Crowdsourced System to Report Traffic Violations
RoadCop: Bi-Modular System

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Abstract: With increasing demand of transportation, implementation of the traffic regulations has become a major challenge for the developing countries. Most of the traffic accidents occur due to violation of traffic rules, thus, resulting in loss of human lives and property. The developed countries have addressed the situation by deploying surveillance systems at intersection, but the solution can be expensive; therefore, due to the cost factor the solution is out of reach for many underdeveloped countries. In order to overcome the situation, a framework is proposed that is based on crowdsourced model to report violations supplemented by the video evidence. The user reports are evaluated in multiple phases. In the first stage, spam is eliminated through evaluation, and associated user profiles are blocked. In the second stage, traffic law experts evaluate the report and on every valid report the users are rewarded with incentive points while ensuring the anonymity. The system is evaluated for usability, advantages to authorities, citizen involvement, skills and resources required and transparency. The results of functional testing indicate that the participants appreciated the purpose of the application and found it quite easy to use. With a large-scale deployment and an effective mechanism to identify offender, this system can lead to much improved implementation of traffic regulations.

1 INTRODUCTION

Transportation is one of the basic necessities of life. With technology advancement, new techniques have been adopted to optimize the transportation system. Moreover, with growing needs of user, one of core objective is to build the system that is safe and easy to manage large number of users. According to the recent statistics[1] the average death rate in Pakistan due to road accidents is approx. 20.22% in the year 2014.These statistics are also alarming in countries such as Iraq, Iran, and Venezuela where the numbers are as high as 43.545%, 41.415%and 41.065% respectively (WHO, 2016). According to World Health Organizations (WHO) fact sheet in the year 2016 ,the road traffic injuries are the leading cause of death among young people. The traffic violations, careless driving attitude and a weak infrastructure are the main causes of traffic accidents resulting in higher casualty rates. Further, according to WHO the road traffic accident will become the seventh leading cause of death by 2030. Therefore, necessary actions and precautionary measures are needed (WHO, 2017).

The traffic accidents can be reduced by penalizing violators. Different countries have addressed the issue by installing surveillance systems to monitor traffic violation at every intersection. However, such systems are expensive and require well installed infrastructure. It is convenient in developed countries due to existing infrastructure; whereas, in underdeveloped countries, the lack of budget and weak infrastructure makes it unfeasible. The deployment of extensive number of traffic constables to monitor violations is not viable either. In the last decade,crowdsourcing has become a widely used technique to solve the problems using end users input. The concept of crowdsourced system has been normalized by social media and smartphones. Today people around the world can easily participate for the sustainable society development without any special skill sets. The sensor based data collection helps to retrieve credible and accurate data. With the advancement in technology and exponential growth of smart phones, users can eas-

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ily share data at low cost. Thus, it enabled the role of crowdsourcing to solve daily life problems. Due to easy access to 3G/4G/5G technologies, multimedia streaming is adopted to share real-time information to help law enforcing agencies. These features and techniques encourage developers to come up with cost efficient solutions for smart cities.

In order to provide a feasible solution, a system is developed using crowdsourced model to report violations along with video evidence and GPS coordinates. The motivation is to reduce the burden on traffic wardens and increase the involvement of general public in law enforcement.

RoadCop is bi-modular solution (Mobile and Web Application) to report traffic violations. These reports are filtered on two stages. The first stage eliminates the spam reports and blocks the spammer.In the second stage of evaluation, the filtered reports are used bu traffic law experts to decide the validity of these reports. the traffic violations that can be reported by the mentioned system are i) Red Light Violation (RLV) ii) Reckless Driving (RD) iii) Illegal Parking (IP) iv) Hit and Run (HR) v) Illegal Lane Change (ILC).

2 LITERATURE REVIEW

This section covers the detailed review of research in this particular area. It discusses the methodologies currently used for monitoring traffic violations and usage of crowdsourced model, geo coordinates and media evidences to solve different day to day problems.

Pakistan is a developing country and public sector has yet to see the boom of information technology. IT has begun to automate various manual processes. One of such fields is transportation management. Traffic Police deals with the offence and penalty of traffic rule violations. Monitoring traffic violations have become a challenge due to the increasing number of vehicles and population over the last few years. In the urban areas, controlling traffic has become a necessity. Traditional technique is traffic wardens identify violator which is used all over the country. It has loopholes due to lack of evidence and human errors. Moreover, it is also vulnerable to harassment and bribes.

