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Survey Article

# CCTV Surveillance Systems and Their Impact on Traffic Compliance and Public Road Behavior in Goa

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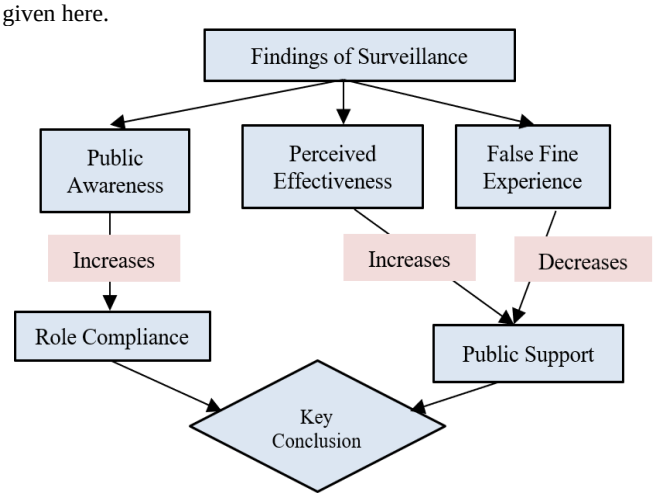
**Abstract:** Traffic violations are a major cause of accidents and reduced traffic safety in Goa. CCTV cameras can enhance monitoring and enforcement. This study examines the link between public awareness, perceptions, and experiences with CCTV surveillance, and how these factors influence actual traffic behavior and support for further expansion. Data were collected through a structured public survey capturing demographic information, driving behaviors, and opinions on CCTV. Three hypotheses were tested using the chi-square test of independence: (1) the relationship between awareness of CCTV and rule compliance, (2) the relationship between perceived effectiveness of CCTV and support for expansion, and (3) the relationship between experiences of false fines and support for expansion. All hypotheses showed statistically significant relationships. Findings indicate that greater public awareness and belief in CCTV effectiveness led to higher compliance and stronger support for deployment. Conversely, negative experiences, such as false fines, reduce public support. The study concludes that public awareness campaigns, system accuracy, and concerns about privacy must be addressed to ensure successful CCTV implementation.

**Keywords:** Traffic Behavior, CCTV Surveillance, Chi-Square Test, Traffic Violations, Public Perception, Road Safety, Goa

**Graphical Abstract:** A graphical abstract, which summarizes the main relationships that have been identified by the study, is given here.




The mentioned relationships start with the public awareness of the CCTV cameras, which results in an increase in the self-reported compliance of traffic rules. Moreover, the perceived effectiveness of the system raises public support for the extension of the system. In contrast, directly negative incidents, like getting a false fine, cause a considerable decrease in public support for the extension of the surveillance network.

## 1. Introduction

Traffic safety and discipline have been a major concern for public health and infrastructure in Goa, a state which is characterized by a high density of two-wheelers and a changeable tourist population. The violations leading—such as over-speeding and not wearing helmets—to accident rates, congestion, and deaths, are the primary contributors [1]. The use of force/policing kind of implementation is the usual way to suppress the unsafe behavior on the roads, however, technological solutions like CCTV surveillance have also become an instrument of easy, automated and incalculable control over the traffic. One of the principles that cannot be disregarded in the CCTV-camera-based research is that the cameras, by their mere existence, have a prompting effect in

observing the authorities and thereby, the compliance of traffic rules is ensured [2]. Still, all these systems function effectively only if they are technologically designed and the public perception, acceptance, and trust prevail [3].

Normally, citizens' paradox is the implementation of CCTV systems for traffic management: it is very likely that safety will be achieved, and order will prevail, but only if the realization of this potential becomes a fact through the support of the people's reach. The issues that first occur revolve around the problems of public trust in the safety system and its positive effects, then on actual experiences of its functioning, such as a case of mistakes – technical issue that causes incorrect fines on a certain person [4]. Privacy issues such as intrusions or doubts about the acceptability of automated systems can be sources of public confidence that contrary to the intentions of the intervention may affect their trust [5]. These relationships are attested in various international studies. However, a significant gap is identified in the literature research which deals with the socio-cultural and technological contexts of Goa [6]. Being peculiar in terms of vehicles and tourist traffic like in the state, the question is how to come up with the local investigative framework.

