

International Case Studies of Smart Cities

Medellin, Colombia

Darío Amar Flórez

Institutions for
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Contact: Mauricio Bouskela, mbouskela@iadb.org.



International Case Studies of Smart Cities

MEDELLIN COLOMBIA

IDB – KRIHS Joint Research



Abstract

This case study is one of ten international case studies developed by the Inter-American Development Bank (IDB), in association with the Korean Research Institute for Human Settlements (KRIHS), for the cities of Anyang, Medellin, Namyangju, Orlando, Pangyo, Rio de Janeiro, Santander, Singapore, Songdo, and Tel Aviv. At the IDB, the Competitiveness and Innovation Division (CTI), the Fiscal and Municipal Management Division (FMM), and the Emerging and Sustainable Cities Initiative (ESCI) coordinated the study. This project was part of technical cooperation ME-T1254, financed by the Knowledge Partnership Korean Fund for Technology and Innovation of the Republic of Korea. At KRIHS, the National Infrastructure Research Division coordinated the project and the Global Development Partnership Center (GDPC) provided the funding.

Medellin launched a series of strategies to become smart city. They are oriented to the citizen, through a series of services that improve their quality of life as they develop capacity and organizational structure in the entities that control mobility, the environment, and safety. In addition, these initiatives have created mechanisms to communicate and interact with citizens in order to promote continuous improvement of smart services.

JEL Codes: L32, L86, L96, O21

Keywords: Smart cities, technology innovation, information and communication technologies, mobility, transportation, transit, citizen security, video surveillance, integrated emergency system, environment, early warning systems, citizen attention systems, social networks, lessons learned, Medellin, Latin America and the Caribbean, integrated operating control centers.

Author: Darío Amar Flórez

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Executive Summary

Medellin is a city that went from being known for its security problems to being an international referent of technological and social innovation, urban transformation, equity, and citizen participation.

This report shows how Medellin has implemented a series of strategies that have made it a smart city that is developing capacity and organic structure in the entities that control mobility, the environment, and security. In subsequent phases, Medellin expects to integrate services under a single control center, which will enable it to centralize monitoring of city operations.

Although there is no single methodological framework for implementation, all of the initiatives share one characteristic: they are aimed at serving the citizens, and they have created mechanisms to communicate and interact with them to promote the continuous improvement of smart services.

Through the Program “MDE: Medellin Smart City,” Medellin is implementing projects to create free Internet access zones, community centers where ICT can be accessed, a Mi-Medellin co-creation portal, open data, online transactions, and other services that aim to achieve citizen participation, open government, social innovation in problem solving, and project sustainability.

Another strategy is the creation of the Smart Mobility System (Sistema Integrado de Movilidad de Medellin, or SIMM) which, through the use of technology, an operations center, and a series of monitoring and control services, has achieved a reduction in the number of accidents, improvement in mobility, and a reduction in incident response time.

In the environmental strategy, the Early Warning System (Sistema de alertas tempranas, or SIATA), the Noise Monitoring Network, and the Air Quality

Network combine with the emergency care network to integrate services that are linked.

Added to this are the Integrated Metropolitan Emergency and Security System (Sistema Integrado de Emergencia y Seguridad Metropolitana, or SIES-M), a systemic strategy of interinstitutional convergence between the security and emergency agencies of the State that integrates more than 10 local and national government agencies.

These initiatives have been continuous since their inception, using operational models that bring together public and private associations and agreements between government entities in different sectors, with the participation of academic institutions and innovation, science, and technological entities.

Not everything along the way has been easy: the integration of entities that provide services has been slow in the absence of inter-administrative agreements that enable information sharing. Technological backwardness in some of the components has made integration impossible, and the lack of resources in some entities has prevented a stronger campaign that communicates information about the services.

Smart city innovation is not only technological; it must also be social. It must also seek sustainability in each project or service by ensuring income sources and/or adjudication to operators that outlast changes in government. It should also encompass technological renovation and maintenance to guarantee continuity of ongoing projects. In Medellin, a series of citizen-centered services are improving residents’ quality of life. Although they still must evolve substantially to achieve integration and predictability, they are already showing results in capacities developed for the future management of a consolidated smart city.



Metro de Medellín, Parque Berrío Station (Source: Medellin Travel)

MEDELLIN, Colombia

1. Introduction

1.1 Overview of the City

Medellin, the capital of the province of Antioquia, has a population of 2,464,322 inhabitants, and is the second most populous city in Colombia. Medellin is located in the center of the Aburra Valley, in the central Andes Mountain Range. Its land area is 680 km², and geographically it is situated on a steep plane that is from 1800 to 1500 meters above sea level. The urban area of Medellin is divided into 16 communes and the rural area, which has five townships.¹

¹ A township is a type of subdivision in the rural areas of different municipalities, which includes a core population.

The communes are: Popular, Santa Cruz, Manrique, Aranjuez, Castilla, Doce de Octubre, Robledo, Villa Hermosa, Buenos Aires, La Candelaria, Laureles-Estadio, La América, San Javier, El Poblado, Guayabal y Belén. Por su parte, los corregimientos son: Palmitas, San Cristóbal, Altavista, San Antonio de Prado, and Santa Elena.²

Image 1. Location of Medellin



Source: Procolombia.