Punjab Traffic Police have been experimenting with Traffic Violation Evidence System for more than a year now. The system is installed over the intersection and automatically generates the e-Ticket on violations which is later approved by authorities and sent to doorstep of violator along with the picture of violations, taken by CCTV cameras. Though, weak infrastructure, lack of funds and absence of proper intersections resulted in dependency of manual identification of violators in other parts of the country.

Transportation and control on traffic accidents has become one of the burning issues for the IT Industry and academia. Different techniques are proposed over the time, one of such techniques is to penalize the violators of horn blowers in restricted areas (a.k.a Silence Zone). Drivers receive a message to "Not Blow Horn" on LCD screen adjusted in the vehicle. On violation SMS along timestamp is generated from vehicle to control station. Registration number is used to penalize the offender. It is a flexible approach and can be modified for different traffic violations (Biswas et al., 2015).

India has digitized existing data under the digital India program and is using smartcards to store registration and license information which is used to provide VPC (Vahan Penalty Card) to drivers. VPC contains penalties balance and license is cancel after crossing threshold and petrol pumps will deny petrol to invalid VPC holders. System is operating on RFID readers installed at the sensitive areas to identify RFID readable license plates of violators. Intelligent Expert Penalty System requires sophisticated equipment like RFID readers, RFID readable number plates, VPC, VPC readers, VPC rechargeable outlets. It also requires legislation and binding agreements between government and petrol pumps (Goel and Shukla, 2016). Another RFID based solution uses RFID tags instead of license plates. Tags store driver's license, bio data and vehicle registration. RFID reader and camera components are used to detect violations and generate warning messages. Crossing threshold can result in cancellation of license. It is used to check speed limit, red light violations and can help reduce vehicle theft(K et al., 2016).

Another system is proposed and tested using a toy car which uses infrared transmitter and receiver, microcontroller, wireless communication and central database of Bangladesh Road Transport Authority. Proposed approach can be seen in Figure 1 (Hossain et al., 2010).

A system for smart cars is proposed which employs VNDN[2] (Vehicle Named Data Network). It uses ID instead of IP and protocol of data exchange with simple interest and response messages. System uses OBUs (Onboard Units) to sense violations and store it in Pending Ticket Entry Table maintained by every Ordinary Vehicle. Cop Vehicles (CVs) receive PTE entries on broadcasting interest messages and issue the ticket against the entry. Payment can be deducted from the registered bank account of the

[2]Vehicle Named Another system for smart cars

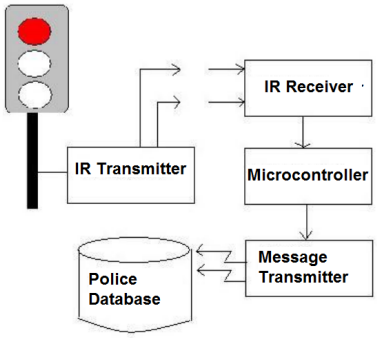


Figure 1: Block Diagram of proposed system in (Hossain et al., 2010).

violator on the next toll booth automatically. This approach targets the urban environment and unmonitored highways due to the pull mechanism. Functional testing concludes that increase in violators will increase the number of Tickets and CV will be required to send more interest messages(Ahmed et al., 2016). Another Intelligent Transportation System collects GPS data and sends it to server where web application matches and calculates the speed of the vehicle and checks it against the OSM speed limit of the streets (Tarapiah et al., 2014).

Advanced Driver Assistance system was proposed to gather data from various sensors and equipment installed in the vehicle and generates a profile for the driver to view traffic violations, speed and other spatial and geographical information on Google Maps via a small monitored screen adjusted in the vehicle(Nourdine Aliane, 2011).

2.1 Overview of Crowdsourcing

Crowdsourcing is a technique to collect data with the help of volunteers, sometimes driven by incentives (monetarily or entertainment)(Ali et al., 2012). Today, there are many applications based on crowdsourcing as an underline mechanism for information retrieval. Examples of such applications are social media, Google Maps, Wikipedia and research journals. The social media collects users interest, opinions and uses it for target advertisement and suggestions. One of the major advantages of crowdsourced applications is to facilitate generation of geographically distributed data. It can be useful in data collection for transportation management(Santani et al., 2015). The contributions in crowdsourced applications are of two types (Chatzimilioudis et al., 2012).