Thus, this research was carried out to statistically outline the interrelationship between public knowledge, experiences, and perceptions of CCTV surveillance and their influence on traffic behavior and support for its expansion in Goa. The research employs the Chi-Square Test of Independence on data collected from a structured public survey and provides empirical evidence for policy considerations that guaranteeing the success of technological enforcement is not only effective but also fair and publicly acceptable. The conclusions are intended to assist in the development of a surveillance philosophy that enjoys the community's favor and, therefore, contributes to road safety in the area.

### 1.1 Objective of the Study

The research study aims to analyze the determinants affecting public support for, and consequent behavioral responses to, CCTV-based traffic surveillance in Goa. The more concrete scientific objectives of the study are:

1. To identify whether there is a statistically significant relationship between public awareness of CCTV camera locations and self-declared strictness in adherence to traffic rules.
2. To study the association between public perceptions regarding the capacity of the CCTV system to enhance road safety and their support for extending infrastructural surveillance.
3. To analyze the effect of unfavorable experiences— such as false fines due to system errors—on the willingness of the public to support wider implementation of CCTV surveillance.

This investigation aims to address the identified problem of low traffic compliance by enabling an evidence-based study of the human–technology interface in enforcement. The results will provide direction to policymakers in evolving more effective, equitable, and socially supported traffic management systems for Goa.

### 1.2 Organization

The article is structured into seven sections. Section 1 presents the introduction and objectives of the study. Section 2 reviews related work concerning traffic surveillance and public perception. Section 3 discusses the materials and methods used for data collection and the statistical measures considered for analysis. Section 4 details the research methodology, research design, and hypothesis formulations, accompanied by a flowchart. Section 5 highlights the results of the study, followed by an elaborate discussion. Section 6 outlines the recommendations derived from the outcomes, and Section 7 concludes the research work with future directions.

## 2. Related Work

This section is about reading material on traffic control Closed Circuit TV (CCTV) systems. It delves into their technical success, social elements influencing people's views, and principal challenges of program execution. These papers lessen anxieties present in the Goan case study [7].

### 2.1. Effectiveness of CCTV in Traffic Violation Deterrence

One of the main reasons for the installation of surveillance cameras in the heavily used areas is their deterrent effect. The phenomenon of red-light running at urban junctions and discovered a 40% decrease in violations after cameras had been put in place, concluding that these have significant psychological deterrent effects [2]. The impact of a speed camera on the long-term driving behavior, uncovering a notable drop in mean speed not only immediately but also over 24 months of observation [8]. Along the same lines, analyzed the effectiveness of camera-based enforcement for motorcycle helmet compliance and reported higher compliance rates than with sporadic manual enforcement [9]. Moreover, an IoT-based study has just been done which goes along with the effectiveness of automated systems in traffic management [10].

### 2.2. Public Perception and Acceptance of Surveillance

One of the biggest factors in the success of surveillance systems, is the degree to which such systems are accepted by the public. The perception of effectiveness for safety improvement was the strongest predictor of support for CCTV, which was able to even surpass privacy concerns for the majority of participants. The transparency in managing the footage and issuing fines is very important for maintaining public trust and for the legitimacy of smart cities. The influence of demographics on the results and stated that young, higher educated people were more willing to accept the installation of cameras but at the same time they were very cautious about data privacy. Public perception, therefore, remains a key variable in the willingness to adopt smart city technologies.

### 2.3. Challenges and Ethical Considerations

Problems that prevent proper function of CCTV implementation are those both from the technical and the moral side of the issue. A small number of wrongly issued tickets could drastically lessen the perceived fairness of the entire system [4]. The threat of hackers taking over the traffic camera network and thereby stealing the data. They also stressed that trusting the system would be the first step to overcoming such risks of breach prevention [14]. The moral values such as data limitation and independent supervision for achieving the balance of safety and privacy [15]. These systems of CCTV, although having a high initial cost, provide a wide range of benefits that go beyond just the savings in hospital services, and include the reduction of incidences in the long run [16].