The economic composition of the city centers on the following industrial sectors, the most representative of which are textiles, at 20 percent;

² Informe de Gestión Anual, Mayor of Medellin, 2014. Available at: <http://www.medellin.gov.co/irj/portal/ciudadanos?NavigationTarget=navurl://0b7c049660dc0cbb3972d4add7cb7eb9>

chemical substances and products, at 14.5 percent; food products, at 10 percent, and beverages, at 11 percent. The remaining 10 percent comprises sectors such as metalworking, electricity, and electronics, among others.

There are also six consolidated clusters: electric energy, construction, textile-clothing design-fashion, medical and dental services, business tourism, and information and communication technologies (ICT).³

This has made Medellín a thriving city that represents 7.9 percent of Colombia's gross domestic product (GDP), with a GDP of US\$30.137 million in 2014. In that same year, it grew by 4.2 percent according to the study Global Metro Monitor by the Brookings Institution,⁴ with a GDP per capita of US\$8,489, an even larger growth than other important cities in the world.

Table 1. Comparison of GDP Per Capita – Growth 2013–2014

City	Population	Country	GDP
Medellín	2,464,322	Colombia	4.20%
Monterrey	1,135,512	Mexico	0.50%
Barcelona	1,602,386	Spain	1.20%
Manchester	2,240,230	UK	2.60%
Chicago	2,853,144	USA	0.70%

Source: Author's elaboration based on information from the Global Metro Monitor of the Brookings Institution.

Medellín was recognized as the most innovative city in 2013⁵ (recognition awarded by the *Wall Street Journal*, Citi, and the Urban Land Institute) and has become a global referent for international delegations wishing to learn about the transformation processes and outlook of a city that

wants to be recognized by 2023 as the innovation capital of Latin America.⁶

The strategy “Medellín, the Most Innovative City”⁷ built by universities, private organizations, local government, and society, has increased investment in innovation for the sole purpose of generating a sustainable economy based on a combination of public and private efforts. In this transformation process, the city has received international recognition that has highlighted its efforts in this area.⁸

This study identifies Medellín as a major player in the area of evaluation of strategies of innovation, entrepreneurship, and competitiveness. This participation has made more visible to citizens the innovation and technological development DNA that the city wants to inculcate in them.

1.2 Overview of the Smart City

1.2.1 Background

Medellín began a process of urban and citizen transformation starting with its 2004–2007 development plan. Since then, the city has gone through an important process of reinventing itself, in which inclusion has been a key ingredient and technologies have enabled the strategy to evolve to the next level.

In the 2015 development plan, “Medellín: Un hogar para la vida,”⁹ the city is seeking to strengthen public administration, institutions, and the public sphere. This strengthening will be achieved by invigorating participation within a framework of political culture, co-responsibility with municipal development, and the strategy of projecting

³ International Cooperation Agency – ACI-Link: <http://www.acimedellin.org/inversion/invierta-en-medellin>

⁴ Procolombia. Link: <http://www.inviertaencolombia.com.co/informacion-regional/medellin.html>

⁵ Most innovative city by Wall Street Journal. Link: <http://online.wsj.com/ad/cityoftheyear>

⁶ Science Strategic Plan. Medellín's Technology and Innovation 2011–2021. Link:

http://rutanmedellin.org/images/programas/plan_cti/Documentos/Plan-de-CTi-de-Medellin.pdf

⁷ Most Innovative City by Wall Street Journal. Link: <http://online.wsj.com/ad/cityoftheyear>

⁸ International Cooperation Agency – ACI-. Link: <http://www.acimedellin.org/inversion/invierta-en-medellin>

⁹ 2012–2015 Development Plan. Medellín City Hall. Link: <https://www.medellin.gov.co>

Medellin as a smart city¹⁰ through technological and social innovation.

Medellin is the only city in Colombia that has a science, technology, and innovation plan,¹¹ which has identified bases to develop health, energy, and information and communication technology groups. This led to the creation of *Ruta N*, a complex centered on business development and innovation, as the heart of the city's innovation ecosystem. It comprises the University of Antioquia, the Explora Park, the Planetarium, the Botanical Garden, and the Innovation and Business Center. Together, these institutions create an urban center that supports advances toward a knowledge-based society and economy.¹²

Image 2. Innovation District: Route N, Medellin



Source: Route N.

Likewise, local government plans, such as “Digital Medellin,” whose aim was to get citizens to adopt ICT, have evolved to “MDE: Medellin Smart City,”¹³ making Medellin the first city in Colombia with a smart city-focused government program.

¹⁰ MDE: Medellin Smart City Program. Link:

<http://www.mdeinteligente.co/>

¹¹ Medellin's Science, Technology, and Innovation Strategic Plan 2011–2012. Link:

http://rutanmedellin.org/images/programas/plan_cti/Documentos/Plan-de-CTi-de-Medellin.pdf

¹² WEF, The Competitiveness of Cities: A Report of the Global Agenda Council on Competitiveness. Link:

http://www3.weforum.org/docs/GAC/2014/WEF_GAC_CompetitivenessOfCities_Report_2014.pdf

¹³ MDE, Medellin Smart City Program. Link:

<http://www.mdeinteligente.co/>

1.2.2 Medellin Smart City Vision

The Medellin Smart City Program consolidates ICT adoption processes, content generation, design of services, and support for public connectivity strategies with the aim of improving the relationship between citizens, their environment, and the municipal administration.

