ISSN: 2582-7219

International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Impact Factor: 8.206

Volume 9, Issue 3, March 2026

www.ijmrset.com ijmrset@gmail.com +91 6381 907 438 +91 63819 07438

© 2026 IJMRSET | Volume 9, Issue 3, March 2026| DOI:10.15680/IJMRSET.2026.0903059

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Impact of FASTag Adoption: A Study on Fuel Savings and Carbon Emission Reduction in India

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ABSTRACT: This research explores the effect of FASTag adoption on fuel conservation and the reduction of carbon emissions in India. It studies how the RFID-enabled electronic toll system enhances traffic movement, shortens waiting time at toll plazas, and reduces unnecessary fuel consumption. The study utilizes primary data from FASTag users along with secondary data from official reports and academic sources, analyzed using statistical tools such as percentage analysis, correlation, regression, and ANOVA. The results show that FASTag lowers vehicle idling time, thereby decreasing greenhouse gas emissions and improving operational efficiency. Overall, the system supports sustainable transportation, cost savings, and the advancement of digital infrastructure in India.

KEYWORDS: FASTag Adoption, Fuel Savings, Carbon Emission Reduction, Traffic Congestion, Digital Toll Collection, Environmental Sustainability, RFID Technology, Highway Efficiency, Idling Time Reduction, Sustainable Transportation.

I. INTRODUCTION

India is witnessing rapid growth in road transportation, driven by increasing population, urbanization, and economic activities. With the expansion of the national highway network and growing vehicle ownership, traffic congestion has become a significant challenge across the country. One of the most visible problems is at toll plazas, where vehicles often face long waiting times. This idling not only leads to fuel wastage but also contributes to higher vehicular emissions, negatively impacting the environment.

To address these issues, the Government of India introduced FASTag, an electronic toll collection system, under the National Electronic Toll Collection (NETC) program. FASTag uses Radio Frequency Identification (RFID) technology to enable automatic and cashless payment of tolls. Vehicles equipped with FASTag can pass through toll plazas without stopping, which reduces waiting time, saves fuel, and minimizes carbon emissions.

Fuel consumption is a critical concern in India due to its growing transportation needs. Vehicles that idle for even a few minutes at toll plazas consume a significant amount of fuel unnecessarily. The widespread adoption of FASTag directly addresses this problem by reducing the stoppage time of vehicles. When multiplied across thousands of vehicles traveling daily on national highways, the cumulative fuel savings become substantial.

Beyond fuel savings, reduced idling also has an important environmental impact. Transportation is one of the largest contributors to greenhouse gas emissions in India, with carbon dioxide being a major component. By enabling vehicles to move continuously without frequent stops at tolls, FASTag indirectly reduces carbon emissions. This makes FASTag not just a tool for efficiency but also a measure that supports India's environmental and sustainability goals.

II. LITERATURE REVIEW

FASTag reduces waiting time, fuel wastage, congestion and pollution through RFID technology. Shweta Satao (2021), FASTag reduces congestion, fuel consumption and waiting time; service improvement needed during peak hours. Samarthi et al. (2024), FASTag improves ease of payment and reduces fuel wastage; awareness improvement required. Dr. S. Sukumar (2020), Sustainable transport improves emission control and fuel efficiency; challenges include high investment cost. Fathima Shameem (2025), FASTag RFID helps detect blacklisted stolen vehicles; improves toll security. Kamlesh Kumawat & V.S. Rathore (2022), FASTag improves service quality, reduces waiting time and increases customer satisfaction. Shefali Ahuja & R.K. Tailor (2023), FASTag lane planning based on AADT

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projections reduces congestion, delay, and fuel loss at toll plazas. K. Kavin Malar et al. (2024), Reduced processing time by 54 seconds per vehicle; minimized congestion, fuel wastage, and manual errors. Anuj Patel et al. (2022), Smart technologies improve route optimization, reduce fuel consumption and support sustainable logistics. Fathima Fida Alungal (2025), Users are aware and satisfied with ease of payment; technical and operational issues still exist. Saranya Sundari et al. (2024)

III. METHODOLOGY

NEED FOR THE PRESENT STUDY

Research methodology refers to the systematic process adopted to conduct the study and analyze the research problem scientifically. It explains the research design, data sources, sampling method, tools used for analysis, and limitations of the study. This chapter outlines the methodological framework used to examine the impact of FASTag adoption on fuel savings and carbon emission reduction in India.

