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R-Secure: A system based on crowdsourcing platforms to improve road safety in the smart city

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***Abstract*—The number of accidents is increasing over time, which has a social and economic impact. According to the World Health Organization (WHO) road accidents are now the main cause of death among 5-29 year old's. In addition, Every day, roads cause roughly 40 serious and minor injuries and 4 fatalities in Tunisia, warns the National Observatory of Road Safety(NORS). The statistics show the seriousness of the current situation of road safety at the global and national level. In order to enhance road safety in Tunisia we propose a new system baptized R-Secure based on data from our crowdsourcing platforms. Our system has two functionalities, the first one consists in collecting rich road anomaly data such as images and GPS location from citizens and road safety experts. And the second is to analyze the information gathered and to inform resident's about the risk areas through a vulnerability map of the city.**

***Index Terms*—Road security, crowdsourcing, road anomaly, decision support, smart city**

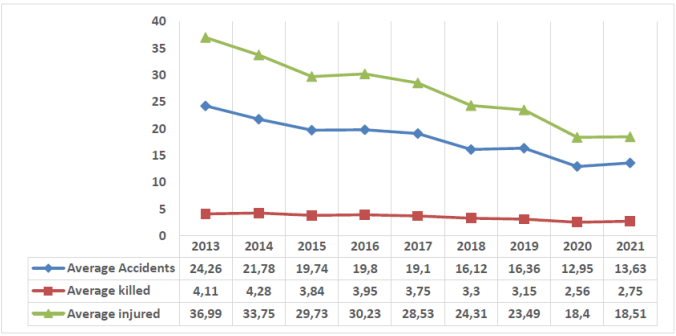
I. Introduction

The latest report published by the World Health Organization (WHO) shows that 1.35 million people are killed and 50 million injured in road crashes worldwide each year [1]. Road safety in Tunisia requires an effective and urgent management because according to the national observatory of road safety Tunisia records a considerable number of victims (about 1007 deaths and 6757 injuries in 2021) [2]. In addition, during the last years, Tunisia records an average of thirty accidents per day; the roads kill an average of 4 people and about forty serious and light injured every day [2].

The graph in figure 1 shows that the number of killed evolves from year to year in a variable and not constant way, we note that the number of accidents, killed and injured recording an increase of the last 2 years as the following figure shows.

The statistics indicate the gravity of the actual situation of traffic conditions in Tunisia. The violation of traffic rules, speeding, non-compliance between residents, the unconsciousness of drivers, driver inattention, poor road conditions, and terrible weather always cause fatal accidents.

To define an overall vision on road safety, the statistical data published by the NROS remain insufficient to grasp certain issues and the complexity of the problem. To enrich their databases, we propose to integrate citizens and road safety experts in the NORS's decision support process.



	2013	2014	2015	2016	2017	2018	2019	2020	2021
Average Accidents	24,26	21,78	19,74	19,8	19,1	16,12	16,36	12,95	13,63
Average killed	4,11	4,28	3,84	3,95	3,75	3,3	3,15	2,56	2,75
Average injured	36,99	33,75	29,73	30,23	28,53	24,31	23,49	18,4	18,51

Fig. 1. Graphical depiction of Tunisia's daily average accident and victim rate from 2013 to 2021

Innovations in technology and digital services have taken over our daily lives and our societies in an effort to raise the standard of living for city community and make their city more appealing. Additionally, the COVID problem has hastened and encouraged organizations' digital development. For these reasons we propose a crowdsourcing system called R-Secure for road safety experts and citizens to collect data on traffic violations committed by citizens and risk points.

In order to help the national observatory of road safety further evaluate road safety issues, our purpose is to identify danger locations, notify citizens about risk regions through the city plan, and identify risk areas.

Our solution is built on crowdsourcing services, which enable knowledge-sharing through the use of smartphone that are always linked to the Internet. innocentive, which is consulted and updated by peoples every day, is an example of this task [3].