It is expected that by 2020, this strategy will improve the quality of life of the citizens, providing continuity and extending existing actions, and developing new strategies using ICTs as a way to contribute to the solution of problems and create opportunities in education, security, mobility, the environment, economic development, housing, citizen participation, and equity.¹⁴ The strategic lines of the Medellin Smart City program are the following:

- **Citizen participation:** Create a culture of participation through adequate spaces that reflect residents' proposals in the city's public policies.
- **Open government:** Generate, promote, and position open data. The information developed by the municipal administration, public bodies, business, and academic institutions must be made available for the use and benefit of citizens, through ICTs, as social networks, web pages, and applications.
- **Social innovation:** Promote processes that allow citizens to modify their environment, transform their reality, and find solutions to their problems.
- **Sustainability:** Develop projects to promote sustainability and ensure economic, environmental, political, and social conditions for current and future generations.

¹⁴ Annual Management report, Medellin City Hall, 2014. Link:

<http://www.medellin.gov.co/irj/portal/ciudadanos?NavigationTarget=navurl://0b7c049660dc0cbb3972d4add7cb7eb9>

In this evolution, Medellín has been implementing a series of initiatives with a high degree of technical and social innovation content, integrating services, systems, and technology from each of the secretariats that comprise the Municipal Administration.

One of the secretariats with the most initiative in the area of innovation and technology is Medellín's Mobility Secretariat, which has modernized its services and created the Medellín Smart Mobility System (Sistema Integrado de Movilidad de Medellín, or SIMM). This system consolidated the creation of the Mobility Control Center, the transit records services, the electronic detection of traffic infractions, cameras for traffic monitoring, variable messaging panels, support systems to the traffic light network, and a system for public transportation control, among others, that have made the city a world referent in the areas of integration to improve mobility and reduce accidents.

Similarly, the Municipal Government Secretariat, which is in charge of citizen security issues, in association with the Metropolitan Area and the Empresa de Seguridad Urbana (ESU), has created a metropolitan radius of action control center. Known as the Integrated Metropolitan Emergency and Security System (Sistema Integrado de Emergencia y Seguridad Metropolitana, or SIES-M), it is a systemic strategy of interinstitutional convergence between the state security apparatus and emergency organizations that integrates citizen security, mobility, and prevention and response to disasters and health and medical emergencies.

With respect to environmental monitoring, air quality, and noise measurement systems, the Aburra Valley Metropolitan Area,¹⁵ as the environmental authority for the municipalities comprising it (Medellín, Bello, Girardota, Barbosa,

Copacabana, La Estrella, Itagüí, Sabaneta, and Caldas), has implemented the SIATA and the Noise and Air Quality Monitoring network.

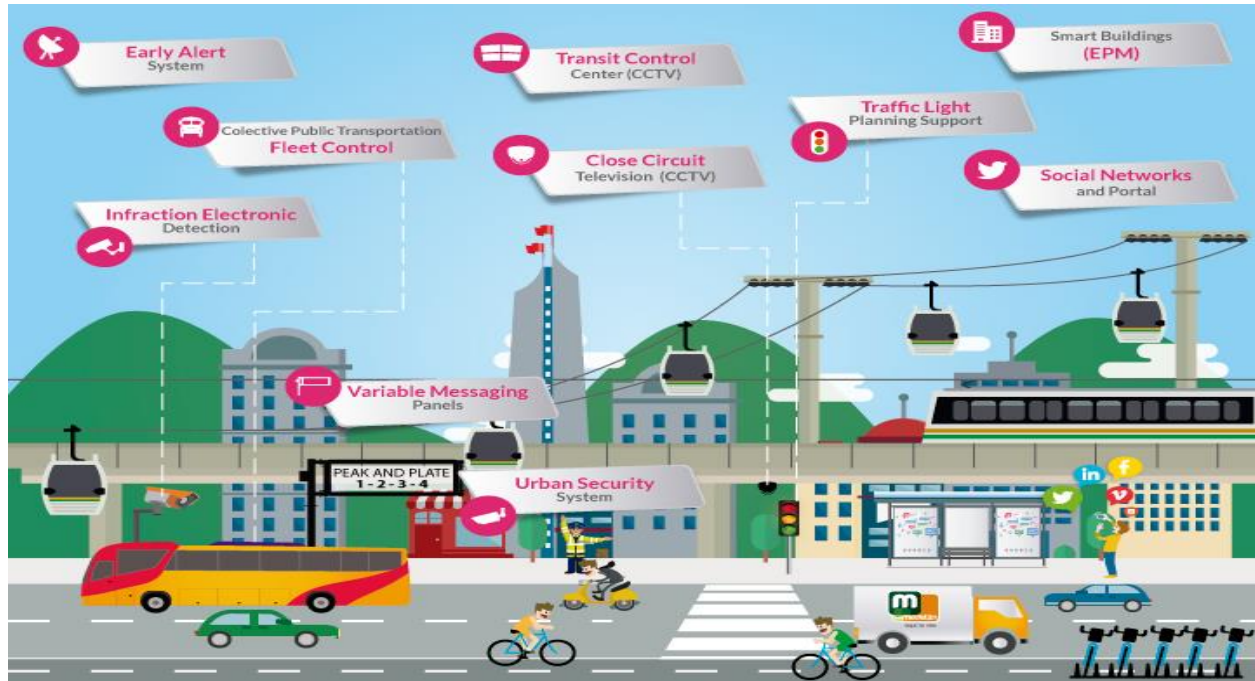
As for efficient energy services, Medellín is a pioneering city in Colombia in terms of the quality of public service delivery, with the public company Medellín Public Enterprises (Empresas Públicas de Medellín, or EPM),¹⁶ organized as the state industrial and commercial company, under the aegis of the Medellín Municipality EPM, offering the highest international quality standards in the services that it provides: electricity, gas by network, water, and sanitation.