### 2.4. Identification of the Research Gap

Even though the current publications discuss the technological, perceptual, and ethical facets of traffic surveillance, one of the main points that keeps coming up is the absence of location-specific studies. Results from metropolitan smart cities or Western settings might not be transferrable to Goa, which is characterized by extraordinary traffic patterns because of tourism, the dominance of two-wheelers, and typical socio-cultural attitudes [6]. Hence this study is aimed to bridge this gap with empirical evidence, from Goa, of the relationships between CCTV awareness, personal experiences, public perception, and compliance behavior.

## 3. Theory

This section elaborates on the theoretical foundation of the Chi-Square Test of Independence, the primary analytical tool used [17].

### 3.1. Theoretical Foundation of the Chi-Square Test.

The Chi-Square Test of Independence is a non-parametric test to see whether there is a significant relationship between two categorical variables [17]. The test operates on the principle of comparing the observed counts in a contingency table with the counts that would be expected if the two variables were independent (the Null Hypothesis, $H_0$). A significant finding means that the observed data distribution is different from what would be expected by chance, hence implying a possible relationship.

The test's correctness depends on two assumptions:

1. The data must represent frequency counts rather than percentages
2. The expected frequency count in each cell of the contingency table should not be less than 5. The standard Chi-Square Test was considered the most suitable method for this research.

### 3.2. Calculation Methodology

The calculation of the Chi-Square statistic follows a systematic process, as outlined in the methodology section and illustrated here using practical context from this study.

For each pair of variables tested, two hypotheses were defined:

- **Null hypothesis ($H_0$):** There is no significant association between the two variables.
- **Alternative hypothesis ($H_1$):** There is a significant association between the two variables.

**Step 2: Construction of Contingency Table**

The survey responses for two categorical questions were cross-tabulated into an r × c contingency table of observed frequencies ($O_{ij}$), where r is the number of rows and c is the number of columns. For instance, for Hypothesis 1 (Q4 vs. Q6), a 2 × 3 table was created.

**Step 3: Calculation of Expected Frequencies**

The Expected frequency ($E_{ij}$) for each cell in the contingency table, assuming the null hypothesis of independence is true, was calculated using the formula:

$$Eij = \frac{(Row\ Totali) \times (Column\ Totalj)}{Grand\ Total} \quad (1)$$

**Step 4: Computation of the Chi-Square Statistic**

The Chi-Square statistic ($X^2$) was computed by summing, for each cell, the squared differences between the observed ($O_{ij}$) and expected ($E_{ij}$) frequencies divided by the expected frequency.

$$X^2 = \sum_{i=1}^{r} \quad \sum_{j=1}^{c} \quad \frac{(Oij - Eij)^2}{Eij} \quad (2)$$

where: $O_{ij}$ = Observed Frequency
$E_{ij}$ = Expected Frequency

A larger$X^2$ value indicates a greater discrepancy between the observed data and the data expected under independence Providing evidence against Null Hypothesis.

**Step 5: Determination of Degrees of Freedom**

The degree of Freedom (df) for the test, which define the shape of the Chi-Square distribution used to assess significance were calculated as:

$$df = (r - 1) * (c - 1) \quad (3)$$

where: r = Number of Rows
c = Number of Columns

**Step 6: Statistical inferences and decision**

The calculated $X^2$value and the corresponding degrees of freedom (df) were used to obtain the p-value from the Chi-Square distribution.

- If $p < \alpha$ (where the significance level $\alpha = 0.05$), the null hypothesis ($H_0$) of independence was rejected, indicating statistically significant association between the two variables.
- If $p \geq \alpha$, the null hypothesis failed to be rejected, indicating insufficient evidence to conclude a significant association between the variables.

This rigorous statistical process provided the empirical basis for accepting or rejecting each of the three hypotheses

concerning CCTV surveillance in Goa, moving beyond theoretical discussion to quantitative validation.

## 4. Experimental Method

This section outlines the systematic approach used to investigate the relationship between CCTV surveillance and public traffic behavior in Goa. It describes the procedures followed from data collection through hypothesis testing, thereby demonstrating the study's implementation and reproducibility.