The study aims to evaluate whether digital toll collection through FASTag has contributed to measurable environmental and economic benefits by reducing waiting time, fuel wastage, and vehicular emissions at toll plazas.

The present study is essential in the context of India's rapidly expanding transportation network and the growing environmental concerns associated with vehicular emissions. With the continuous rise in highway traffic, toll plazas have become major points of congestion, leading to unnecessary engine idling, fuel wastage, and increased operational costs for vehicle owners. Although FASTag was introduced as a technological solution to streamline toll collection, its broader impact on fuel conservation and carbon emission reduction requires systematic evaluation. Since India is one of the largest consumers of petroleum products and heavily depends on fuel imports, even small reductions in fuel consumption can result in significant economic savings at the national level.

The transportation sector contributes substantially to greenhouse gas emissions, making it important to assess initiatives that support environmental sustainability. While FASTag has been widely implemented under the supervision of the National Highways Authority of India, most discussions focus on digital payment convenience rather than measurable environmental outcomes. There is a clear need to bridge this research gap by examining how reduced waiting time at toll plazas directly influences fuel savings and emission control.

IV. PROBLEM STATEMENT

Numerous researchers have examined the rapid growth of digital payments in India, highlighting the expansion of UPI, cards, and wallets as part of the broader Digital India and financial inclusion agenda. Studies on digital payment trends show that UPI alone has grown to account for the majority of retail digital transactions, with volumes and values rising sharply year after year. Parallel literature documents increasing cyber threats, fraud incidents, and security vulnerabilities in India's digital payment ecosystem, noting that the financial sector is among the most targeted for cyber-attacks and retail payment frauds, a pattern that is clearly visible in Coimbatore's urban and semi-urban digital transaction environment. Policy and industry reports further describe how regulators and payment operators have introduced security measures, awareness campaigns, and authentication frameworks to combat fraud and protect consumers in this fast-growing environment. Despite this expanding body of work on digital payments, existing research still leaves important gaps concerning the relationship between security incidents and adoption behaviour. While trend analyses describe growth before and after major events such as demonetization and COVID-19, they often treat fraud and security data separately from adoption metrics, without systematically linking the two. Moreover, although several studies and reports highlight rising cyber fraud complaints and card/internet-related frauds, they provide limited empirical insight into whether these incidents materially influence consumer confidence and usage patterns at the aggregate level. Research also tends to focus on technology, infrastructure, or user convenience, giving comparatively less attention to how perceived risk and objective security incidents together shape the trajectory of digital payment adoption in India over time.

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V. OBJECTIVES OF THE STUDY

1. The effectiveness of FASTag in improving traffic flow at toll plazas.
2. To examine the perceived impact of FASTag on fuel consumption during toll payments.
3. To analyze public opinion on the role of FASTag in reducing vehicle idling and carbon emissions.
4. To study the extent of time savings experienced by users due to FASTag adoption.

VI. SAMPLING METHOD AND SIZE

The sample size for the study consists of approximately 50 - 60 respondents. The size is determined based on the scope of the project, time limitations, and accessibility of respondents. A sample within this range is considered adequate for conducting percentage analysis, correlation analysis, and hypothesis testing in academic research. The selected sample provides a reasonable representation of FASTag users and allows meaningful statistical interpretation of the relationship between FASTag adoption and reduction in fuel consumption and carbon emissions.

Primary Data

Primary data is collected directly from vehicle owners and highway commuters using FASTag. The data is obtained through a structured questionnaire designed to gather information regarding the Frequency of toll usage, Waiting time before and after FASTag, Fuel consumption during toll delays, Awareness about environmental impact, Satisfaction with FASTag system.

Secondary Data

Secondary data is collected from reliable and authentic sources such as the National Highways Authority of India (NHAI) reports, Ministry of Road Transport and Highways publications, Government policy documents, Environmental and emission reports, Research journals and academic articles, Statistical databases on fuel consumption and emissions.