Finally, Medellín and the province of Antioquia have implemented a series of public communication strategies with television channels, social network management, integrated procedure portals, and apps. They are contributing to increasing knowledge-based citizen participation and creating public policies.

¹⁵ Aburra Valley Metropolitan Area.. Link: <http://www.metropol.gov.co/>

¹⁶ Empresas Públicas de Medellín. Link: <http://www.epm.com.co/>

Image 3. Smart City Medellin Scheme



Source: Author's elaboration.

2. Smart City Services

2.1 General Description

To support the smart city services that it offers, Medellin has focused on implementing the use of technology aimed at improving public services, which is inherent in improving the quality of life of the people of Medellin. The city began this journey from the transit and transportation sector, adopting the example of smart cities such as Barcelona, which have prioritized mobility and integrated all of their services into a single format. Likewise, Medellin has centered its efforts on optimizing this niche through the construction of the Mobility Control Center, equipped with latest-generation technology. From this starting point, it is expected that in 2020, other sectors will adopt this format. This is now occurring in the areas of security and the environment.

2.2 Transportation and Urban Mobility: Medellin's Smart Mobility System (SIMM)

The increase in the number of vehicles, population growth, urbanization, industrialization, and population densification have a considerable impact on the city's mobility. They reduce the efficiency of the transportation infrastructure and increase commuting time, air pollution, and fuel consumption.

For all of these reasons, in 2010, the municipality of Medellin began studying the need to implement a mobility system (SIMM),¹⁷ which integrates information technologies, communication, transportation infrastructure, and the different types of vehicles. This system seeks to manage all of these components efficiently to improve mobility in the city by optimizing the use of the roads, improving security, reducing commuting

¹⁷ See <https://www.medellin.gov.co/simm>.

times, pollution, and fuel consumption, and disseminating information to users so that they can make better decisions related to their travel.

SIMM seeks to employ technological solutions to lessen mobility constraints. SIMM is a successful case of public-private partnership. It has seven technologic components integrated in a transit control center for surveillance and mobility management within the city.

2.2.1 Electronic Detection of Traffic Infractions

The city has installed 40 electronic traffic infraction detection cameras that can rotate in up to 70 fixed control points. These cameras detect infractions such as speeding, peak and plate (vehicular restrictions), red light running, forbidden lane circulation, and driving in the pedestrian walkway.

The system reads 1 million circulating plates daily, using the information to study mobility, set rules, and evaluate drivers' knowledge. This has reduced infractions by more than 80 percent in the monitored sites, thanks to the fact that the Mobility Secretariat's strategy focuses on accident prevention and driver education.¹⁸

2.2.2 Closed-circuit Television

At the moment, Medellín has 80 visualization cameras with video analytics, operated by the Transit Control Center (TCC), that allow visual monitoring of the road network (photograph and video), for the purpose of detecting incidents that affect traffic. Moreover, several of the cameras (depending on their location) are used for automatic incident detection through smart software that identifies situations such as a detained vehicle, a slow-moving vehicle in fluid traffic, and congestion. It is also possible to capture traffic information, such as intensity, occupation, average speed, number of vehicles, and inter-

vehicular distance.

Additionally, the CCTV system integrates and has visualization (without the possibility of manipulation) of over 823 cameras of the USC, which provide support for monitoring the state of the roads.

Medellin's CCTV system allows the operators in the control center to make informed and timely decisions to respond to accidents in the least possible time (the operators calculate the best route from the information provided), as well as inform drivers in real time of any incident by communicating via the variable messaging panel (VMP) system. The indicators captured by this system are stored as historic and used to make medium and long-term decision that affect city planning and the creation of strategies to support public policies.

2.2.3 Variable Messaging Panels

The VMP system consists of 22 electronic boards located in places where there is heavy traffic. They allow drivers to make informed, smart, and timely decisions, such as alternate route selection, to reduce travel time, traffic congestion, and accidents. Among the messages that are published, the following figure prominently:

- Beginning and ending times of vehicular restriction (peak and plate)
- Regulatory, preventive, and informative signs
- Traffic incidents such as accidents, stranded vehicles, road closures, and others
- Vehicular traffic jams due to heavy traffic flow
- Driver education messages

The implementation of VMPs in Medellín enables the city to inform citizens on the road about traffic situations in real time, as well as disclose information about official events that may

¹⁸ See: <https://www.medellin.gov.co/simm>.

influence normal mobility in the city.

2.2.4 Traffic Light Control Center

The network has over 600 traffic light intersections interconnected by a wireless and fiber optic broadband communications network, owned by the city, which enables it to take action in real time on any traffic situations that may occur and to make immediate decisions to achieve greater mobility on the urban perimeter.¹⁹

Additionally, the city has installed sensors on the road that measure traffic variables in real time. These sensors continuously measure travel times, road occupation, and traffic volumes to monitor and improve mobility through decongestion strategies.