### 4.1 Overall Experimental Design

The research employed a quantitative, cross-sectional design. A consent-based survey was the primary methodology used to collect data on categorical variables from a representative sample of the Goan population. These variables were then analyzed using inferential statistics (the Chi-Square Test of Independence) to test the hypotheses related to public awareness, perception, and behavior. The entire experimental workflow is illustrated in Figure 1 and described in detail in the following subsections.

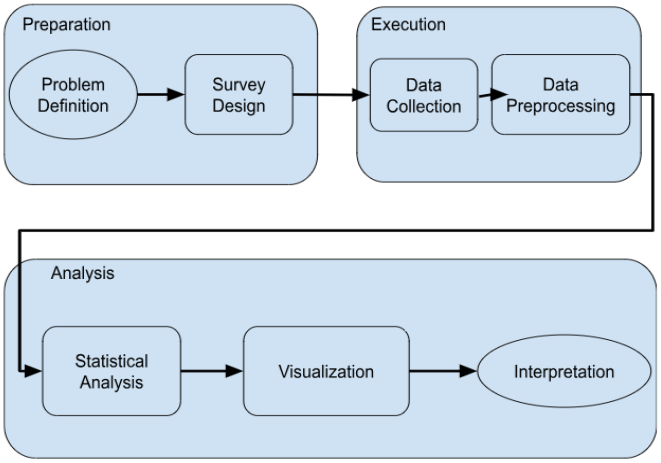



Figure 1. Flowchart of the Experimental Procedure

### 4.2 Algorithm for Hypothesis Testing

For each variable pair, the hypothesis testing was done through the following steps:

1. **State Hypotheses:** Set up $H_0$ and $H_1$ defining $H_0$ as no association and $H_1$ as the association.
2. **Construct Contingency Table:** Record the observed frequencies.
3. **Get Expected Frequencies:** Use formula (1) for every cell.
4. **Calculate Chi-Square Statistic:** Use formula (2) to compute.
5. **Figure out Degrees of Freedom:** Use formula (3) to do this.
6. **Get P-value:** With the help of a statistical software.
7. **Take a Decision:** Reject $H_0$ if p-value < 0.05.

### 4.3 Proposed Analytical Model

Theoretical model assumes that factors outside the subject (Awareness, Perception, Experience) have impact on behavior outcomes (Compliance, Support). The effects of the model have been checked basing on three hypotheses:

1. H1: Awareness (Q4) has impact on Compliance Behavior (Q6).
2. H2: Perceived Effectiveness (Q5) has impact on Support for Expansion (Q16).
3. H3: Negative Experience (Q9) has impact on Support for Expansion (Q16).

### 4.4 Tools and Implementation

The experimental process was programmatically executed using the following Python-based data analysis pipeline:

- **Pandas & NumPy:** These libraries were used for loading, cleaning, and manipulating the data, as well as for constructing contingency tables.
- **SciPy.stats:** The chi_contingency function performed automatic calculations of the Chi-Square statistic, degrees of freedom, and p-value based on the observed contingency table, thereby implementing the algorithm described in Section 4.2.
- **Matplotlib & Seaborn:** These libraries were used to generate clear and interpretable bar charts and heatmaps, visualizing the observed associations and facilitating the interpretation of statistical results.

The key factors in this systematic experimental design were: (a) a rigorous step-by-step procedure, (b) a clear line of visibility, and (c) standardization of the process to achieve the research objectives.

## 5. Results and Discussion

This section presents the empirical results of the statistical analysis conducted to test the three hypotheses. Each finding is accompanied by a discussion that outlines the objectives of the study and interprets the results in the context of existing literature.

### 5.1 Hypothesis 1: Association Between Awareness of CCTV Cameras and Strictness in Following Rules

To study the relationship between public knowledge of CCTV cameras (Q4) and the self-reported strictness in following traffic rules (Q6), the Chi-Square Test of Independence was employed. The test result was significant from a statistical point of view ($X^2 = 14.6243$, df = 2, p = 0.0007) and hence, the null hypothesis was rejected. Therefore, the association between the two variables is found to be significant.