- Participatory Contribution:based on Users input
- Opportunistic Contribution:based on Sensors

The results derived from crowdsourced system are dependent on the credibility of the contributors. Following are few techniques to ensure credibility (Cvijikj et al., 2015). Crime-mapping a technique to display crime's location over a map. Media Evidence can help eliminating spamming. Incentives (Monetary, Entertainment and etc) is a way to motivate crowd.Assurance of user anonymity publicly may encourage users to report. On the other hand, system can store credentials of the user to ensure its credibility and most importantly reduce textual input and restrict it to predefined range.

Following section discusses the crowdsourced applications and research in the transportation sector.

2.2 Crowdsourcing Applications in Transportation

Crowdsourced systems uses citizens input and smartphones to collect transportation data, manage traffic situations and exploit that information to make decisions and plan infrastructure changes (Mostashari et al., 2011). In the last few years, most of the research and development of Intelligent Transportation System has shifted from sophisticated expensive equipped framework to crowdsourced systems. It is a cost efficient solution with great potential due to technology advancement. Transportation management is linked to geographically distributed data and high mobility so a crowdsourced solution is match made in heaven.

CrowdITS is a mobile application to report and notify traffic congestion, accidents, construction and breakdown. This system does not use the external sensors and equipment which makes it affordable (Misra et al., 2014). Another crowdsourced system is proposed to report road hazards along GPS coordinates and media evidence for Nairobi, Kenya to meet the development challenges and solve infrastructure problems. Media evidence is crossed check by Amazon Mechanical Turk to eliminate spam (Santani et al., 2015). Another Mobile Application uses GPS sensor, accelerometer, GSM radio and microphones to collect data of traffic and road conditions such as potholes, bumps, braking, and honking. It is an experimental project deployed in Banglore, India and has delivered promising results(Mohan et al., 2008).

Vehicular Ad-hoc Networks and Vehicular Named Data Networking solutions can be used to send traffic information to other vehicles and collected information can be used to reroute dynamically in order to save time. System was testing in Portland and produced good results (Leontiadis et al., 2011). Cloud

computing can provide storage and computing facilities to process big data collected through the crowd for traffic model construction and congestion prediction(Nourdine Aliane, 2011). We would like to mention about a public sector app Public Eye: BTP Official App Smart Mobile Application for managing Traffic Violations that describes work similar to what we have proposed but it lacks the location tracking facility for traffic violations.To the best of our knowledge most of the research did not cover the utilization of crowdsourced model to report traffic violation using handheld smartphones.

Table 1: Comparison between existing approaches to report traffic violations.

No	Existing Approach	Pros	Cons
1	Manual Violations Identification by Traffic Wardens	Useful in absence of technology.	Prone to bribe and harassment Lack of evidence Prone to Human error
2	CCTV and e-Ticketing Systems	Efficient Effective Accurate	Expensive Equipment Unmonitored areas
3	RFID Sensors and RFID Tag Based Solution	Sophisticated Technique Less prone to Error Accurate. Easy Maintenance of record due to RFID.	Expensive Equipment Cost on either Government or Consumer Maintenance budget cost

3 PROPOSED SYSTEM

This section gives an overview of the proposed system and need of such systems. Table 1 compares the existing solutions for traffic management and control. It concludes that sophisticated systems generate better results in monitoring traffic situations and violations. In countries with appalling law and order situation, employing expensive equipment is not feasible due to theft possibility.The role of general public is very crucial for the development of sustainable society. A crowdsourced system to counter the problem is not only cost-efficient but also beneficial for development of well-grounded society.The proposed system enables general public to report traffic violations along media evidence and its location. Mobile Application enables users to report traffic violations. On the other hand, Web Application is available for the administration. It allows admin to filter spam, review reports, view details of vehicles and vehicle registered owner, total number of violations reported and reward points/score in case of valid reports. The admin can view all reports on Google Maps (type of violation, area, timings or combination of all three). The graphs generated gives results such as number of violations in a specific area, number of violations in a specific period of time and number of specific violations in a certain time. These and other customized cubes can help concerned departments to make decision regarding infrastructure and traffic surveillance.