2.2.5 Support for Planning the Traffic Light Network

To permanently monitor vehicular behavior, especially volume, the routes over the different roads, and optimize the traffic light network, Medellín has 120 evaluation units in 21 traffic light intersections, composed of vehicle detection sensor (VDS) cameras and video analytics software, which capture traffic information—intensity, occupation, average speed, number of vehicles, and inter-vehicular distance—for three types of vehicles: lightweight, truck, and motorcycle. Because of the results obtained using the current units, 300 additional devices are expected to be added for this purpose over the next four years.

2.2.6 Fleet Management

Public transportation companies must guarantee that the cars in their fleet are equipped with the technological devices necessary to allow real-time collection and transmission of the data required to monitor the quality, efficiency, and security indicators of the service, in accordance with the Transportation and Transit Secretariat's

regulations. The following variables are monitored:

- Driving a vehicle above the speed limit
- A change in the route of public transportation vehicles authorized by the corresponding transit organization
- Leaving or picking up passengers at stops other than those permitted by the authorities
- Driving a vehicle with one or more doors open
- Failure to implement the circulation plan of the company's vehicle fleet, or failure to report it every six months or when indicated before that time
- Failure to comply with the dispatch schedules and authorized frequencies
- Exceeding the transportation capacity authorized by the company
- Failure to maintain in operation the minimum authorized transportation capacity
- Providing the service while exceeding the authorized transportation capacity, in the number of passengers, in accordance with what is established in the homologation sheet (overcrowding)

The system monitors 3,800 buses in the city and nearly 6,000 in the metropolitan area. This enables the city to improve the behavior of drivers and support better planning of routes and frequencies.

2.2.7 User Information System

The Mobility Secretariat integrates a series of strategies to meet the needs of citizens, including virtual services, attention in 18 decentralized branches, contact center, social networks, mobile attention unit, vehicle dealer attention points, and mobility apps, among others.

¹⁹ See: <https://www.medellin.gov.co/simm>.

In 2014, the SIMM web page received 276,623 visits. It received 38,632 visits thanks to promotion and referencing from links on social media (Facebook attracted 29,676; Youtube, 2,499; and Twitter, 6,457 visitors). With this it achieved a high Google search ranking, which attracted a total of 95,393 visitors. This indicates that the web page showed up within the first results when people searched a subject related to the project, obtaining a very good positioning.

2.3 Protection, Citizen Security, and Emergency Services

2.3.1 Urban Security System and Single Emergency Number

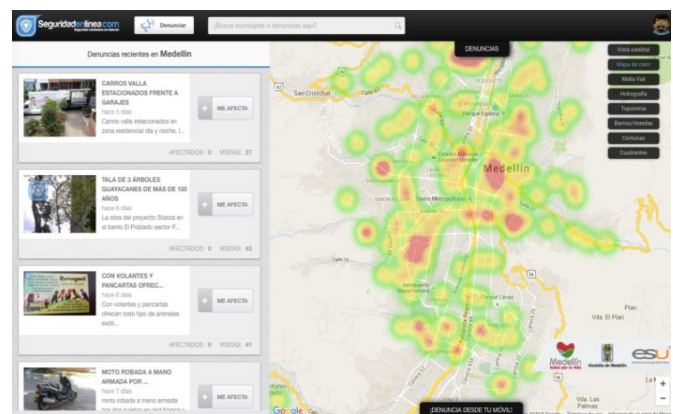
The Office of the Mayor of Medellin, through the USC, coordinates the Integrated Metropolitan Emergency and Security System (Sistema Integrado de Emergencia y Seguridad Metropolitana, or SIES-M), a systemic strategy of interinstitutional convergence between State security and emergency organizations. It integrates different components such as: citizen security, mobility, prevention and response to disasters and health and medical emergencies.²⁰ Citizens can access SIES-M through a single security and emergency number, 123, which has 60 lines through which it receives an average of 30,000 calls per day.

2.3.2 Security Online (seguridadenlinea.com)

With the aim of making the complaint process easier, faster, and more accessible to the citizens, in August, 2013, the Office of the Mayor of Medellin launched the first integrated digital complaint system in Colombia. This is the main input that security and justice organizations have to identify

culprits and prosecute them. It currently has 20,000 users.²¹

Image 4: Security Online



Source: Web Portal www.Seguridadenlinea.com.

As of 2014, the application had contributed significantly to the security strategy planned by the Office of the Mayor. Thus:

- In 2014, Security online received 499 formal complaints of failure to provide food assistance, 398 cases of domestic violence, 2,324 cases of theft against individuals, 581 cases of theft against business establishments, 479 complaints of theft of automobiles or essential vehicle parts, and 225 complaints of home invasion.
- In 2014 there were 11,118 anonymous complaints, for a total of 15,936 complaints, both anonymous and criminal.

2.3.3 Video Surveillance System

The video surveillance system has 823 cameras distributed throughout Medellín. Each camera covers a 120-meter radius. Forty percent of them are placed in high-crime areas. The cameras have high-definition optic zoom capability of up to 22X linked by fiber optics and radio frecuencies with a capture of 30 frames per second by IP video.