The objective of the smart city is to improve the quality of life of residents by using new technologies [4]. Crowdsourcing is one of the new techniques that allows to exploit the intelligence of a group of people in order to find solutions to existing problems [5], an example of this techniques is CityObserver, which uses crowdsourcing tools to gather data

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from citizens for urbanization campaigns [6].

In order to decrease the number of accidents and increase road safety, we propose a new crowdsourcing system to collect and disseminate information on road safety.

In this paper we present the following sections, we present related work as well as a comparative study in sectionII. Then, we present our R-Secure system in SectionIII. We discuss possible improvements for our system in Section VI. Finally we conclude this paper and present our research perspectives in SectionV.

II. Related Work

R-Secure is a new system based on two web and mobile crowdsourcing platforms to improve the quality of life of citizens in smart cities and increase road safety and decrease the number of accidents. This type of platform is growing rapidly to facilitate the collection and sharing of information among citizens and speed up the process of solving problems.

Different crowdsourcing applications have been offered, including uSafe [7], a mobile platform that enables users to express their individual perceptions of safety in urban environment. Users can report information about their towns with this participative application, such as a violent crime or a dark alley. After the aggregation of these data, city planners and other users can obtain summary maps. Administrators can modify and enhance their urban plans by include lighting, for instance, based on the data gathered from citizens. Additionally, the application offers protection for residents' privacy.

We also mention Crowdsafe [19] is a crowdsourcing system that allows users to report and locate criminal incidents in real time, then the system uses the gathered data to rank roads according to their length and security.

Another application called S-Road Assist based on smartphone sensors has been developed for tracking driver behavior [8].

Or the RoadCop system that allows road users to report traffic violations with video evidence after which the data collected will be processed by road safety experts from official authorities [9].

We also bring up CrowdOut [10], a mobile crowdsourcing service that identifies traffic infractions and other events in a city that are related to traffic. This program intends to improve the quality of life for citizens living in their city by warning users of harmful places and enabling administrators to change signage or certain risky roadways.

Additionally, there is the mobile crowdsourcing application CommuniSense [11]. The application's two main features are data collection and data visualization for Nairobi's road conditions. The Android platform was used to create this application. The application uses the Android platform, which enables the collection of a variety of meaningful data, including multimedia (pictures), location (GPS), and other sensors. And utilize Twitter hashtags as a method to engage the public in presenting these poor road conditions to their attention.

Users can express their subjective perception using UrbainEmotions [12], a system that takes context into account (traffic, hospital, tourism...). This system's goal is to create an emotional database that will help with innovative planning and urban planning.

Another system [13] that detects potholes by a crowdsourcing application and image processing algorithms enables citizens to publish problems in the form of images and to express their opinions. These information's are processed by official authorities to enhance the road infrastructure and notify citizens by a vulnerability map.

There is also the mobile platform Transafe [14], which detect and analyzes public evaluation of safety to provide collective intelligence in the city of Melbourne, Australia, so these views may represent insecurity factors for visitors and inhabitants of the city.

Another example is an application [15] that enables drivers to indicate speed bumps on a map plan and to share them with other user. it can also detect poor road conditions with an application based on smartphone sensors (GPS and accelerometer) [16].

R-Safety a mobile crowdsourcing platform that allows to gather data through citizens concerning road safety in Tunisia [20].

The mentioned approach enables citizens to report traffic infractions in real time ([9], [10], [15]), or to give their subjective evaluations ([7], [14]), or to assess the road infrastructure ([11], [16]). However,these approaches are unable to evaluate all the risks that can have an impact on the road safety index.

In addition, the R-Safety mobile platform [20] only considers citizens' perceptions, but the R-Secure system combines data from citizens with data from road safety experts to build a more reliable and complementary database in order to increase the accuracy of the analysis and to help the NORS to take the best possible solutions to the road safety problems in Tunisia.