3.1 System Workflow and Architecture

Web Application can be hosted on existing data centers of public sector entities. Mobile Application can be installed on the android smartphones. It launches camera to record video. Reporter can choose to report immediately or save it for later. Mobile application uses background service to collect GPS coordinates of traffic violations location while recording video. User can add the license plate number and choose violation type from predefined list.User requires Wi-Fi connection to submit report otherwise it is stored locally on SQLite database and sent along timestamp when connected to Wi-Fi.It will avoid the cost of mobile data. User transmit video to server in multimedia encrypted form and remaining fields of report (license plate number, traffic violation type, GPS coordinates, and timestamp and user credentials) in JSON (JavaScript Object Notation) format.Video files are stored on server in directory instead of database to avoid increasing size of database.Data is delivered to the restful service which inserts it in central database via hibernate query. Web application interacts via Ajax calls to restful services for manipulation of the database. Admin view of the web application gives the status of reports on Google Maps with color coded markers. Admin can review the reports. First Stage Admin will block the spammer. Admin can validate if the violation meets the legal criteria. If yes, then the ticket along with the screenshot of the report and time will be sent to the registered contact details of the vehicle and valid reports point will be given to the reporter. System Architecture can be seen in Figure 2.

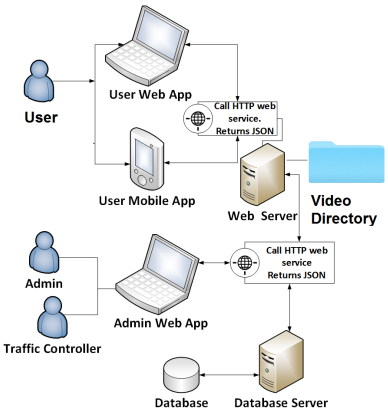


Figure 2: Architecture of Proposed System.

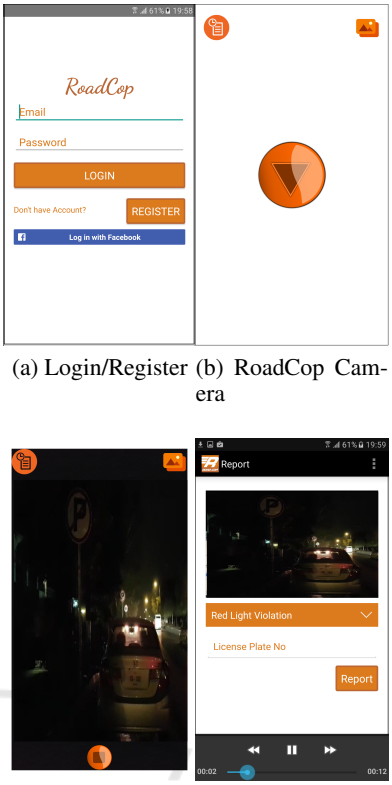
4 SYSTEM COMPONENTS AND IMPLEMENTATION DETAILS

This section discusses the detail of systems components their features and implementation details.

4.1 Mobile Application

Mobile Application is developed for Android Operating System. Basic requirement to run the proposed application on the smartphones are i)Android OS Version 2.3 (Gingerbread and above) ii) Wi-Fi iii) GPS Sensor iii) Camera with minimum 2MP. The proposed implementation has enrich UI which works on major screen sizes such as LDPI, MDPI, HDPI, XHDPI, XXHDPI, XXXHDPI. It also allows login via Facebook which uses Graph API and Facebook SDK to request public fields such as name, gender, `user_id` and fullname of a particular user as shown in Figure 3a. After logging into the system, video recording for traffic violation screen appear as shown in the Figure 3b. User can also view the already recorded but not reported violations along with history of reports status.

- **GPS Coordinates:** : These are integral part of the system. It gives exact location of the traffic violation. In case of a valid report, location can be sent with the ticket to the violator.
- **Video Evidence:** Video Evidence is captured via the camera in the application. It has VGA settings with standard dimensions of 640x480 pixels. It is stored in mp4 format with H.264 encoding which is a block-oriented, motion-compensation based video compression standard. Video size limit of 15MB is enforced. Video is encrypted using AES/CBC/PKCS5Padding which makes it transmission safe and ensures end to end security.