²⁰ See: <http://www.esu.com.co/esu/index.php/es/portafolio/sistemas-integrados-de-seguridad/sies>.

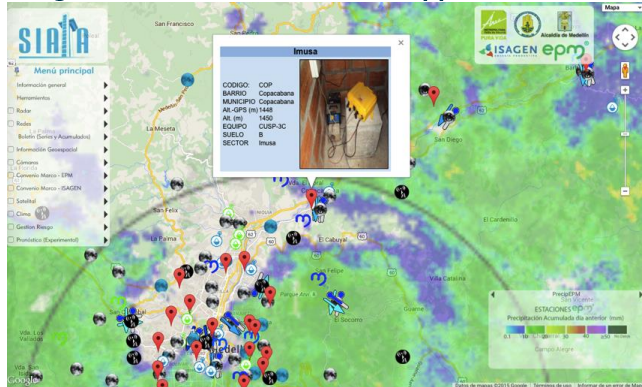
²¹ Management Report, Medellín City Hall, 2014. Link: <https://www.medellin.gov.co/irj/porta/ciudadanos?NavigationTarget=navurl:/0b7c049660dc0cbb3972d4add7cb7eb9>

2.4 Environment

2.4.1 Early Warning System

The early warning system (SIATA) is a project of various public institutions, such as the City's Department of Risk Management (DRM); private companies, EPM, and the Energy Generation and Distribution Company, ISAGEN. This system is one of the main risk management strategies of the DRM and the Municipal Risk Management Councils (MRMC).

Image 5. SIATA Portal and Web Application



Source: SIATA Medellín.

The main objective of the project is to warn the community in a timely manner about the probability of an extreme hydrometeorological event that could create an emergency situation, and in this way reduce its impacts by implementing measures to respond to an imminent threat. Other objectives of SIATA are water basin and micro-basin monitoring in real time, and regional hydrological and meteorological modelling, in order to generate vital information for environmental and risk management.

Currently, SIATA has a number of networks for rain monitoring (71 sensors); meteorological variables, such as temperature and wind direction and speed (seven stations); water level of streams (eight sensors), and soil moisture (in calibration). In addition, it has a live-streaming camera network (seven cameras). With the information generated by these networks together with the information from the hydrometeorological radar (installed in

Santa Elena), the community is warned about the possible occurrence of an event that could create an emergency.

2.4.2 Environmental Noise Monitoring Network

The Aburra Valley Metropolitan Area noise monitoring network manages, analyzes, and publishes the data generated by the eight monitoring stations that measure minute by minute, 24 hours a day, the noise levels in five municipalities under its jurisdiction.

The network has seven fixed environmental noise monitoring stations and one mobile station located throughout the Aburra Valley. Two of them have been operating since 2009, and the other six were acquired in 2011.²²

2.5 Energy Efficiency

2.5.1 Smart Grids Pilot

Since 2010, Colombia has been working on the conceptualization of smart electrical grids and at strategic points in the country, as part of the Smart Colombia program.²³

In 2016, Medellín will allocate about US\$10 million for technology transfer on the subject of smart grids. As part of this program, energy ecosystem development is favored. The city has generated innovations in multiservice and multiprotocol management systems. The flagship project to date is prepaid electricity meters, which in a subsequent phase will be applied to gas and water. The company has 120,000 meters installed in the city, in low-income sectors with a high penetration

²² Colombian Polytechnic, Aburra Valley Metropolitan Area Noise Information Management Network Report. Link: <http://www.metropol.gov.co/CalidadAire/IsdocRuido/CA%20243%20Gestion%20informacion%20red%20ruido%20%20junio.pdf>.

²³ See: <http://www.colombiainteligente.com.co/>

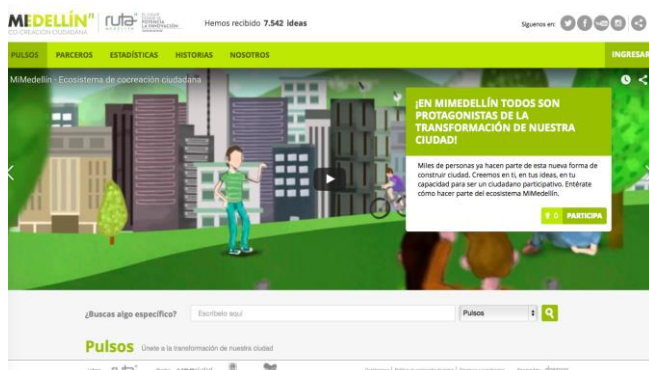
Smart Colombia is the intersectional strategic context that proposes guidelines and follow-up metrics of a route to an efficient and sustainable electricity sector with a reliable and safe operation of the electric grid.

of micropayments, which on average make seven monthly refills of around US\$7 million.

2.6 Interaction with Citizens and Communication Mechanisms

2.6.1 Co-creation Portal: MiMedellin

Image 6. Mi Medellín Portal



Source: MiMedellin Portal.

MiMedellin is a citizen co-creation platform where everybody's ideas and inspiration are a part of the city's transformation. In less than two years in operation, it attracted 13,000 citizens and captured nearly 8,000 ideas.