Table 1. Observed Frequencies for Q4 and Q6

| Are you aware that CCTV cameras are installed at traffic signals in Goa? | No | Not Sure | Yes |
|---|---|---|---|
| Do you follow traffic rules more strictly...? – No | 2 | 4 | 6 |
| Do you follow traffic rules more strictly...? – Yes | 10 | 10 | 148 |

Table 2. Expected Frequencies for Q4 and Q6

| Are you aware that CCTV cameras are installed at traffic signals in Goa? | No | Not Sure | Yes |
|---|---|---|---|
| Do you follow traffic rules more strictly...? – No | 0.8 | 0.93 | 10.27 |
| Do you follow traffic rules more strictly...? – Yes | 11.2 | 13.07 | 143.73 |

The data presented in Figures 2 and 3 reveal a striking contrast. Most respondents (148 out of 158) who were aware of the CCTV cameras reported a noticeably higher adherence to traffic rules. In contrast, respondents who were unaware or uncertain about the cameras exhibited a significantly higher frequency of non-compliance.

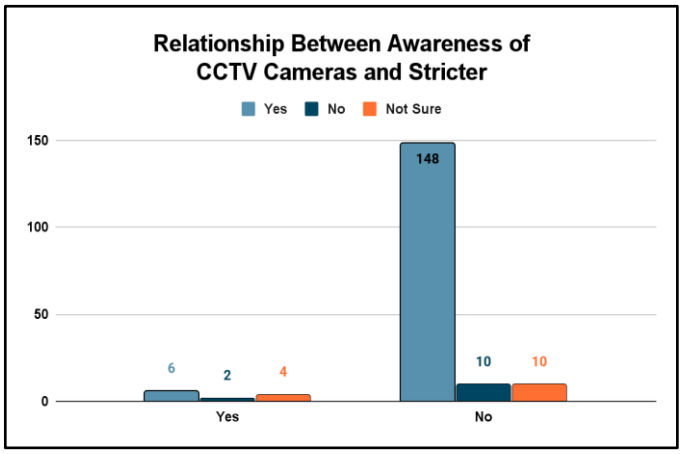



Figure 2. Bar Graph for Association Between Awareness of CCTV Cameras and Strictness in Following Rules

**Discussion:**

This finding provides solid evidence to the support of deterrence theory [2], that the one most powerful reason why individual feel compelled to abide by the rules is that they get caught for sure. The existence of CCTV cameras gives this impression, thus a change in the behavior. A very important implementation insight is that the deterrent effect relies on public knowledge. A hidden camera can do nothing to change behavior, so public awareness campaigns are necessary for the traffic programs to be successful [6].

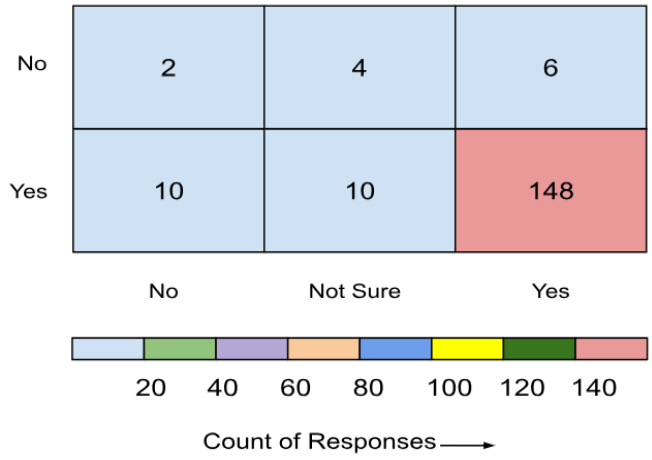



Figure 3. Heat Map for Association Between Awareness of CCTV Cameras and Strictness in Following Rules

### 5.2 Hypothesis 2: Association Between Perceived Effectiveness of CCTV and Support for Expansion

The analysis of the relationship between the perceived effectiveness of CCTV (Q5) and support for its expansion (Q16) also revealed a statistically significant association ($X^2$ = 6.2255, df = 2, p = 0.0445). This result allows for the rejection of the null hypothesis at the 0.05 significance level.