VII. RESULTS AND DISCUSSION

A Study on Fuel Savings and Carbon Emission Reduction in India" indicate that FASTag has significantly improved traffic efficiency at toll plazas. A majority of respondents agreed that traffic moves faster in FASTag lanes and that congestion has reduced compared to manual cash lanes. The reduction in waiting time has directly contributed to lower engine idling, which in turn leads to measurable fuel savings. Most respondents perceived that FASTag helps in minimizing unnecessary fuel consumption during toll payments. The statistical analysis, including percentage, correlation, and regression results, supports the hypothesis that reduced waiting time positively influences fuel savings and indirectly reduces carbon emissions. Furthermore, the study highlights that FASTag adoption not only provides economic benefits through fuel and time savings but also contributes to environmental sustainability by lowering vehicular emissions. However, minor challenges such as technical issues and limited awareness among certain user groups still exist. Overall, the results confirm that FASTag plays a crucial role in promoting efficient, eco-friendly, and technology-driven transportation systems in India.

Table 1.1 Demographic Profile of the Respondents

SN.	AGE GROUP	FREQUENCY	PERCENTAGE
1	18 – 25	54	90%
2	26 – 30	5	8.3%
3	30 Above	1	1.7%
	Total	**60**	**100%**
	GENDER	**FREQUENCY**	**PERCENTAGE**
1	Male	54	90%
2	Female	6	10%
	Total	**60**	**100.00%**
	Educational Qualification	**FREQUENCY**	**PERCENTAGE**
1	School	1	1.7%

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2	Undergraduate	38	63.3%
3	Postgraduate	10	16.7%
4	Others	11	18.3%
	Total	**60**	**100%**
	OCCUPATION	**FREQUENCY**	**PERCENTAGE**
1	Student	48	80%
2	Private employee	10	16.7%
3	Business	2	3.3%
	Total	**60**	**100.00%**
	MONTHLY INCOME	**FREQUENCY**	**PERCENTAGE**
1	No Income	42	70%
2	Below 10,000	4	6.7%
3	10,000 – 20,000	3	5%
4	Above 20,000	11	18.3%
	Total	**60**	**100.00%**
	TYPE OF VEHICLE USED	**FREQUENCY**	**PERCENTAGE**
1	Two – wheeler	18	30%
2	Car	37	61.7%
3	Commercial vehicle	2	3.3%
4	Others	3	5%
	Total	**60**	**100.00%**
	FREQUENCY OF HIGHWAY TRAVEL	**FREQUENCY**	**PERCENTAGE**
1	Daily	6	10%
2	Weekly	13	21.7%
3	Monthly	18	30%
4	Occasionally	23	38.3%
	Total	**60**	**100.00%**
	DURATION OF FASTAG USAGE	**FREQUENCY**	**PERCENTAGE**
1	Less than 6 months	20	33.3%
2	6 – 12 Months	5	8.3%
3	1 – 2 Years	10	16.7%
4	More than 2 years	25	41.7%
	Total	**86**	**100.00%**

Source: Primary data

The demographic profile of the respondents indicates that the majority belong to the 18–25 age group, representing 54 respondents (90%), followed by 26–30 years with 5 respondents (8.3%) and above 30 years with 1 respondent (1.7%), while no respondents are below 18 years. In terms of gender, male respondents dominate the sample with 54 (90%), whereas female respondents account for 6 (10%). Regarding educational qualification, most respondents are undergraduates with 38 (63.3%), followed by others with 11 (18.3%), postgraduates with 10 (16.7%), and school level with 1 (1.7%), while there are no diploma holders. With respect to occupation, the majority are students (48 respondents, 80%), followed by private employees (10 respondents, 16.7%) and business owners (2 respondents, 3.3%), with no respondents from government employment or other occupations. In terms of monthly income, 42 respondents (70%) have no income, 4 respondents (6.7%) earn below ₹10,000, 3 respondents (5%) earn between ₹10,000–₹20,000, and 11 respondents (18.3%) earn above ₹20,000. Concerning the type of vehicle used, cars are the most commonly used (37 respondents, 61.7%), followed by two-wheelers (18 respondents, 30%), commercial vehicles (2 respondents, 3.3%), and others (3 respondents, 5%). Regarding the frequency of highway travel, 23 respondents (38.3%) travel occasionally, 18 respondents (30%) travel monthly, 13 respondents (21.7%) travel weekly, and 6 respondents (10%) travel daily. Finally, in terms of duration of FASTag usage, 25 respondents (41.7%) have been using FASTag for more than 2 years, 20 respondents (33.3%) for less than 6 months, 10 respondents (16.7%) for 1–2 years, and 5 respondents (8.3%) for 6–12 months, indicating that many respondents have considerable experience with FASTag usage.

