Research Article

Socio-Economic Impacts Resulting From The Integration Of Artificial Intelligence Into Electronic Surveillance Systems In Traffic

Mesut Samastı[1,*]
[1] Cerrahpaşa Department of Industrial Engineering, TÜBİTAK Turkish Institute of Management Sciences, Istanbul University, Istanbul, Turkey
**Correspondence:* *mesutsamasti@gmail.com*
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Abstract:

Traffic management is becoming increasingly difficult due to the increasing population and number of vehicles. In the last decade, the use of electronic surveillance systems has increased in the effective and efficient management of traffic management systems. These systems contribute to traffic regulations by monitoring traffic violations, taking necessary actions and imposing sanctions. The active use of these systems increases drivers' compliance with traffic rules, which has a positive impact on the reduction of losses due to traffic accidents. Artificial intelligence (AI) applications, which have become widespread in various fields in recent years, are expected to increase the benefits to be obtained by using them in traffic electronic surveillance systems. In this study, the socio-economic impacts of AI integration into traffic surveillance systems are analyzed in detail in terms of mobility, economy, environment, health and quality of life.

Keywords: Artificial intelligence, socio-economic impact, life quality

Trafikteki Elektronik Gözetim Sistemlerine Yapay Zeka Entegrasyonu Sonucu Elde Edilecek Sosyo-Ekonomik Etkiler

Özet:

Artan nüfus ve araç sayısı nedeniyle trafik yönetimi giderek zorlaşmaktadır. Son on yılda, trafik yönetim sistemlerinin etkin ve verimli şekilde yönetilmesinde elektronik gözetim sistemlerinin kullanımı artmıştır. Bu sistemler, trafik kural ihlallerini izleyerek gerekli aksiyonları almakta ve yaptırımlar uygulayarak trafik düzenlemelerine katkı sağlamaktadır. Bu sistemlerin aktif olarak kullanılması, sürücülerin trafik kurallarına uyumunu artırmakta ve bu da trafik kazalarına bağlı kayıpların azalmasına olumlu etki yapmaktadır. Son yıllarda çeşitli alanlarda yaygınlaşan yapay zeka (AI) uygulamalarının trafik elektronik gözetim sistemlerinde kullanılmasıyla elde edilecek faydanın daha da artacağı öngörülmektedir. Bu çalışmada, trafikteki elektronik gözetim sistemlerine yapay zeka entegrasyonu sonucu elde edilecek sosyo-ekonomik etkiler mobilite, ekonomi, çevre, sağlık ve yaşam kalitesi boyutları açısından detaylı bir şekilde analiz edilmiştir.

Anahtar Kelimeler: Yapay zeka, sosyoekonomik etki, yaşam kalitesi

* Corresponding author.
E-mail address: mesutsamasti@gmail.com
ORCID: 0000-0002-4900-8279 (in hierarchical order)
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1. Introduction

The Electronic Traffic Control and Fault Detection/Analysis System (EDS) implementation, supported by Artificial Intelligence, serves as a supervision system designed to manage traffic flow, optimize transportation, detect illegal vehicle movements and apply the necessary sanctions and make urban life in accordance with the normative structure within certain rules. This system detects vehicles with image processing technology and checks whether the relevant vehicle is moving within the specified rules. Due to the deterrent penalty policies applied to vehicles that violate the rules, it creates a compelling factor for the drivers of vehicles that violate the rules to correct their behavior over time. Thus, it helps to ensure the safety of life and property by preventing accidents caused by vehicles causing traffic disorder.

Red light violation detection system, one of the EDS implementations, reduces the number of fatal accidents by reducing the severity of accidents. In a study, it was found that this system reduced right-angle crashes at intersections by 25% and rear-end crashes by 15% (Council et al, 2005; Decina et al, 2007; Poole et al, 2012). In Edmonton, Canada, where a red light violation system and a speed violation detection system were integrated, total crashes decreased by 25%, angle crashes by 33% and rear-end crashes by 11% (Contini and El-Basyouny, 2016).

There are many benefits of electronic monitoring systems (EDS) and fault detection/analysis systems, and studies from around the world attest to this. It positively influences driver behavior, reducing high speeds, reducing accident severity, reducing the number of accidents and enabling rapid detection of vehicle faults.