Table 3. Observed Frequencies for Q5 and Q16

| Do you think CCTV cameras are effective in monitoring traffic violations? | Maybe | No | Yes |
|---|---|---|---|
| Would you support the expansion...? – Negative | 3 | 5 | 10 |
| Would you support the expansion...? – Positive | 21 | 15 | 126 |

**Table 4.** Expected Frequencies for Q5 and Q16

| Are you aware that CCTV cameras are installed at traffic signals in Goa? | Maybe | No | Yes |
|---|---|---|---|
| Would you support the expansion? – Negative | 2.4 | 2 | 13.6 |
| Would you support the expansion? – Positive | 21.6 | 18 | 122.4 |

Figure 4 and Figure 5 show that all respondents who considered CCTV to be an effective measure (the "Yes" group) supported its expansion, with a total of 126 out of 126 participants in this category favoring the extension of the system.

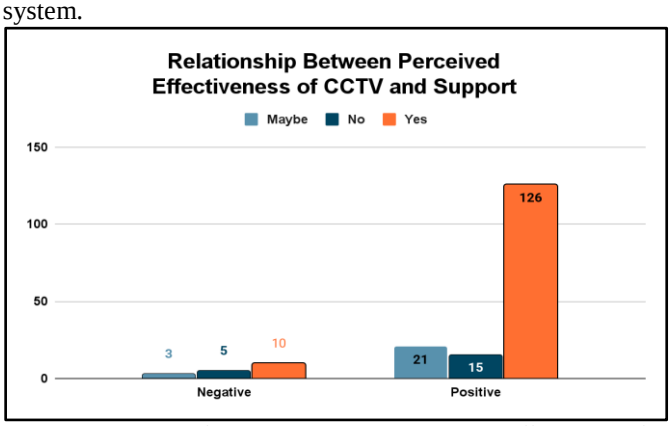



Figure 4. Bar Graph for Association Between Perceived Effectiveness of CCTV and Support for Expansion

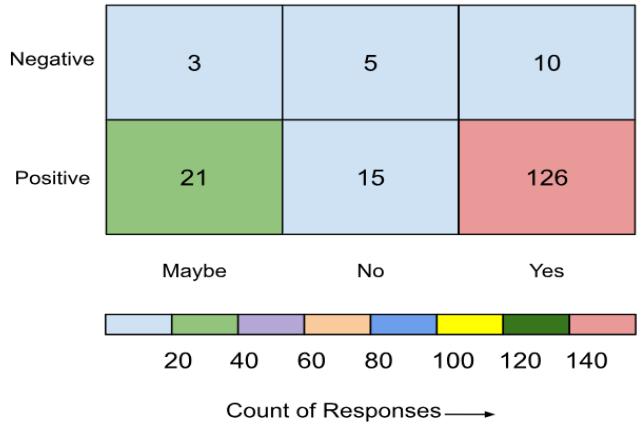



**Figure 5.** Heat Map for Association Between Perceived Effectiveness of CCTV and Support for Expansion

**Discussion:**
This discovery is in tune with technology acceptance models [5, 11], which indicate that public backing is obtained by proven use. The Goan public links their backing of increased surveillance to the extent to which it is deemed effective in the improvement of road safety. This highlights the necessity of the authorities being open with the public by disclosing performance measures like lowered violations or accidents in order to gain and maintain public support [13].

### 5.3 Hypothesis 3: Association Between Experiencing False Fines and Support for CCTV Expansion

A significant relationship was found between the experience of false fines (Q9) and support for CCTV expansion (Q16) ($X^2 = 7.3846$, df = 2, p = 0.0249). The null hypothesis of independence is rejected, confirming that negative experiences impact public support.

Table 5. Observed Frequencies for Q9 and Q16

| Have you or someone you know ever received a false fine due to a CCTV error? | Maybe | No | Yes |
|---|---|---|---|
| Would you support the expansion of CCTV surveillance...? – No | 22 | 12 | 111 |
| Would you support the expansion of CCTV surveillance...? – Yes | 2 | 8 | 25 |

Table 6. Expected Frequencies for Q9 and Q16

| Have you or someone you know ever received a false fine due to a CCTV error? | Maybe | No | Yes |
|---|---|---|---|
| Would you support the expansion of CCTV surveillance...? – No | 19.33 | 16.11 | 109.66 |
| Would you support the expansion of CCTV surveillance...? – Yes | 4.67 | 3.89 | 26.44 |

The information in Figure 6 and Figure 7 reveals a clear pattern: respondents who reported a negative experience (answered "Yes" to Q9) were predominantly not in favor of CCTV expansion, with 25 out of 35 participants expressing opposition.