On the one hand, our system offers citizens the possibility to evaluate road components and express their subjective and objective perceptions through our mobile platform. On the other hand, we offer a web platform that enables experts to report road risks. The information collected through our two platforms will enrich the database of the national observatory of road safety for decision support.

III. Proposed System

Nowadays, smartphones and mobile applications facilitate our daily life. On the one hand, citizens use mobile applications and web services for most of their daily tasks: managing emails, managing their bank accounts, wind and shopping online and also for communication with their friends via instant messaging applications.

A report published by Digitale Tunisia shows that the use of internet and smartphone by citizens has increased considerably from year to year [17]. On the other hand crowdsourcing is a technique of data collection by citizens via mobile and web applications to improve road safety [18].

For these reasons we propose a system based on two crowdsourcing platforms called Road Secure or R-Secure to improve road safety in Tunisia. We offer a mobile crowdsourcing

platform that allows citizens to inform administrators about road violations or consult the vulnerability map of the city to know the risk points. We also offer a web/mobile platform that allows road safety experts to report risks on the city map. Our crowdsourcing platforms give citizens and experts the possibility to share road problems in order to inform citizens about risk points and make the city more and more intelligent.

A. System demonstration

To make cities more and more smart and to facilitate life of citizens and accelerate the collection of information concerning road safety we propose a new crowdsourcing system. Our system contains two crowdsourcing platforms: mobile and web.

On the one hand, the mobile crowdsourcing platform offers a a low financial cost that exploits mobile technology and allows citizens to send in complaints about traffic violations and indicate their subjective perceptions.

On the other hand, the web crowdsourcing platform facilitates the sharing of road risk data between different users to reduce the risk of accidents.

The contributions of this system are:

- to gather information on traffic flow in order to prioritize road traffic work by the governorate and to identify the first areas to support and monitor their road circulation.
- Increase the ability to collect credible data to evaluate the performance of various traffic stakeholders at the national or regional level.
- Include the citizens' sense of safety index and the experts' risk points in the periodic evaluations and analyses published by the NORS .
- To increase the ability to analyze road safety problems in greater depth at various levels...

B. System overview

R-Secure is based on our crowdsourcing platforms that have as objective the reporting of problems related to road safety. Our system collects data through two types of users; users who do not have expertise and others who have expertise and specific objectives.

In our approach we propose two platforms. The first one is a mobile platform for citizens and the second one is a web platform for road safety experts.

On the one hand, our mobile crowdsourcing platform was created using the Android operating system. This service provides a low financial cost solution that makes use of digital applications. Users can gather detailed information using our mobile platform, including GPS position and photos.

Our mobile application has two features; the first one enables users to report traffic infractions that have been committed. These information will be kept in a database and then examined by the NORS. The second feature enables users to access a map of the city and look up hazards reported by other users and road safety experts.

On the other hand, we propose a web platform that offers the possibility to several road safety experts to actively participate in the dissemination of information about road hazards.

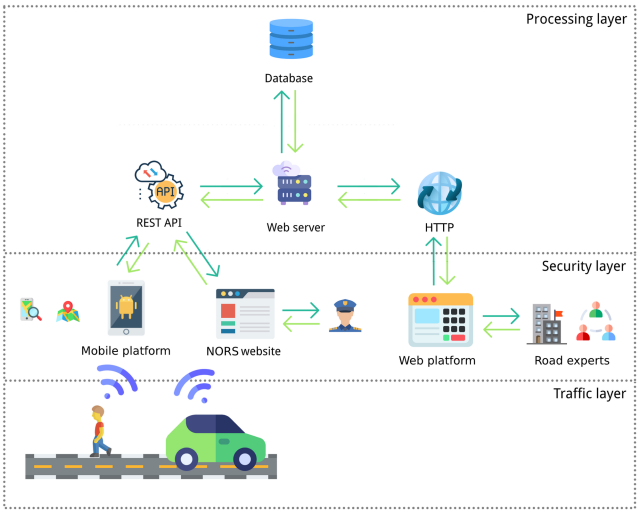

Fig. 2. R-secure architecture

The system architecture of R-secure, shown in Figure 5, is described in this section. R-secure is divided into three essential parts.