Traffic management and proper behavior in the region is important for reducing delays and ensuring shorter and safer journeys. While this may be small on an individual basis, it is a significant gain when the population of the region is taken into account. Reduced fuel consumption and emissions are also positive for the environment and the economy. Some of the main expectations and benefits of EDS and fault detection/analysis system projects can be as follows:

- Increase in the rate of compliance with traffic rules by people living in or traveling through the region
- Facilitating the operation of traffic management practices in the region at the desired level
- Reduced traffic congestion and delays
- Reduced travel times
- Saving time
- Reduced fuel consumption and gas emissions
- Decrease in traffic accidents
- Easy identification of accident locations

1.1. Literature

Studies on traffic problems with artificial intelligence approaches have been examined in detail. Amiri et al. (2021) studied age, education level, average household income and other factors that cause the occurrence of traffic accidents with artificial neural networks considering public health. It was observed that male population density, unemployment rate and education level are among the important factors affecting traffic accidents (Amiri et al, 2021). Akgüngör and Doğan (2010) used artificial neural networks to predict the number of accidents, fatalities and injuries in Ankara, Turkey using historical accident data (Akgüngör ans Doğan, 2010). Kushwaha and Abirami (2023) proposed an intelligent system to reduce the severity of accidents based on a machine learning model to prevent loss of life and property due to traffic accidents. In the developed model, artificial neural networks showed an accuracy of 0.856 (Kushwaha and Abirami, 2023). Meenu and Neresh (2022) conducted a socioeconomic analysis of deaths and injuries due to traffic accidents. By conducting interviews with individuals who were disabled after the accident, medical, legal, professional, social, economic problems experienced after traffic accidents were examined and it was stated that socioeconomic negative effects will decrease with the widespread use of autonomous vehicles supported by artificial intelligence (Meenu and Neresh, 2022). Ulu et al. (2024) developed a three-stage geohash-based model using decision tree (DT), k-nearest neighbor (k-NN), random forest (RF) and support vector machine (SVM) algorithms to predict the locations of traffic incidents, including traffic failures and other events.

Prasad Das et al. (2021) conducted a study on health problems caused by traffic noise with "two-staged Structural Equation Modeling-Artificial Neural Network". The statistical relationship of the disorders with the duration of exposure to traffic noise, occupation, sleep disturbance and gender were analyzed (Prasad Das et al, 2021). Moncayo et al. (2017) modeled the effect of road noise on a person's willingness to pay using artificial neural networks. A prediction model for willingness to pay based on the duration of exposure to a modeled noise and demographic and socioeconomic conditions was developed (Moncayo et al, 2017). Gu et al. (2020) conducted studies to predict traffic congestion by taking into account the travel time of the public transport vehicle between two stops to improve the quality of service with a focus on travel time and reliability of public transport systems (Gu et al, 2020). Mondal and Rehena (2020) focused on the traffic congestion problem to improve the quality of life of citizens within the scope of the smart city concept. Existing infrastructure and resources were optimized for traffic management through data collection, storage, processing and application (Mondal and Rehena, 2020).

Herath and Mittal (2022) drew attention to the importance of artificial intelligence effects on smart city applications in health, education, environment, waste management, agriculture, mobility, transportation, risk management, and risk management in order to make life in cities more cost-effective and comfortable with the increasing population in cities (Herath and Mittal, 2022). Olatode et al. (2023) developed a hybrid model with artificial neural networks and PSO to reduce traffic congestion caused by short and long trucks on highways and to reduce the number of accidents involving vehicles (Olayode et al, 2022). Dodia et al. (2023) studied variable duration and dynamic traffic lights that will allow vehicles with priority to move faster in emergency situations instead of fixed lighting times at traffic lights. After the emergency vehicles with priority to pass are detected by the system, the light durations are changed by intelligent systems. Simulation studies for the related topic have shown clear improvements in vehicle waiting times Dodia et al, 2023). Cunneen et al. (2019) put forward a conceptual discussion on the ethical shortcomings of risk-reducing decision-making mechanisms of autonomous vehicles socially supported by artificial intelligence (Cunneen et al, 2019). Ulu et al. (2022), BWM and SWARA methods were used to calculate the weights of factors affecting traffic accidents (Ulu et al, 2022).

Cunneen, M. (2023) emphasized that the widespread use of autonomous vehicles will have significant economic, environmental and social impacts due to increased productivity and supply chain efficiency (Cunneen, 2023). Biagioni et al (2021), in order to achieve energy efficiency in the integrated mobility system, they put forward the needs in the research to be carried out with machine learning and artificial intelligence methods of big data collected from the sources of the system (Biagioni et al, 2021).