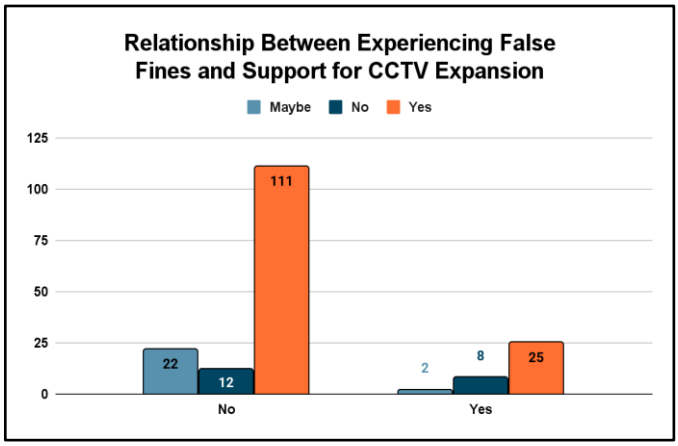



**Figure 6.** Bar graph showing the relationship between experiencing false fines and support for CCTV expansion.


**Figure 7.** Heatmap for the relationship between false fine experience and support for the CCTV expansion.

**Discussion:**
The truth hereby supports procedural justice concepts [4] [15], that "fairness of the treatment" is not less significant than the end result. A false fine is a violation of the relationship of trust which, in response, diminishes the recognized authority of the whole enforcement system. Such a situation reveals an essential vulnerability of automated enforcement whereby mistakes of a technical nature have a significantly larger effect on the public view. Moreover, it emphasizes the need for a minimal error rate of the system as well as a trustworthy appeal system for the maintenance of public trust [11].

### 5.4 General Discussion and Limitations

Research illustrates that interactions between the public and surveillance are transactional, thus dependent on the understanding, perceived benefit, and trust. These results from Goa act as an essential local verification of worldwide research on surveillance and technology acceptance [2] [5][11].

One of the main restrictions is the use of self-reported data for measuring compliance (Q6), which is prone to social desirability bias. Moreover, the sample, although important, is limited to Goa. The unique socio-cultural and traffic environment of the state may restrict the extent to which the findings can be applied directly to other parts of India with varying driving cultures. Future research should focus on obtaining larger and more diverse samples and using objective measures of behavioral compliance in which case behavioral compliance can be verified through objective measures of behavior.

## 6. Conclusion and Future Scope

The research dealt with the influence of CCTV monitoring on traffic control in Goa, India, specifically the socio-behavioral aspect. A survey data examination by the Chi-Square Test of Independence indicated that knowledge of CCTV cameras being installed is one of the main factors that lead to compliance with traffic rules as per the self-report of the people. Confidence in how well the system works is a strong

factor that leads to the expansion of the support for the system by the public, whereas the support disengagement greatly caused by the false fines significantly worsened. One of the main inferences is that technological means of law enforcement need to perform not only technically but also be accepted by the society, with public trust, perceived fairness, and awareness as important factors. The results offer valuable insights for smart city deployments, indicating a need to go beyond the technological solution and foster community trust.

**Future Scope**

Research in the future must take this work deeper to bigger and diverse populations spanning multiple states of India to be able to say that the findings are more broadly applicable. Those advanced statistical methods like logistic regression or structural equation modeling may reveal the unobserved variable interactions and mediating factors. Moreover, qualitative research on the point of view of the people for whom privacy is the main concern would offer more profound insights into the balancing of security and privacy rights. The public opinions and actions over time after the continuous use of automated traffic enforcement systems need to be researched through the use of longitudinal studies.

## Author's Statements

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**Conflict of Interest:** The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

**Study Limitations:** This research is limited by its sample being confined to Goa, the potential subjectivity of self-reported survey responses, and the use of cross-sectional data, which restricts the ability to infer causality.

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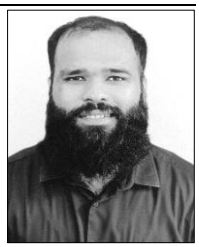
**AUTHORS PROFILE**



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