Towards Improving Safety in Urban Mobility Using Crowdsourcing Incident Data Collection

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***Abstract*— This paper describes the Safe Commuting System (SCS) which aims to improve the safety of commuters in urban areas using both historical and real-time crowdsourced data (through mobile devices) about safety incidents. The SCS informs commuters about at-risk areas and will provide alternative commuting routes. The current SCS implementation includes a mobile device application that enables the collection of crowdsourced data and user notifications about safety incidents in the proximity. The crowdsourced information serves two main functions: alerting users about safety incidents and assisting residents in decision-making about safe mobility. The current SCS prototype enables the collection of data including emergency alerts through a panic button and safety incidents through user reports. User reports are organized into three different categories: (1) criminal activity, (2) perceived danger, and (3) suspicious activities. Future work includes the generation of safe routes for commuters. The SCS system can be considered a Smart Cities solution in the Smart Mobility area, given that the proposed use of technology and data fosters the safety of commuters, and thus contributes to an improved quality of life. Efforts towards informing and collecting relevant information for mobility are important to address the demands of urban areas and convert them into Smart Cities.**

Keywords—safety, mobility, routing, crowdsourcing, Smart Cities

I. Introduction

Research and application in routing and mobility traditionally consider factors representative of the transportation domain such as travel time, traffic volume, speed, and/or delay. However, in places with increased danger, safety and security concerns must also be taken into consideration [1]. This research team analyzed safety data of the Guadalajara Metropolitan Area (GMA). During the urbanization period of the GMA in the Mexican state of Jalisco, the composition of the municipalities of Guadalajara, Tonala, San Pedro Tlaquepaque, El Salto, Tlajomulco de Zuniga, and Zapopan has resulted in a population close to 4.4 million. This rapid settlement, in addition to the unique location and socioeconomic context, has contributed to the overcrowding of the urban area. Along with this population growth security concerns raised, for which government agencies are finding difficult to address with comprehensive solutions. The National Survey on Victimization and Perception of Public Security (ENVIPE) conducted by the Institute of National Statistics and Geography (INEGI) [2], found that in the State of Jalisco, as much as 75.9% of the adults felt unsafe (See Fig. 1). Moreover, the percentage of adults who felt unsafe has an increasing trend from 2017 to 2018.

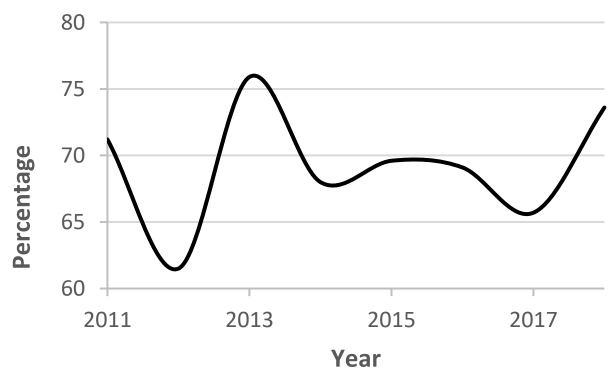

Fig. 1. Yearly percentage of adults feeling unsafe provided by Jalisco ENVIPE in the last eight years.

As of September 2013, INEGI conducted the National Survey of Urban Public Security (ENSU). The objective of this survey was to capture the public perception of insecurity in urban areas and support policymaking. Additionally, ENSU is

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responsible for identifying public spaces with higher perceptions of insecurity, quantifying the most common experienced/witnessed criminal occurrences, determining the level of performance of public authorities addressing insecurity, and estimating changes in residents' behavior due to fear of crime victimization. Authorized by the State of Jalisco, the Institute of Statistical and Geographical Information (IIEG) has analyzed the 2018 data provided by ENSU and has summarized the findings for the GMA, as listed below [3].

- 77.1% of the adult population felt unsafe, representing 3.5% above the State of Jalisco's average.
- 55.3% of the population found themselves obligated to stop carrying valuable items.
- 50.0% of the parents prevented minors from leaving their residences.
- 47.3% avoided walking in public places at night.
- 29.6% stopped visiting friends or relatives outside their familiar zones.
- 71.9% considered the government inefficient in meeting the challenges affecting the GMA.
- 82.9% of women perceived the GMA as insecure, while 70.1% of men had the same sentiment.
- 53.4% of the population 18 years of age and older experienced at least one altercation.