2. Case Study Area

In Turkey, 30 out of 81 provinces have electronic monitoring systems (EDS). There are 1257 fixed and mobile EDSs covering 4,682 km [1], of the 61,729 km road network (KGM, 2023) in Turkey (EGM). Figure 1 shows the distribution of EDS implementations in Turkey.

Figure 1. EDS Usage in Turkey [2]

[1] https://www.egm.gov.tr/hiz-ihlallerine-yonelik-pts-eds-ortalama-hiz-ihlal-tespit-sistemleri-devrede

[2] https://onlineislemler.egm.gov.tr/trafik/sayfalar/edsharita.aspx

Istanbul is the province where EDS implementations are used most intensively. With EDS implementations, critical road sections and important intersections in Istanbul are monitored 24/7 (İBB, 2023). There are 457 EDSs throughout Istanbul. This figure corresponds to 36.4% of the total number of EDS implementations in Turkey. Similarly, in Konya, where there are EDS implementations, the number of daily speed limit violations has decreased from 21,000 to 1,000 with the EDS system providing 24/7 service. The use of the EDS system also led to a 54% to 63% reduction in injury and fatal accidents. In Konya, there are 20 average speed violation detection systems on 6 different streets[3]. In Kayseri, there are examples of speed, turning and parking violation detection systems.

3. Socioeconomic Impact Analysis of EDS

The behavior of people who do not follow traffic rules can be detrimental to the community and the region and can have negative impacts on other people. For example, when an accident occurs at a signalized intersection due to a red light violation, the vehicles involved in the accident are damaged, while other drivers, pedestrians and businesses using the intersection are also affected. Similarly, other traffic violations have direct and indirect social, economic and environmental impacts. Regionally, EDS aims to identify and punish red light and hatched area violations at signalized intersections, parking violations in no-parking zones, speed violations on designated road axes, and other traffic violations through mobile enforcement. In this way, traffic management is made more effective by reducing the number of people who do not obey traffic rules. The electronic surveillance system should serve reliably at appropriate points to help people avoid unlawful behavior in traffic. This contributes to the maintenance of traffic order. In addition, electronic surveillance systems can be used to track and trace people who pose a danger to public safety or illegal or stolen vehicles. Therefore, these systems are known to contribute to public safety. Considering all these factors, it is thought that the quality of life of people living or traveling in the region will increase. This study analyzes the socio-economic impacts of the operational EDS implementations.

3.1. Impact of EDS Implementation on National Economy

The introduction of Artificial Intelligence Supported EDS has effects on the national economy. Since the rate of compliance with traffic rules will increase with the EDS system, the number of accidents will decrease. Apart from the material losses due to traffic accidents, economic losses occur due to the loss of labor force in fatal and injury accidents. In addition, the economic value of time in traffic due to accidents and accidents with injuries increase expenditures in the health sector.

In the feasibility studies conducted for EDS and Fault Detection applications, it is predicted that there will be a decrease in traffic fines by 3.8% in the first year, 3.3% in the second year and 2.8% in the third year (TÜSSİDE, 2021). According to TUIK, it is known that there were 26,482,847 vehicles in 2021 and 1,234,327 accidents occurred (TUIK, 2022). Considering these data, the increase in the number of vehicles and the number of accidents predicted to occur accordingly were calculated. In the report prepared by the General Directorate of Security, 288,118 accidents with material damage took place in 2022, excluding accidents in which people agreed among themselves and filed a report (EGM, 2022). As a result of accidents, 2,282 people lost their lives and 291,151 people were injured. Since the data of the individuals who died within 30 days in the health units to which they were referred after the accident were not available for 2022 and the following years, only the data of the individuals who died at the accident scene were included in the statistics.

In the accident data, when the accidents in which people filed a report among themselves are analyzed, it is seen that there were 941,723 accidents with material damage on average annually between 2019 and 2021 (TUIK, 2021).

Using accident data from previous years, the number of accidents expected to occur until 2025 was calculated. Considering the projected reduction rates in these accident numbers, estimates were made for the number of accidents with material damage, injuries and fatalities. The data used in Table 1,

[3] http://www.konya.pol.tr/konya-emniyet-eds-elektronik-denetleme-sistemleri-trafik-polis-radar

which is prepared for the estimation of the change in accident statistics by years for Turkey in general, is compiled from the reports prepared by TUIK (TUIK, 2022a; TUIK, 2021b; TÜSSİDE, 2021).