(a) Login/Register (b) RoadCop Camera

(c) Evidence Capturing (d) Reporting Traffic Violations

Figure 3: Mobile Application.

- **Type of Violations:** Scope of the research is limited to i) Red Light Violation ii) Reckless Driving iii) Illegal Parking iv) Hit and Run v) Illegal Lane Change.
- **Reward Points:** Valid report is rewarded with points. These points, in this study, are just like scores but later can be used to offer some incentives(monetary, entertainment or fuel) This can elevate the interest of reporter.

4.2 Web Application

Web application and webservices are deployed on apache tomcat with hibernate support and JBoss data services. Hibernate layer communicates with the central database. It receives and sends data via restful services on client side by jQueryAjax. JQueryAjax then uses HTML5 markups and bootstrap to show and format data. Layered Architecture can be seen in Figure 5. Web Application is developed for the Administration. It gives details of total violations reported and total number of users registered with the system. Administrators can perform first and second stage filtering. Figure 4 shows web application view.

- **View Violation Map:** It gives the view of the reports with color coded markers on Google Maps which can be viewed by different dimensions such as by area, timing and type of violations. It helps in understanding the trends of violations by area. Place on Google Map with maximum markers is most vulnerable area.
- **Eliminate and Block Spammers:** There are two levels of Administration Staff. First Stage Admin will filter spam reports and block spammers.
- **Review Reports and cross validate against the registered Vehicles:** Second Level Admin are the Traffic Law Expert who can review ham reports based on traffic rules and regulations while system ensure reporters anonymity. Data is fetched against the license plate number from the registered vehicles database for ticketing once report is validated by traffic expert and reporter is rewarded.

Central database contains tables user, report,reward and vehicles. User has credentials and password which is encrypted by MD5 encryption algorithm to ensure privacy. Reported violations are stored in report table, reward table has status of reported violations also rewardpoints and registered vehicles can be fetched from vehicles table.

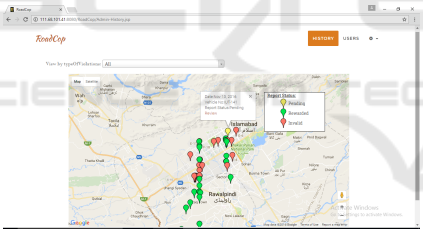


Figure 4: Map of Reported Violations.

4.3 Statistics for Decision Making

Crowdsourcing is a technique of information retrieval. Usually the data collected by the crowd in this stage can later be used for different statistical analysis. Statistics such as number of violations by cities/area, number of violations by time (Date, Day, Month and Year) and type of violations on different parameters. Visual representation in the form of graphs can give very promising trends that can be used by transportation management department as well as infrastructure planners. API used for visual representation is an open source JavaScriptAPI called Chart.js. It is used to generate client side visual aid such as pie charts, histograms and barcharts. Data sciences have changed the prospect of data collection and analysis. Utilization of intelligent systems trained on collected data can help overcome similar events in the future to avoid mishaps or management failures.

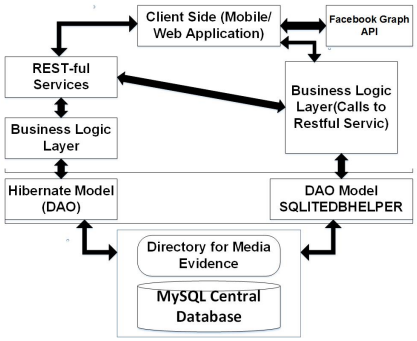


Figure 5: Layered Architecture of Bi Modular System.

Table 2: Evaluation criteria of proposed system.

No	Evaluation Criteria	Description
1	Usability	User-friendly and easy to use Design
2	Advantage for Authorities (LEA,GOVT officials)	Helps in locating violators
3	Citizen Involvement	Involving Citizens in process law enforcement
4	Linkage and Trust	Associating Trustworthy organization
5	Skills and Resources Required	What Kind of Skill set required for the usage of Application
6	Transparency	Ensuring privacy control of user

5 FUNCTIONAL TESTING AND CHALLENGES

In order to test the proposed system and evaluate it on parameters shown in the Table 2; system is deployed on a windows server. Mobile Application is provided to 50 volunteers for testing and requested to report a traffic violation at least once over the period of four weeks. More than 53 reports are collected. Volunteers are selected from Islamabad and Rawalpindi. Admin evaluated the reports in the first stage and removed total 15 reports (12 videos spams and 3 license plate numbers spams) and blocked spammers. Total 35 reports are sent for expert's review known as the final stage evaluation. The experts marked 23 reports invalid and rewarded 12 reports. The experts reviewed and evaluated reports with the help of regional transportation department.