These statistics demonstrate that there is a gap between the existing services provided to ensure safety and the perception of safety by residents. To bridge this gap, the government of the State of Jalisco initiated a program focusing on the student population, as a result of the increasing crime in the vicinity of educational institutions.

The plan presented under the solicitation of the Federation of University Students from the University of Guadalajara proposes the incorporation of "Senderos Seguros" (safe corridors) in the GMA. A safe corridor may be defined as a corridor that is protected and guarded by the community through an established synergy composed by neighbors, merchants, parents, faculty, and authorities, in order for students to attend and return from their institutions without becoming victims of violence and delinquency during their mobility. This initiative was deemed necessary given that students are a vulnerable population to delinquent events including assault, sexual harassment, homicide, rape, kidnapping, physical aggravation, femicide, and sale and abuse of substances [4].

The SCS system contributes to the Senderos Seguros initiative. The research team visited a community called "Unidad Modelo" to gain social context and understand the residents' needs. "Unidad Modelo" is located at the municipality of Guadalajara. During the visit, the research team elicited needs and understood the problems from different stakeholders including high school and university students, government institutions, neighborhood representatives, and school and police officials. The results of these informal conversations indicated that although a sense of community has been established through programs designed to instill trust in these government initiatives, significant progress has to be made to safeguard the security within the municipality. The combination of insufficient security personnel, low-income households, inadequate street and pedestrian infrastructure, limited transportation options and inadequate alarm systems represents only a few of the factors that influence the persistence of delinquency events in "Unidad Modelo".

The "Unidad Modelo" corridor was selected as part of the Living Lab testbed for the SCS system to facilitate the collection and sharing of data among stakeholders to foster safety in the corridor. The SCS design and implementation is highly informed by stakeholders. In this research, Smart Cities is defined as the integration of technology and humans to enhance the productivity, sustainability, and efficiency of services and resources for the improvement of quality of life of residents [5]. The SCS project aims to answer the following research questions:

1. *How can mobile devices contribute to personal mobility safety?*
2. *How can mobility safety risks be addressed with crowdsourced data?*
3. *How do personal mobility information of crowdsourced and public agency data, contribute to mobility safety metrics?*

The remainder of the article is separated into the following sections: literature review, methodology, discussions, future work, and conclusions.

II. Literature Review

Smart Mobility is an important area of Smart Cities. The SCS system contributes to the safety perspective of Smart Mobility. Safety has yet to be well-integrated into current Smart Cities solutions. Currently, there are numerous systems and mobile applications for the generation of safe routes and the provision of safety tips or criminal incident reports. Table 1 shows that the maximum services provided by relevant current tools provide only up to two services offered by the SCS system. The asterisk (*) represents a feature to be introduced in the next SCS system release. A distinguishing feature of SCS compared to the current systems listed in Table 1, is the data collection strategies and the purpose of collecting such data.

For example, in the United States, the open government and data initiative articulated under President Barack Obama's administration provided public access to datasets for the contribution of innovative solutions. Such is the case of a case study using crime datasets from Chicago, Illinois and Philadelphia, Pennsylvania for the generation of safe, urban navigation. Safe Paths (SP), the developed system, through a risk analysis model, calculates the probability that a crime will occur again. An algorithm then generates a route based on the calculated risk [6]. In Mexico, a similar study by researchers at the National Polytechnic Institute (IPN) predicts the safety of routes by integrating both historical data and crowdsourcing information, and semantically classifying them utilizing Bayes Algorithm [7]. Although both of these systems generate safe routes, only IPN researcher's work incorporates crowdsourced information. One problem associated with crowdsourcing is the validation of the information compiled from social media because there is no way to verify the veracity of the reports. In addition, the government is unable to provide real-time data. The above shortcomings affect the perception of safety within the route. Avisora (available at http://landing.avisora.mx/) and Waze (available at https://www.waze.com/) represent two crowdsourcing mobile applications which have already been implemented in large scales and are currently publicly available in multiple operating systems. Avisora is a tool for users to report a variety of incidents. Its users mostly report infrastructure necessities such as public lighting, potholes, and obstruction of the public right of way. Waze uses traffic events reported by users for the generation of faster rather than the safest routes. While both applications make use of user-reported information, this information serves a different purpose – provide fast routes.