Table 1. Estimation of change in accident statistics by years (Turkey-wide)

	2021	2022	2023	2024	2025
Population	84.680.273	85.279.553	85.883.074	86.490.866	87.102.960
Number of Vehicles	25.249.119	26.482.847	27.776.858	29.134.097	30.557.653
Number of Accidents	1.110.241	1.234.327	1.372.282	1.525.655	1.696.170
Number of accidents with material damage	998.390	941.724	924.549	954.888	940.387
Accident Rate	**4,0%**	**3,6%**	**3,3%**	**3,3%**	**3,1%**
Reduction Rate of Accidents with EDS			3,8%	3,3%	2,8%
Number of fatal accidents (person)	2362	2282	2.394	2.510	2.633
Number of injured		291.151	280.087	270.844	263.261

The annual cost of traffic accidents to the national economy is around $15 billion (Annual damage of traffic accidents to the economy). In case of injuries due to traffic accidents, accident-related health expenses are €2,500 per person, and €1,800 per person is lost due to loss of productivity[4]. For deaths due to traffic accidents, a calculation was made based on the current minimum wage (8,500TL) (Minimum wage x Defect rate 20% x Disability rate 60% x 37 (a 30-year-old person's right to passive work for 7 years)). After calculating the unit costs, the savings to be achieved with reductions of 3.8%, 3.3% and 2.8% depending on the years were calculated.

For the socioeconomic analysis of the AI-supported EDS application, calculations were made by taking into account the provinces served by the ESD system. There are EDS applications in 30 different provinces across Turkey. A certain ratio was obtained for each province by proportioning the lengths of the highway lengths of these provinces and the lengths of the road sections where EDS monitoring is carried out. By multiplying the province-based statistics on traffic accidents by the ratio, the accident rates on roads where EDS implementation is effective were calculated. The economic gains obtained after these calculations are given in Table 2. In the preparation of this table, reports of TurkStat and TUSSIDE as well as data obtained from insurance companies were used .

Table 2. Yearly savings with EDS (provinces with EDS implementation)

Description	2023	2024	2025
Number of Accidents	44.490	46.664	48.944
Number of fatalities at the time of the accident	162	169	178
Financial savings upon death	11.160.638	21.753.818	31.948.144
Number of injured	34.615	38.484	42.785
Financial savings due to injury	68.597.345	142.493.492	220.894.507
Labor productivity loss material savings	49.390.088	102.595.314	159.044.045
Accident cost savings	10.922.089.245	10.978.856.861	11.035.624.477

* The number of vehicles on roads with EDS application in 2022 is 12,537,050, the number of accidents is 42,417, the number of fatalities is 156 and the number of injured people is 31,136.

[4] Social Security Institution's annual health expenses due to traffic accidents, https://www.sdplatform.com/Dergi/1022/SGKnin-odedigi-trafik-kazalarina-bagli-saglik-giderleri.aspx

With EDS, the average speed of vehicles will increase and the time they stay in traffic will decrease as the rate of compliance with traffic rules increases and accidents decrease. This will also reduce fuel consumption, which is an imported input. It is estimated that the fuel savings to be achieved due to the decrease in the time spent in traffic will be around 463,393 tons per year on average. The calculations take into account the fuel savings that vehicles in provinces with EDS implementation will achieve depending on the time they will save in traffic. The economic value of this fuel is around 32.5 billion TL for 3 years. Table 3 shows the annual value of the fuel savings to be achieved.

Table 3. Fuel savings with EDS (Annual)

	2023	2024	2025
Fuel Savings (LT)	243.609.372	470.316.712	679.254.149
Fuel Savings Amount (TL)	5.690.714.924	10.986.598.383	15.867.376.923
Fuel Saving Approval	1,40%	2,59%	3,59%

When the economic impact of EDS implementation at the national level is analyzed, there is a potential gain of approximately 32.5 Billion TL until the end of 2025.

3.2. Impact of EDS Application on Mobility

It was mentioned in the previous sections that with EDS, the average speed of vehicles will increase and the duration of their stay in traffic will decrease, while the rate of compliance with traffic rules will increase and accidents will decrease. The average annual CO2 emission of a vehicle is around 4.6 metric tons per year and emits 404 g of CO2 for every 1.6 km. Taking the average number of working days per year as 250, it is calculated that a vehicle travels an average of 73 km per day. The speed values of some of the main transportation arteries during peak hours on weekdays were checked via Google Maps application and average speeds were calculated. As a result of these calculations, it was observed that there is an average traffic flow of 36 km/h during peak hours. When the travel time was calculated according to the average daily travel distance, it was found that an average of 121 minutes was spent in traffic. When the gains to be achieved with EDS are analyzed depending on the years, it is estimated that by 2025, the traffic speed will be 39.68 km/h, the travel time will decrease to 110 minutes and the time spent in traffic will decrease by 11.27 minutes. By the end of 2025, the economic value of this time saved is estimated to be approximately 71.1 billion TL. Table 4, prepared within the scope of this study, shows the impact of EDS on mobility and travel times.