Evaluation criteria of system mention in table 2. A small survey was conducted among the volunteers of functional testing to evaluate the system. It was close ended questionnaire to get feedback regarding usability and skills set required for app usage. Due to the easy design, understanding the purpose of the system was not a problem. 85% of the participants understood the main functionality of application. Users did not feel the need of tutorials. Citizen involvement can be increased by collaboration with the official authorities. More than 76% of the people think association of the application with concerned authorities can increase the frequency of reporting. Users trust the system with frequent responses and actions against violator. 60% of the users think that the application gave them a sense of responsibility and contribution towards law enforcement. Challenges faced in the process of functional testing are of following four types:

5.1 Design Challenges

Crowdsourced systems are for the people with minimum technological skills. Few of the major design decisions are to reduce textual inputs and use affordances icons.

5.2 Legal Challenges

For consideration of an evidence it must possess four characteristics.i) Materiality ii) Relevance, iii) Authenticity, and iv) Competence. In the proposed system, one of the major challenges is to ensure authenticity while keeping the reporter anonymous. The reports authenticity is ensured by the GPS coordinates. It is impossible for a reporter to change the GPS coordinates values. Media Evidence can ensure both authenticity and competence. During the research and development phase, Traffic Police Department recommended to ensure that evidence is captured through app. Uploading a video can give user/reporter a chance to edit it.

5.3 Adaptability Challenges

Crimes reporting crowdsourced systems are for the public to contribute in collecting geographically distributed data. Such systems could support modern ideas of open government. Popular crowdsourced applications, like social media are trendy and user contribution in such systems are presumed to strengthen their social standing. On the contrary, crowdsourced applications by governments raise different concerns. Anonymity: Insurance of reporter's anonymity Relevance: Will justice be served if reported? Ensuring privacy while keeping authenticity of data is a major challenge which can be solved by concealing the source of report on public view but keeping it in the record. To increase the awareness and acceptance of such systems some measures are discussed in Table 3. Adaption of the system by authorities has been another major challenge because association with authorities can make system reliable. On the other hand, authorities are not easily convinced to adopt new technology.(Cvijikj et al., 2015) Authorities expect quality of contribution which is ensured by media evidence. (Quinn and Bederson, 2011) Acceptance can also be achieved with the help of academic stakeholders and through capacity building of government's IT professionals.

5.4 Vehicle Registration Challenges

Complete Evaluation of such a system is not convenient due to many reasons, particularly in Pakistan. Vehicles are registered once and registrations are usually not transferred to new owners.Computerized registration of vehicles is the priority of interior ministry and traffic police department. Process is at final stages in Punjab and KPK. Motor Transport Management Information System is the online vehicle verification system which is functional in Punjab, KPK, Sindh and Islamabad.

6 CONCLUSION

Research and development of proposed system concluded that such systems can be very useful towards the development of intelligent transportation systems and information retrieval for decision making. It gives a technique for collection of traffic violation reports from general public to increase awareness of traffic laws and awake the sense of responsibility in drivers. It can help in publishing a real time map of violations by area and time period. Functional testing gives interesting inferences. It shows how people would prefer such systems if they are associated with a trustworthy organization such as Traffic Police or Communication and Works Departments. This system is novel approach and opens many doors for future research. If the proposed system is correctly and efficiently implemented then it can not only produce better results than manual capturing of violators but also help in collection of data which can be useful in the future.

Table 3: Measures to increase adaptability of traffic violations reporting crowdsourced system.

No	Measures	Description
1	Incentives	Reward for Users to motivate the participation also shows seriousness of authorities.
2	Provision of Valid Information	Discard spams and public availability of valid reports.
3	Frequent Information Update/ Quick Response	Regular updated information can increase interest of public. Action on reports and update regarding it can increase trust and ensure adaptability.
4	Association of Trustworthy Organization	Association of Government entity can help build trust.

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