Citizens of Medellin and the entire world are invited to participate in the formulation of new ideas. Projects in each topic are published through the website www.MiMedellin.org. Using social technologies, citizens can vote, filter, comment on, and share ideas. Those authors and ideas that receive the most votes will be publicly recognized at the end of each season. The ideas of the finalists will be taken into consideration by those responsible for executing the projects that will transform the city.

The Organization of American States (OAS) has recognized this effort, granting it the Inter-American Innovation Award for Effective Public Management. It earned first place in the Open

Government and Information Access category in 2015.

2.6.2 Portal of the Office of the Mayor of Medellin

The portal of the Office of the Mayor of Medellin aims to be the single channel of interaction between citizens and the municipal government, as a mechanism for communication and disclosure of its inclusive public policies. Its main aim is to improve, through online disclosure, the quality of life of residents of the municipality. The portal offers the possibility of accessing transactions, programs, and projects of the secretariats in each of the following areas.²⁴

²⁴ Web Portal, Office of the Mayor of Medellin. Link: <https://www.medellin.gov.co/irj/portal/medellin>

Table 2. Transactions that Can Be Processed through the Portal of the Office of the Mayor of Medellín

Office	Transaction	
Citizen Services	<ul style="list-style-type: none"> • Procedural Guide • Government Palace and closer 	<ul style="list-style-type: none"> • Petitions, complaints, anonymous complaints, claims, suggestions, consultations
Social Wellbeing and Development	<ul style="list-style-type: none"> • Social Wellbeing Secretariat Service Portfolio 	
Contracting	<ul style="list-style-type: none"> • Proponents inscription • Bill consultation • Direct contracting • Monthly contracting report 	<ul style="list-style-type: none"> • Public tenders • Contracting processes search • Purchasing plan, documents and rules
Treasury	<ul style="list-style-type: none"> • Tax payment • Taxpayer payment list • Certificate of good standing • Virtual tax consultation 	<ul style="list-style-type: none"> • Properties consultation • Tax service portfolio • Assistance for online payments
Environment	<ul style="list-style-type: none"> • Educational/environmental projects 	<ul style="list-style-type: none"> • School environmental project index
Mobility and Transportation	<ul style="list-style-type: none"> • Photo-detections consultation • Account statement and ticket payment • Exempt vehicle consultation • Transaction information (vehicles: car and motorcycle) • Transaction formats (vehicles: car and motorcycle) • Instructions for transactions (vehicles: car and motorcycle) • Suspended license data • Status of transactions 	<ul style="list-style-type: none"> • Payment of traffic tickets • Driver record • Vehicle condition • Driver's license validation and consultation • Consultation of the citizen's status in the RUNT ^a • Operator card verification • Surrender of immobilized vehicles • Hearings • Administrative acts consultation
Municipal Planning	<ul style="list-style-type: none"> • Building license procedures • Make topographic calculations and register proponents • Manage topographic calculations • Territorial Ordinance Plan maps 	<ul style="list-style-type: none"> • Maps of Medellín • Public Policies Observatory • Georeference of real estate • Public space licenses • Application for real estate loan • Topographic calculations
Health	<ul style="list-style-type: none"> • Subsidized system 	<ul style="list-style-type: none"> • SISBEN survey

Source: Portal, Office of the Mayor of Medellín.

^a RUNT is a centralized system used to register, authorize, validate, and maintain an up-to-date database of vehicles, drivers, drivers' licenses, transportation-related companies, infractions, insurance, trailers, traffic accidents, and agricultural and construction machinery.

2.6.3 Social Networks: Office of the Mayor of Medellin Web 2.0

The Office of the Mayor implemented a social networking strategy that establishes an integrated network on Twitter, Facebook, Flickr, Youtube, and Instagram. In 2014, it published 62,136 contents in multiple formats, including informational messages, responses, and instructional messages to the community that follows the Office of the Mayor. Exchanges were held in Spanish, English, and French.

The videos uploaded to Youtube had 446,617 visits in 193 countries. Additionally, the pictures hosted on Flickr had 589,284 visits, proving the importance of social media in publicizing Medellin's transformation.

In 2014, the Office of the Mayor added 146,616 new followers to its virtual community. Twitter saw the largest growth that year.

