this way, travel time, traffic volume, and greenhouse gas emissions can be reduced.

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## References

Barth, M. J., Wu, G., & Boriboonsomsin, K. (2015). Intelligent transportation systems and greenhouse gas reductions. *Current Sustainable/Renewable Energy Reports*, *2*(3), 90-97. https://doi.org/10.1007/s40518-015-0032-y

Dandala, T. T., Krishnamurthy, V., & Alwan, R. (2017, January). Internet of Vehicles (IoV) for traffic management. In *2017 International conference on computer, communication and signal processing (ICCCSP)* (pp. 1-4). IEEE.. https://doi.org/10.1109/ICCCSP.2017.7944096

d'Orey, P. M., & Ferreira, M. (2013). ITS for sustainable mobility: A survey on applications and impact assessment tools. *IEEE Transactions on Intelligent Transportation Systems*, 15(2), 477-493. https://doi.org/10.1109/TITS.2013.2287257

Ebrahimi, A., & Fatemi, M. (2019). "Study of Effective Factors of Smart City on Creating a Sustainable Transportation System With a Green Economy Approach," *the first international conference and the second international conference on urban planning, architecture, civil engineering and knowledge-based art.*

Ghadbik, D., and Ehsanifar, M. (2019). "Development and Application of the Model of Urban Traffic Management Evaluation Framework and Intelligent Transportation Systems", *the 4th International Conference on New Research in Civil Engineering, Architecture, Urban Management and Environment.*,

Ghanbari, M., Mehr, A. G., & Nehzat, H. (2015). Introducing an intelligent transportation system decision support model for the highways in Iran based on fuzzy logic. *International Journal of Soft Computing and Engineering*, *5*(5), 101-104.

Ghane Ezabadi, N., Azhdar, S., & Jamali, A. A. (2021). Analysis of dust changes using satellite images in Giovanni NASA and Sentinel in Google Earth Engine in western Iran. *Journal of Nature and Spatial Sciences (JONASS)*, *1*(1), 17-26. https://dx.doi.org/10.30495/jonass.2021.680327

Jamadi, H., & Jamadi, H. (2019). "Study of the impact of intelligent transportation systems on traffic management", *the first national conference on geography and urban and rural planning.*

Jamali, A. A., Naeeni, M. A. M., & Zarei, G. (2020). Assessing the expansion of saline lands through vegetation and wetland loss using remote sensing and GIS. *Remote Sensing Applications: Society and Environment*, *20*, 100428. https://doi.org/10.1016/j.rsase.2020.100428

Jamali, A. A., Tabatabaee, R., & Randhir, T. O. (2021). Ecotourism and socioeconomic strategies for Khansar River watershed of Iran. *Environment, Development and Sustainability*, *23*(11), 17077-17093. https://doi.org/10.1007/s10668-021-01334-y

Khodabandeh Lou, R., Kowsari, A., Garshasbi, M.A., & Zohrehvand, R. (2019). "Improving and Controlling Smart Traffic by Increasing Urban and Suburban Transportation Services (Intelligent Transportation Systems)", *Sixth International Conference New findings of science and technology with a focus on science in the service of development*.

Lee, S., Kim, Y., Kahng, H., Lee, S. K., Chung, S., Cheong, T., ... & Kim, S. B. (2020). Intelligent traffic control for autonomous vehicle systems based on machine learning. *Expert Systems with Applications*, *144*, 113074. https://doi.org/10.1016/j.eswa.2019.113074

Lee, H., & Taheri, S. (2017). Intelligent tires? A review of tire characterization literature. *IEEE Intelligent Transportation Systems Magazine*, *9*(2), 114-135. https://doi.org/10.1109/MITS.2017.2666584

Mohammadi, A., Qasem, I., & Hamzeh Zarghani, F. (2019). "Hardware and Software Infrastructure in the Implementation of Intelligent Transportation System and Urban Traffic", *the first conference on computer science, electrical engineering, communications and information technology Iran in the Islamic world.*

Mfenjou, M. L., Ari, A. A. A., Abdou, W., & Spies, F. (2018). Methodology and trends for an intelligent transport system in developing countries. *Sustainable Computing: Informatics and Systems*, *19*, 96-111. https://doi.org/10.1016/j.suscom.2018.08.002

Möller, D. P., & Vakilzadian, H. (2016, May). Cyber-physical systems in smart transportation. In *2016 IEEE international conference on electro information technology (EIT)* (pp. 0776-0781). IEEE. https://doi.org/10.1109/EIT.2016.7535338

Rahbar, M., Hickman, M., Mesbah, M., & Tavassoli, A. (2018). Calibrating a Bayesian transit assignment model using smart card data. *IEEE Transactions on Intelligent Transportation Systems*, *20*(4), 1574-1583. https://doi.org/10.1109/TITS.2018.2852726

Samavi, M. R., Panahi, M., & Abedi, Z. (2022). ASSESSING THE ECONOMIC IMPACT OF USING ITSS (INTELLIGENT TRANSPORTATION SYSTEMS) ON GASOLINE CONSUMPTION IN IRAN (CASE STUDY OF KARAJ-CHALOUS AXIS). *Journal of Positive School Psychology*, *6*(7), 216-230.

Saeedifard, A., Jahanian, M., & Faryadres, M. (2019). "Intelligent Transportation Systems in Urban Traffic Management", *7th National Conference on Computer Science and Engineering and Information Technology.*

Wu, X., Wu, Y., Zhang, S., Liu, H., Fu, L., & Hao, J. (2016). Assessment of vehicle emission programs in China during 1998–2013: Achievement, challenges and implications. *Environmental Pollution*, *214*, 556-567. https://doi.org/10.1016/j.envpol.2016.04.042

Zoghi, H., Baqalnejad, A., & Payvand, M. (2014). "Functional Analysis of Intelligent ERP Systems in the Development of the Transportation Industry", *the first conference on intelligent road transportation systems.*