The traffic conditions layer: this layer is responsible for collecting data about road risks and violations through our mobile and web crowdsourcing platforms. Pedestrians and drivers can assess the road space and inform about violations of traffic rules. As well as road experts can report on risk points.

The security layer: This layer includes information gathered from citizens through our crowdsourcing service, which was created on the Android platform, as well as the NORS accident database. This layer also includes information from experts that was gathered via our online crowdsourcing tool. The information concerning traffic offenses, accidents, and risky areas is all contained in the safety layer.

The Data processing layer: This layer is in charge of aggregating and fusing and using the information that the lower layers have offered. In order to be able to locate unsafe zones on a map, R-Secure categorizes the levels of insecurity and traffic conditions on each road.

Figure 2 illustrates how our platforms are linked to a web server, which handles user and road expert authentication, reports receipt, and communication management. A MySQL database will house all data sent by users and experts. Only NORS administrators will have access to the data gathered in order to ensure the privacy of our mobile platform users. The NORS database will now include this information.

Our system offers users three different functionalities: they can either report a hazard using pictograms and other information, check the map, or get in touch with the NORS, civil protection, or national guard. We use a development API for Google Map to display the pictograms on the city map.

C. System functioning

In this section, we present the functionality of our two mobile and web crowdsourcing platforms.

1) Web crowdsourcing platform: In order to enrich the knowledge and improve the result of data analysis of the NORS we propose a new web crowdsourcing platform intended for members of the forum of regional road safety councils and road safety associations. This platform allows users to report risk points in order to inform citizens and help NORS in decision making.

TABLE I
ROAD RISKS

Permeating risks	Periodic risks	Casual risks
Schools near a national or regional road, establishments frequented by senior citizens, black points, risk of falling rocks. , forests with large wild animals (wild boars).	Pavement damage related to floods, sandstorms, snow , red light failure.	Race on a road (2 wheels or on foot) , festival or fair, road works, high frequency of slow vehicles during agricultural seasons, weekly souks.

The table I represents the types of risks that can be reclaimed by the road safety experts, the risks are classified in three main types which are the following:

- The permanent risks: they are durable and constant risks such as schools near a national or regional road
- Periodic risks: these are temporary risks such as road damage due to flooding.
- The casual risks: these are risks related to events such as festivals, road races, etc.

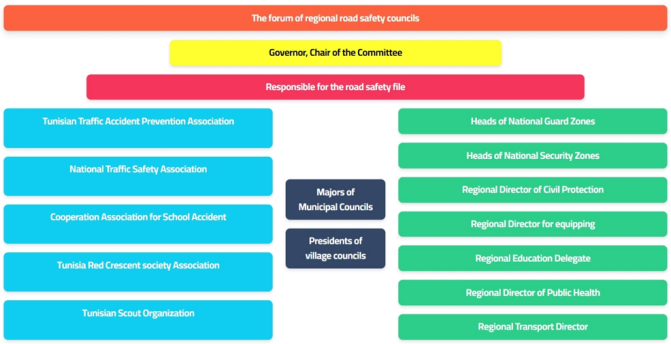

Fig. 3. the members of the forum of regional road safety councils

Figure 3 shows the members of the forum of regional road safety councils. The members of the forum are experts who are part of several official authorities such as the national grade, the national police, associations, etc. The objective of the forum is to propose recommendations and apply them to improve road safety.

Figure 4 shows the interface that allows experts to report a risk point. This interface contains the necessary information to describe a road hazard such as the type of hazard, the degree of hazard, the GPS location, and a picture of the hazard etc.