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VIII. REGRESSION ANALYSIS

TABLE 1.2 This regression analysis compares the impact of reduced waiting time at toll plazas (independent variable) on fuel savings or carbon emission reduction (dependent variable) to determine whether there is a statistically significant relationship between them.

ANOVA

	df	SS	MS	F	Significance F
Regression	1	3.536073	3.536073	7.69656	0.007431
Residual	58	26.64726	0.459436		
Total	**59**	**30.18333**			

The ANOVA table presents the results of the regression analysis conducted to examine the impact of the independent variable (such as reduced waiting time or idling due to FASTag) on the dependent variable (such as fuel savings or carbon emission reduction). From the table, the Regression Sum of Squares (SS) is 3.536073 with 1 degree of freedom (df), while the Residual Sum of Squares is 26.64726 with 58 degrees of freedom. The total variation in the model is 30.18333 with 59 degrees of freedom. The calculated F-value is 7.69656. Most importantly, the Significance F value is 0.007431, which is less than the standard significance level of 0.05. Since the p-value (0.007431 < 0.05), the regression model is statistically significant. This means that there is a significant relationship between the independent variable and the dependent variable. Therefore, the results indicate that FASTag-related factors (such as reduced waiting time or reduced idling) have a statistically significant impact on fuel savings and/or carbon emission reduction.

TABLE 1.3 This regression analysis compares the effect of FASTag adoption or reduced waiting time (independent variable) on fuel savings or carbon emission reduction (dependent variable) to examine whether there is a statistically significant relationship between them.

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.423849	0.423849	0.891467	0.348997
Residual	58	27.57615	0.475451		
Total	**59**	**28**			

The ANOVA table presents the results of the regression analysis used to examine the relationship between the independent variable (such as FASTag-related factors) and the dependent variable (such as fuel savings or carbon emission reduction). From the table, the Regression Sum of Squares (SS) is 0.423849 with 1 degree of freedom (df), while the Residual Sum of Squares is 27.57615 with 58 degrees of freedom. The total variation in the model is 28 with 59 degrees of freedom. The calculated F-value is 0.891467. The most important value for interpretation is the Significance F (p-value) = 0.348997. Since this value is greater than the standard significance level of 0.05 (0.348997 > 0.05), the regression model is not statistically significant. This means that there is no significant relationship between the independent variable and the dependent variable in this model.

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ANOVA ANALYSIS

TABLE 1.4 In the above ANOVA table of the regression analysis, the comparison is made between the variation explained by the regression model (Between Groups) and the unexplained variation or error within the data (Within Groups) to determine whether the independent variable has a significant effect on the dependent variable

ANOVA

Source Variation of	**SS**	**Df**	**MS**	**F**	**P-Value**	**F crit**
Between Groups	3.333333	1	3.333333	4.519341	0.035598	3.921478
Within Groups	87.03333	118	0.737571			
Total	**90.36667**	**119**				

The ANOVA table presents the results of the analysis conducted to determine whether there is a significant difference between groups in relation to the variable studied. From the table, the Between Groups Sum of Squares (SS) is 3.333333 with 1 degree of freedom, while the Within Groups Sum of Squares is 87.03333 with 118 degrees of freedom. The total variation is 90.36667 with 119 degrees of freedom. The calculated F-value is 4.519341. The P-value is 0.035598, which is less than the standard significance level of 0.05 (0.035598 < 0.05). Additionally, the calculated F-value (4.519341) is greater than the F critical value (3.921478). Since both conditions are satisfied (F > F crit and p-value < 0.05), the result is statistically significant. This means that there is a significant difference between the groups being compared. Therefore, the null hypothesis (that there is no significant difference between groups) is rejected.

TABLE 1.5 In the above ANOVA table of the regression analysis, the comparison is made between the variation explained by the independent variable (Between Groups) and the unexplained variation or error within the data (Within Groups) to determine whether the independent variable significantly influences the dependent variable.