TABLE 1. COMPARISON OF SAFETY APPLICATION SERVICES

Service	System				
	SCS	*SP*	*Avisora*	*Waze*	*IPN*
Panic Alert	X				
Event Report	X		X	X	
Route Generation	*	X		X	X

III. The SCS Design and Implementation

This section provides details on the progress towards the development of the SCS system as well as anticipated features.

A. The SCS Design

The SCS system design follows a hierarchical *Layered Style* architecture (see Fig. 2) where each layer provides a set of services to the layer above and relies on services of the layer below. Layers may contain modules that perform similar set of services. The relation among layers represents the *allowed-to-use* function.

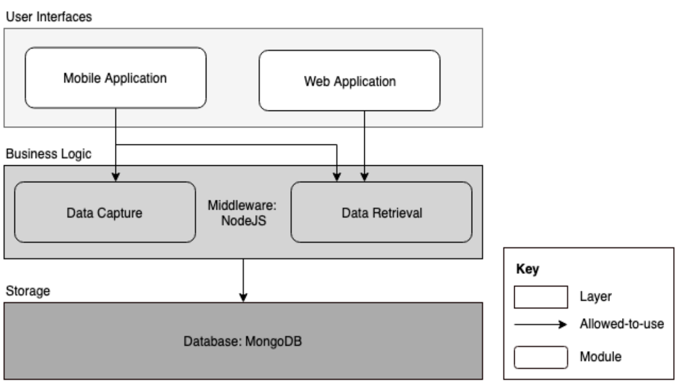

Fig. 2. SCS system architecture - layer view.

The *User interfaces* layer consists of two modules: Mobile Application and Web Application. The first module enables the input of emergency alerts and safety incidents through the SCS mobile or web application. For emergency alerts, the system automatically includes the location and timestamp of the event. For incident reports, users can provide more detailed information including the type of safety incident and a short description. The SCS system relies on the collection of data by users acting as sensors. The SCS prototype front-end was developed for Android operating systems in Android Studio using the Java language. Based on user preferences, SCS design supports the portability of the solution by supporting two languages: English and Spanish. The Web Application module enables the display of safety incidents data in a map and the generation of a list of safety incidents reports. The visualization component requests geocoded data about safety reports in a specific area using Python. A JavaScript library called *Leaflet* is used to display the safety reports as markers in a web map.

The *Business Logic* layer consists of two modules that provide the main services of the SCS prototype. Data collected from the Mobile Application module goes through the Data Capture module into the database where it gets stored. The Web Application module is allowed-to-use the Data Retrieval module to be able to retrieve and display reports stored in the database. To accomplish this, *NodeJS* is used as the middleware between the front and back-end. NodeJS is an open source server environment that can run on various platforms like Windows, Linux, and Mac.

The *Storage* layer uses *MongoDB,* a NoSQL cross-platform, document-oriented database program. The safety incidents data is stored using JSON documents, see Fig. 7.

B. SCS Use Case Diagram

A Use Case diagram provides a graphical representation to define the scope of a system. A Use Case diagram illustrates the main functions (services) provided by the system, represented by ovals, and external entities called actors, represented by human's icons. A use case represents a service provided by the system and one or more actors may interact with the system. By incorporating a representation of actors and services, the diagram provides guidance during and after the design process to demonstrate the interactions that exist between the different actors and services that interact with the functionality of the prototype.

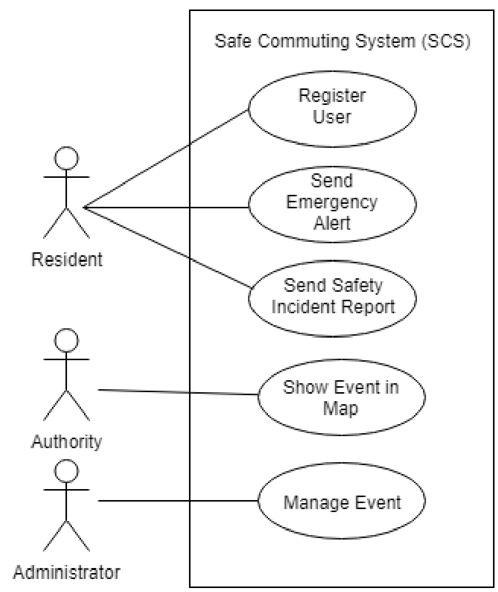

Fig. 3. SCS system use case diagram.