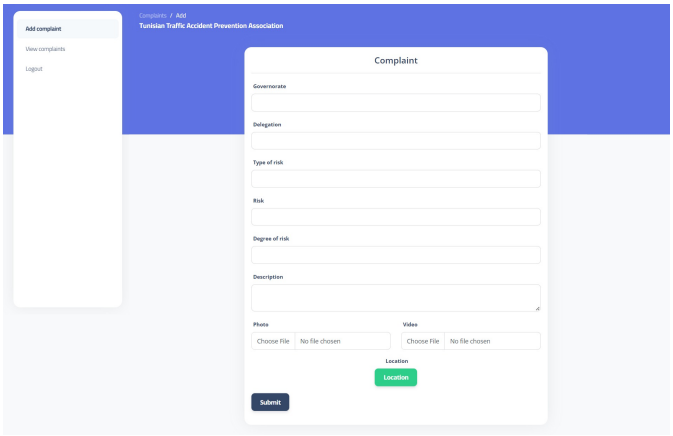

Fig. 4. Interfaces of submitting reports

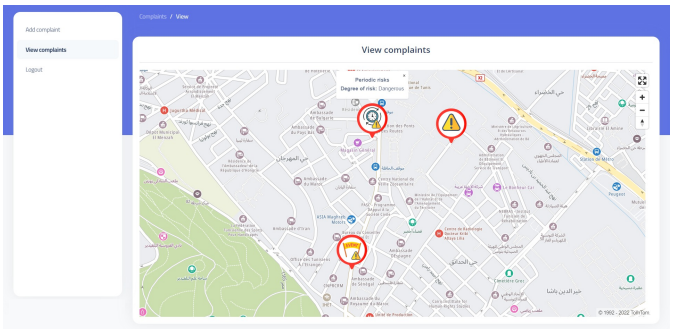

Fig. 5. Identification of risks on the city map

As shown in figure 5, there are several types of pictograms that are used to localize the risks on the city map. For example the pictogram event shows that there is an event and the other pictogram shows that there is a periodic risk and the degree of risk is dangerous.

2) Mobile crowdsourcing platform: R-Safety platform is a part of our system that serves to collect a large amount of data from residents about roughly three key factors that have a significant impact on road safety. Our mobile crowdsourcing platform can be found on google play store [21]. These three components are:

- **The human components** : concerns behavioral evaluation of public or private transport drivers and behavioral evaluation of pedestrians.
- **The road services** : include the evaluation of civil protection services, the evaluation of road police services, etc.
- **The road components** : cover the evaluation of the road infrastructure, the evaluation of the safety of public transport means.

To explain the functioning of our platforms we consider the following scenarios, When the user notices a danger or a traffic violation, using his smartphone connected to the internet the user can indicate this danger. And the road safety experts should point out the risk points on the city map.

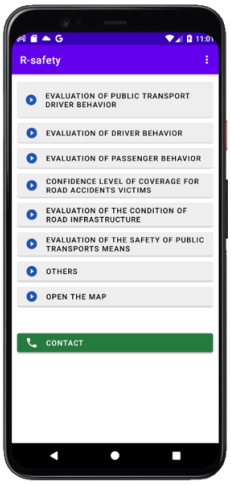

Fig. 6. Interfaces of submitting reports

The first interface of our mobile platform after the successful authentication process allows users to choose the road indicator they want to evaluate and also allows to see the map of the city and see the traffic violations committed by citizens and the risk points.

As shown in figure 6, the user has the possibility to evaluate a set of road safety indicators, to see the vulnerability map of the city or to contact the NORS, the civil protection, etc.

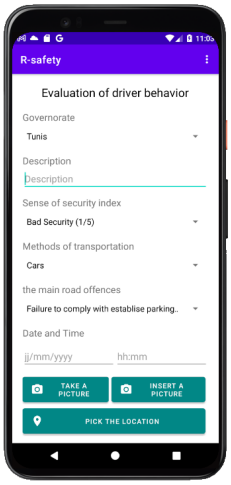

Fig. 7. Evaluation of driver behavior

As shown in figure 7 the user can send a set of information about the observed hazard concerning the driver's behaviors such as a picture about this hazard, GPS location, date, time, governorate, their feeling index, etc.