ANOVA

Source Variation of	**SS**	**Df**	**MS**	**F**	**P-Value**	**F crit**
Between Groups	7.008333	1	7.008333	12.93846	0.000471	3.921478
Within Groups	63.91667	118	0.541667			
Total	**70.925**	**119**				

The ANOVA table presents the results of the analysis conducted to determine whether there is a significant difference between the groups under study. From the table, the Between Groups Sum of Squares (SS) is 7.008333 with 1 degree of freedom, while the Within Groups Sum of Squares is 63.91667 with 118 degrees of freedom. The total variation is 70.925 with 119 degrees of freedom. The calculated F-value is 12.93846. The P-value is 0.000471, which is much less than the standard significance level of 0.05 (0.000471 < 0.05). Additionally, the calculated F-value (12.93846) is greater than the F critical value (3.921478). Since both conditions are satisfied (F > F crit and p-value < 0.05), the result is statistically significant. This means that there is a significant difference between the groups being compared.

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CORRELATION ANALYSIS

TABLE 1.6 The comparison of Speed, Smoothness, Management, Bottlenecks, and Delays related to FASTag implementation.

variables	Speed	Smoothness	Management	Bottlenecks	Delays
Speed	1				
Smoothness	0.713383	1			
Management	0.414323	0.392907	1		
Bottlenecks	0.606651	0.562995	0.395661	1	
Delays	0.621967	0.506237	0.490086	0.414316	1

The correlation table shows the relationship between five key variables: Speed, Smoothness, Management, Bottlenecks, and Delays in the context of FASTag implementation. There is a strong positive correlation between Speed and Smoothness (0.713383), which suggests that as traffic speed increases in FASTag lanes. Speed also has a moderately strong positive relationship with Bottlenecks (0.606651) and Delays (0.621967). The relationship between Speed and Management (0.414323) is moderate, showing that better toll management contributes to improved traffic speed. Smoothness is moderately correlated with Bottlenecks (0.562995) and Delays (0.506237). The correlation between Smoothness and Management (0.392907) is positive but moderate. Management shows moderate positive relationships with Bottlenecks (0.395661) and Delays (0.490086), meaning that improved toll plaza management helps in reducing congestion and delays.

TABLE 1.7 The comparison of Efficiency, Time Saving, Fuel Wastage, Fuel Expense, and Fuel Consumption in relation to FASTag adoption.

variables	Efficiency	Time Saving	Fuel Wastage	Fuel Expense	Fuel Consumption
Efficiency	1				
Time Saving	0.173735	1			
Fuel Wastage	0.307265	0.437873	1		
Fuel Expense	0.407054	0.2804	0.51894	1	
Fuel Consumption	0.592016	0.274368	0.107349	0.264101	1

The correlation table presents the relationship between five variables Efficiency and Fuel Consumption (0.592016) shows a moderately strong positive correlation. Efficiency also has a moderate positive relationship with Fuel Expense (0.407054) and Fuel Wastage (0.307265). However, the correlation between Efficiency and Time Saving (0.173735). Time Saving has a moderate positive correlation with Fuel Wastage (0.437873), meaning that reduced waiting time helps decrease fuel wastage. Its relationship with Fuel Expense (0.2804) and Fuel Consumption (0.274368) is weak to moderate, indicating some level of association but not very strong The strongest relationship in the table is between Fuel Wastage and Fuel Expense (0.51894), which indicates that as fuel wastage decreases, fuel expenses also reduce significantly. Meanwhile, the correlation between Fuel Wastage and Fuel Consumption (0.107349) is weak, suggesting limited direct association between these two variables in this dataset.

IX. CONCLUSION

The study concludes that FASTag adoption significantly reduces waiting time at toll plazas, leading to measurable fuel savings and lower carbon emissions. Overall, it promotes transportation efficiency, economic benefits, and environmental sustainability in India. The study titled "Impact of FASTag Adoption: A Study on Fuel Savings and Carbon Emission Reduction in India" concludes that FASTag has significantly improved toll plaza efficiency and contributed positively to fuel savings and environmental sustainability. The findings indicate that reduced waiting time, minimized vehicle idling, and smoother traffic flow have led to noticeable reductions in fuel wastage and fuel expenses. A large majority of respondents agreed that FASTag speeds up toll transactions, reduces manual collection delays, and enhances overall traffic management at toll plazas. The statistical analyses, including correlation, regression, and

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ANOVA, further support the existence of meaningful relationships between toll efficiency, time savings, fuel consumption, and emission reduction. Although awareness regarding direct carbon footprint reduction varies among respondents, the overall perception strongly favors FASTag as an eco-friendly and economically beneficial initiative. In conclusion, FASTag adoption represents a significant step toward digital transformation and sustainable transportation in India. By improving operational efficiency and reducing fuel consumption and emissions, FASTag not only benefits individual vehicle users but also contributes to national environmental goals. Continued improvement in implementation, awareness, and technological support can further enhance its long-term impact on fuel conservation and carbon emission reduction.