As seen in Fig. 3, the SCS Use Case diagram has three actors and five use cases (system's services). In the current and functional SCS prototype, the actors involved are *resident*, *authority*, and *administrator*. In the context of the "Unidad Modelo" testbed, the resident actor includes students, inhabitants, or merchants within the safe path established in the community; the authority actor includes the security personnel of the safe path (school personnel), police, and neighborhood representatives; and the administrator actor includes security personnel of the safe path. The services allocated to these actors include user registration, send an alert, send report, show event in the map, and manage the event.

The SCS *user registration service* provides the advantage of registering residents of the community, allowing the SCS to validate accounts and obtain only factual alerts and reports. This SCS user registration service allows for the termination of accounts in the event the reported incidents are deemed false or misleading by the administrator. Additionally, the resident has the option to report an incident based on two different circumstances: (1) in the event of an emergency, and (2) in the instance in which the actor's integrity is not compromised. In the first event, residents have the advantage of sending a geocoded and time-stamped emergency alert via a panic button incorporated within the application. In the second scenario, residents provide a detailed description of the event either witnessed or experienced in order to provide other users with information to make them aware of the occurrences happening within their community and their mobility route. These scenarios, combined with the third service provided by SCS to residents, allows these actors to avoid possible altercations posing a threat to their personal wellbeing by a direct visualization of the crowdsourced-obtained emergency alerts and incident reports in a map. This visualization is represented in the diagram as *Show event in the map*, and both the resident and authority have access within their personal mobile devices.

The last service contributing to the SCS functionality involves the administration of events. This service managed directly by the administrator, allows for an emergency alert to obtain immediate assistance and follow-up procedures. Intended as an internal security system for the University of Guadalajara security personnel, this feature provides information for the dispatch of personnel to investigate the emergency while providing an alert status.

C. SCS Mobile Application

The two types of events described in *Subsection B* are illustrated in Fig. 4. An emergency alert is illustrated by a *red* icon, while a *blue* icon illustrates that a report has been submitted. As seen in Fig. 4, latitude and longitude coordinates are displayed to show the exact location where the events occur. By clicking the report icon, further information about the safety incident is shown. This information may contain not only the type of incident but also a picture or video to better articulate the context of the event submitted.

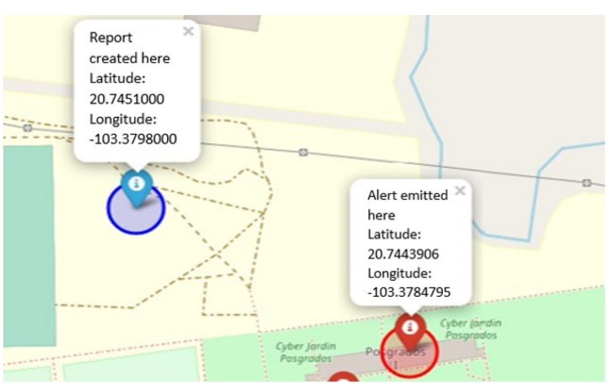

Fig. 4. Visualization of safety incident reports and emergency alerts in a map.

We believe that the use of visual artifacts will foster a better understanding of the current safety situation by the user.

The Home Screen menu of the SCS mobile application provides direct links to all available functions. A red square enables the input of an emergency alert, this icon is strategically placed for users to press and send an instant geocoded message in a case of an emergency situation.

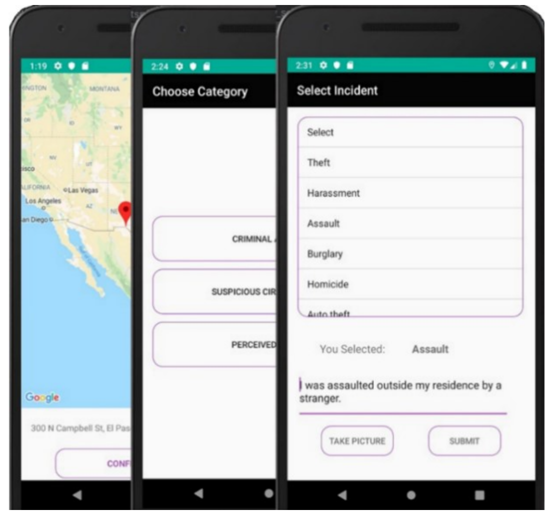

Fig. 5. SCS UI elements for the generation of safety incident reports.