As shown in Figure 8, the city map contains a set of pictograms, each of which represents a hazard, for example the bus pictogram indicates that a traffic violation has been committed by a bus driver.Our goal is to provide users a greater understanding of the current traffic safety situation in the city.

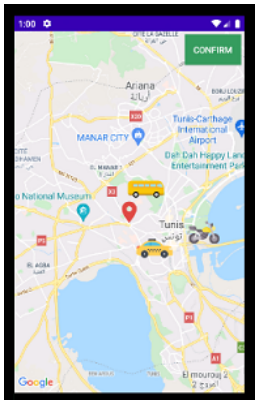

Fig. 8. Geographical location of hazards

D. Classification of regions

To provide to the user and to the national observatory of the road safety in Tunisia a good geographical representation of the reality of the road safety we classify the zones according to their degree of safety.

To determine the high-risk governorate we created a Python algorithm to classify the regions based on the complaints sent by the citizens and the road safety experts. On the one hand, in order to evaluate a danger the citizens have to indicate their safety feeling index which is a number between 1 and 5.

On the other hand, the road safety experts have to indicate the degree of risk of each risk point, which is a number between 1 and 5. These information will be saved in a server and then the data will be analyzed for deduce the safety index of each governorate.

TABLE II
CLASSIFICATION OF SECURITY LEVELS

Safety index	***Security Levels***
1	Very dangerous
2	Dangerous
3	Not secured
4	Medium
5	Secure

As shown in Table II, each index has a specific security rate, as the security index decreases the risk increases and vice versa. A Python script creates the mapping that displays each governorate's security index by the corresponding color based on the security index of each governorate.

The vulnerability map serves to identify dangerous regions, on the one hand this map will be published on the NORS' official pages to inform the residents or through notifications through our mobile platform, on the other hand the map helps the NORS to increase the capacity to analyze more in detail the traffic problems at various levels.

IV. Discussion

We discuss the advantages of our crowdsourcing system in this section. Our system offers new services and features to

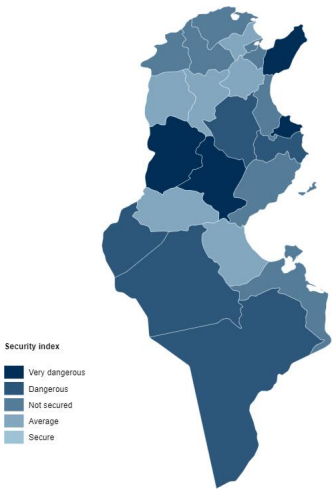

Fig. 9. Identification of risk areas

citizens and road experts to increase road safety in Tunisia while also supplying the national observatory of road safety with new incoming data to enriching their databases.

In order to identify risk zones and alert people to risky regions, R-Secure integrates the assessments of citizens and road safety specialists. Our crowdsourcing platforms provide new input data and involve users in the decision-support process of the NORS. On the other side, R-Secure reacts to actual research addressed with NORS members to enhance planning policies for urban, social, and economic development as well as road safety.

Our system's architecture is built on the client/server model. Our R-Secure system's goal is to gather a lot more data and make it instantly accessible to a wide range of users in order to lower the frequency of accidents.

Our system is being tested in the city of Tunis, Tunisia in order to test the reliability and usability of our Framework with real data brought by several components.

V. Conclusion

In order to improve the decision support process of the national observatory of road safety through the increase of data reliability, we propose a new system of data collection and exploitation from different sources based on two crowdsourcing platforms. The latter allows citizens and safety experts to actively participate in the collection of data through the assessment and mapping of road risks. The collected data will be disseminated among users in order to increase road safety.

In addition, the data collected will improve the analysis of accidents, which is recommended by national best practices and consequently the reduction of accidents.

In our future work we will implement a credibility management system for the users of our mobile platform for increase the credibility of the collected data. Additionally, we will create algorithms to analyze the gathered data in more detail and map dangerous roads.

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