Table 4. Impact of EDS on mobility and travel times

	2021	2023	2024	2025
Traffic flow rate during peak hours (km/h)	36	37,37	38,60	39,68
Average travel time (min)	121	117	113	110
Savings in travel time (min)		4,45	8,18	11,27
Economic value of time saved (TL)		12.434.017.222	24.005.341.214	34.669.675.173

3.3. Impact of EDS Implementation on the Health System

Reductions in traffic accidents as a result of EDS applications help to reduce expenditures in the health system, reduce congestion and increase service quality. In 2021, according to TurkStat data, health expenditures amounted to 280 billion 220 million TL (TUIK, 2021c). Health expenditures, which increased by 16-22% on average over the years, increased by 41.48% with the effect of the pandemic. When it is assumed that these values will show a normal increasing trend with the decrease in the pandemic effect, it is predicted that total health expenditures on a national scale will be around 377 Billion TL by 2023. With the decrease in the number of accidents and injuries to be achieved with EDS systems, an average annual saving of 0.03% will be achieved in health sector expenditures. Apart from economic savings, there will also be an increase in the quality of the service provided in the health system due to the decrease in density. Table 5, created with the data compiled within the scope of this study, shows the impact of the EDS implementation on the health system.

Table 5. Impact of EDS implementation on the health system

	2023	2024	2025
Financial savings due to injury	68.597.345	142.493.492	220.894.507
Estimated General Health expenditure (TL)	377.063.411.914	437.393.557.820	507.376.527.071
Savings rate	0,02%	0,03%	0,04%

3.4. Environmental Impact of EDS Implementation

Since vehicles can reach their target locations faster with EDS applications, the amount of fuel they will consume and exhaust emission emissions will decrease. With the consumption of 1 liter of gasoline, 2.35 g of CO2 is emitted. Vehicles consume between 1-2 lt/h while idling. It is assumed that an average of 1 liter of additional fuel will be consumed during traffic-related waits. The estimated reduction in CO2 emissions wsa calculated by multiplying the consumption of vehicles per minute by the time savings achieved. It is assumed that the number of working days per year will be 250 days. The impact of each extra minute that vehicles spend in traffic is taken into account and the positive environmental impact of EDS implementations is analyzed in Table 6.

Table 6. Environmental impact of EDS implementations

	2023	2024	2025
Amount of CO_2 emission in 1 min (gr)	**0,039**	**0,039**	**0,039**
CO_2 emission savings (tons)	**572,7**	**1.105,7**	**1.597,0**

3.5. The Effect of EDS Application on Quality of Life

Apart from the measurable economic gains that can be obtained as a result of EDS applications, there are also impacts that have a positive impact on the quality of life of individuals but are difficult to measure metrically. When the effects of the measurable impacts mentioned in the above headings on quality of life are analyzed, the following findings were made.

- Reduced negative psychological impact on individuals and families due to reduced death and injury rates,
- Reduced economic hardship for individuals and families due to loss of labor force,
- Reduced stress levels and increased happiness index due to less time in traffic,
- Spending more time with family and strengthening communication ties,
- Reduced personal expenditure due to lower fuel consumption,
- Preventing possible respiratory-related health problems with improved air quality.

4. Results and Discussion

Artificial intelligence supported EDS and Fault Detection systems are among the applications that have been widely used in Turkey in recent years. For this reason, this report examines the potential gains that can be achieved as a result of the widespread use of EDS systems on a national scale. Analyses based on the collected data show that EDS applications have positive impacts on economic, mobility, health, environmental and quality of life.

In the analyses conducted within the scope of this report, calculations were made on the assumption that they are used on a national scale. Currently, there is a need for a publicly controlled platform that can collect data such as the number of road sections on which EDS systems are in place, the time periods between which these systems are used, the number of vehicles using these road sections, average fuel consumption rates varying depending on vehicle types, the number of accidents before and after the system on these road sections, the types of accidents, the number of deaths and injuries, etc. in a certain standard and order. In this way, when a new EDS system is installed, the socio-economic analyses that this system will generate will be systematic. The net gains obtained based on clear data will also serve as a role model for other regions that want to implement this system.

Declaration of Contribution Rate of Researchers

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

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Conflict of Interest Statement

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

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