For the second type of event – safety incident, the SCS User Interface (UI) provides the user with the capability to send a report within three different categories: criminal activity, perceived danger, and suspicious activities. An additional option includes selecting "other" to enable the user to report an incident that is not classified in any of the predefined categories. The initial categories of the SCS mobile application were created based on the historical data about safety incidents that affected university students. The SCS UI aims to provide easy-to-use menus and to submit a report (See Fig. 5).

Fig. 6. SCS emergency alert interface for event status management.

Depending on the category of the report, additional information may be required. For example, if the criminal activity category is selected by a user, some of the events listed include theft, assault, and burglary. Taking and attaching a picture to the report is optional for those users that would like to include a visual of the event being reported.

The SCS system also provides information to law-enforcement personnel to support the management of the safety incident reports and emergency alerts. Through a password-protected and secure website, law-enforcement personnel such as the university police can visualize the events being reported and update the status of the event based on progress reported by other communication channels. This feature was requested by university police members of the Sendero Seguro initiative in Guadalajara, Mexico. SCS will include a Secure Sockets Layer (SSL) protocol to encrypt the mobile application data before it is sent to the database. Fig. 6 illustrates the possible different status of the reports using different colors in the map. *Red* represents the report has been received, *yellow* the assignation of resources, and *green* the closing of the emergency alert.

D. Data Model

The SCS mobile application requires a user to register by creating a username and password. This functionality provides secure access to the system as well as the ability to access the system from multiple devices. Additionally, users may provide personal information such as first name, last name, age range, and gender. Information will be transferred to the SCS server, sensitive information such as password is encrypted using SSL.


```
_id: ObjectId("5d545c281c9d440000a82643")
firstName: "John"
lastName: "Doe"
ageRange: "25-29"
gender: "male"
password: "27721e914d139h407a444afcbE2b4b39ac3e50c120252050ac439f
salt: "00bc9ac44b4fcb4"
username: "jdoe2"

_id: ObjectId("5d545de91c9d440000a82644")
latitude: "20.74406178"
longitude: "-103.37890547"
timestamp: "1550199954095"
```


Fig. 7. An excerpt of a file stored on the SCS backend.

When reporting an incident, the SCS App will provide the location for the device for the user to confirm (in terms of address) and will send the specific coordinates to the server. The event will be identified with a unique, autogenerated number. Fig. 7 shows a sample of the information collected and stored by the SCS application in JSON format.

IV. Discussion

The SCS system is evaluated as a Smart Cities solution and it must meet the following core principles: *resiliency*, *security*, *scalability*, *interoperability*, and *modularity*.

Resiliency: This refers to the ability of any system to recover within a reasonable amount of time after a failure. In a city, critical infrastructure requires highly resilient architectures such as traffic systems, security systems, healthcare services, among others, with components ranging from sensors/actuators, telecommunications, and software hosted in a dedicated server. The SCS system is designed in such a way that in the event that the resident does not have an active service connection with the server, the user can still create a report specifying the details where the incident occurs and the report will be sent once connection is restored. The SCS research team is exploring the use of wearable devices like a bracelet, necklace and other items that may be unnoticed. A wearable device can be connected to the phone via Bluetooth or directly to the internet via Wi-Fi or a data plan to facilitate the process of sending the alert in case of panic. The alert will specify the location and information about the user. This can be a better option for residents that need an easy-to-use device. Another option being explored is the use of test messaging SMS for sending reports that rely on a different network, with the disadvantage that will limit the ability to send images.