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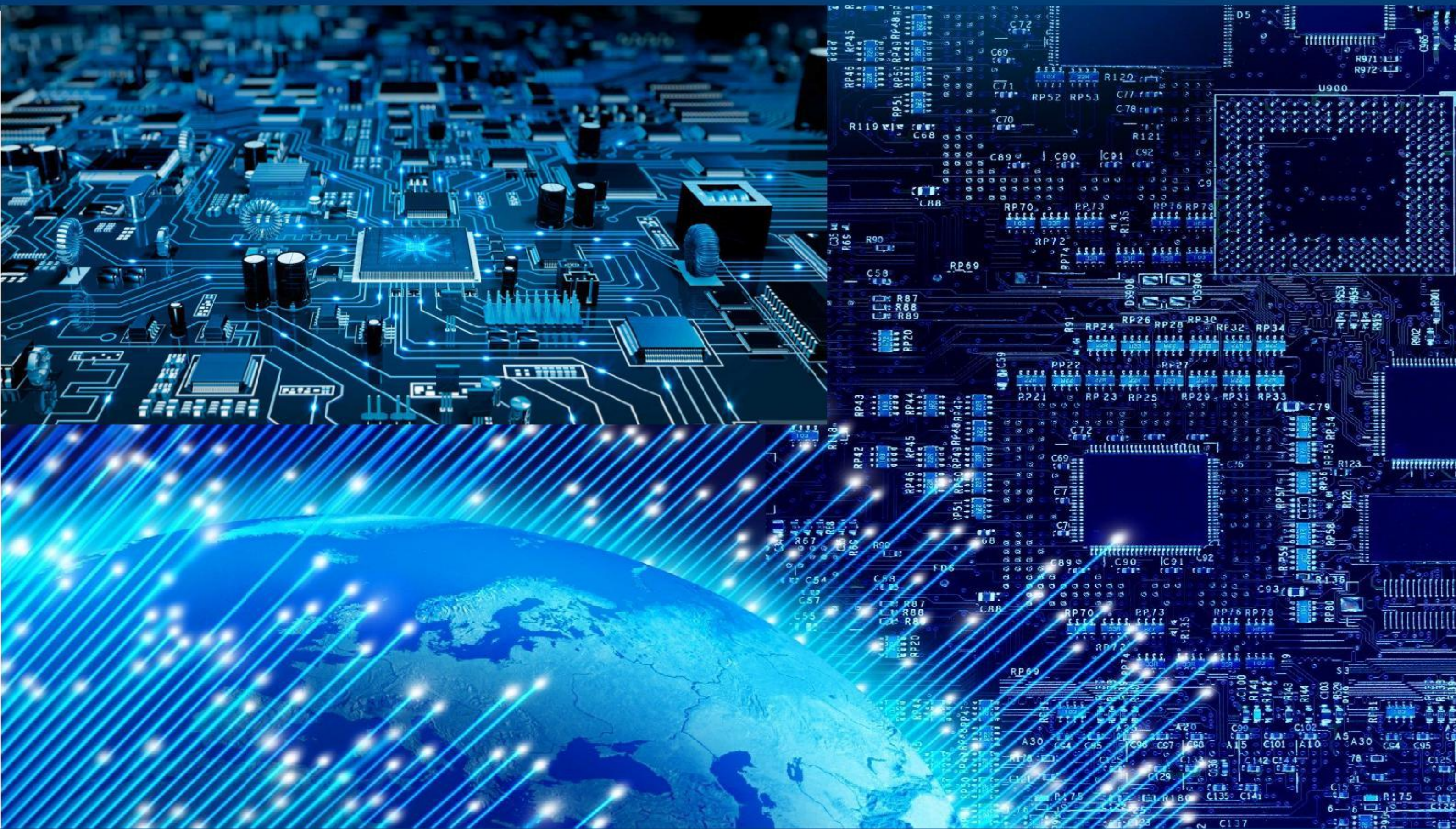

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