Security: This refers to the measure of the system to prevent unauthorized access. This also includes preventing any attempt to access data, modify data, and deny services to legitimate users [8]. Components of mobile application solution must be compliant with appropriate security protocols and mechanisms. In the SCS, passwords are encrypted when stored in the database. This is done through the module *Crypto* located in NodeJS that deals with encryption and decryption of an algorithm, in our case the password of the user. To ensure even more security, a Salt Hash technique was also utilized to prevent attacks. The Salt Hash technique takes the password and a random string, and it combines them through an algorithm. Several mobile applications such as WeHelp!, Uber and Lyft require users to provide their telephone number in order to verify the account and prevent unauthorized access to the account. The research team is exploring an additional level of security based on the verification of the identity of the user with an authentication process during registration. In our testbed, users must prove that they live in the neighborhood or commute in the neighborhood as students to be able to send reports.

Scalability: This concept addresses the system's architecture and the infrastructure that supports the increase of user demand for system services. For example, back-end services, cloud technologies, and support for concurrency. The team addressed the scalability of the database and the visualization of the data. As a result, SCS makes use of open street map tool, which is an open-source solution to display maps. This design decision avoids paying fees to other companies that charge applications for the use of maps. In addition, SCS uses a robust and distributed database called MongoDB, which can grow in different servers.

Interoperability: This refers to the ability of different systems to exchange data between each other, in an effective and secure way. SCS compiles with the principle of interoperability because the system requires to share data between three components. It is composed of an Android mobile application and an interface that displays a map with markers, both to retrieve and visualize data. However, to be able to exchange the data from one to another they need to be connected to a database like MongoDB where all the information is stored. Once connected to MongoDB the system can post and retrieve data between both interfaces.

Modularity: This refers to the decoupling of a program into independent, interchangeable modules, such that one does not depend on the other. SCS complies with this principle since its front-end services developed for the Android operating system is completely separated from the platforms used for our backend services such as NodeJS and MongoDB. Modularity feature builds on scalable and interoperable architectures. SCS follows a layer-based architecture, meaning that the system has three layers: user interface, business layer, and data storage.

This facilitates reusing layers with minimal changes to the code when migrating the system to other development platforms such as Flutter. Although the Android platform ties the UI with the control of the application, the model classes do not.

V. Future Work

Refinement of the SCS system will incorporate a composite safety index and use it to generate safe routes. Having the functional service running in Unidad Modelo, valuable data entries are expected to be stored in the database. This will provide the opportunity of implementing in our system the ability to generate different routes by taking into consideration the different safety factors. The new version of the SCS system will show to the users the different options that they can select in addition to suggesting the best option.

After the historical occurrences obtained from multiple events are integrated into a composite mobility index, the combination of the Dijkstra Algorithm and the Critical Path Algorithm may be applied to obtain the safest alternative routes. While Dijkstra is an algorithm for finding the shortest path between an origin and destination (nodes) distribution, Critical Path is an algorithm that through the summation of sequences, or events, generates a route. After assigning statistical weights based on the event's likelihood to influence commuting decisions, the combination of both algorithms is expected to provide routing options to SCS users.

The research team will explore the use of mobile devices hardware to facilitate the prompt submission of emergency alerts, such as the combination of buttons. An evaluation using a survey instrument will be conducted. The survey will evaluate SCS usability following the guidelines provided by the U.S. Department of Health & Human Services (available at https://usability.gov). The survey questions will also include questions about the perception of users on their safety when using SCS during their commute. The survey will be distributed to all the stakeholders after proper Institutional Review Board (IRB) approval is obtained. The usefulness of the system will also be evaluated through the number of users of the SCS mobile application after its release. Finally, the research team intends to migrate the SCS application to support both the Android and iOS platforms to make it accessible to the majority of users.

VI. Conclusion

Safe Commuting System (SCS) is a mobile application developed to foster the safety of commuters in urban areas. The SCS initial testbed includes the "Unidad Modelo" community. SCS enables users to report emergency alerts through a panic button and provides a crowdsourcing functionality to document safety incident for criminal activity, perceived danger, and suspicious activities. The SCS system provides a feature to display the safety incident reports and to assist residents in decision-making when commuting on at-risk areas. These features of the SCS system address research question number one. SCS addresses safety risks with respect to mobility by gathering appropriate data using crowdsourcing, which align with research question number two. The work is expected to continue with the integration of historical occurrences to generate a composite mobility index to assist in the generation of safe routes. This work in progress is an effort towards research question three. SCS is a novel application that incorporates the services mentioned above as a Smart City application to improve the safe mobility that leads to a better quality of life of residents.

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