2.6.4 Regional Television Channels

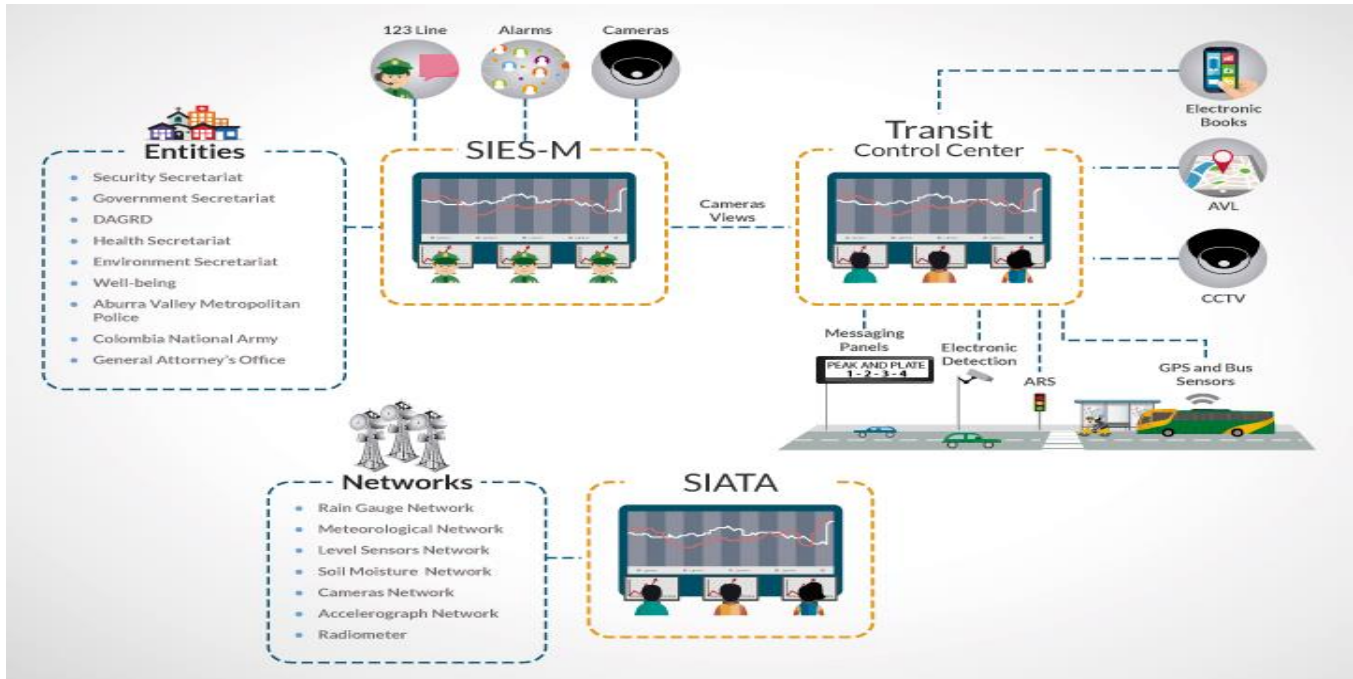
Telemedellin is a local public nonprofit, open-signal television channel whose main partner is the Office of the Mayor of Medellin. Its purpose is to showcase the life of the city and its metropolitan area, through the space created for citizen participation and culture. In TV programs such as "La Movida," Medellin's Mobility Secretariat presents information on services, driver education projects, and citizen campaigns, among others. Finally, in "Medellin—Safe City," a program sponsored by Medellin's Security Secretariat, advances in the integrated security and coexistence strategy are made public.

3. System Configuration

3.1 General Description

In the configuration of the smart city solutions implemented by the city of Medellin, there are three main areas in which services are provided: mobility, security, and environment. Each of these is linked to information systems and communication mechanisms. Following are the technical configurations of each smart city service.

Figure 1. System Configuration



Source: Author's elaboration.

a- The Integrated Metropolitan Emergency and Security System integrates within a single operations center representatives from more than 10 government agencies and member entities for emergency response. It connects them through the incident response information system known as Subsystem 123 (Positron). The process starts with a report by users through a call, a community alarm, or the network of cooperators. Once an incident is reported, it is recorded in the reception modules and processed through the competent entity for each case.

Image 7. SIES-M Control Center



Source: Medellin's Mobility Secretariat.

b- The Early Warning System integrates information from over 100 sensors in seven different types of networks to capture environmental information. These networks are the hydrometeorological network, the level sensors network, the soil moisture network, meteorological radar, the accelerograph network, the air quality network, and the river network.²⁵

²⁵ See: <http://siata.gov.co/newpage/web/nosotros.php>.

Currently, SIATA communicates with the risk management agencies through warnings sent to leaders in the network by text message, email, an app, or direct communication, depending on the urgency of the event.

Image 8. SIATA



Source: SIATA Medellin.

c- The Mobility Control Center employs ITS technology, logistics monitoring, predictive systems, citizen communication systems, and decentralized services. This control center works within the Mobility Secretariat installations, with technological and physical infrastructure designed to project the control center as a pillar that can integrate even more mobility and city services. Currently, it is integrated with the emergency response system to deal with cases related to traffic incidents, and it has access to the security cameras.

Image 9. Mobility Control Center



Source: Medellin's Mobility Secretariat.

The smart city services that come together in the control center provide the opportunity to monitor and take action in real time.

3.2 Transit Control Center: Medellin Smart Mobility System (SIMM)

Among the social objectives that motivated the implementation of SIMM are: reducing infraction and accident rates, improving mobility, and reducing pollution and fuel consumption. These translate into the following technical purposes: opportunity to respond to incidents, monitoring of public transportation, timely information conveyed to citizens, and real-time monitoring and analysis of traffic flow.

3.1.1. History

The implementation of the control center is the result of the modernization process undertaken by the Mobility Secretariat in 2002, with the implementation of technological solutions. In 2006, it entered into an inter-administrative agreement with a public-private company for the modernization and optimization of the management of administrative services of the Medellin Transportation and Transit Secretariat.

Given the mobility needs identified by the Transportation and Transit Secretariat, on December 30, 2010, the Inter-administrative

Agreement was broadened, including among its contractual obligations the implementation and operation of SIMM until 2025.

3.1.2 Components

The Transit Control Center (TCC) operates 24 hours a day, 365 days a year. Its personnel works on the planning, operation, and analysis of mobility in the city.

The TCC manages the following components:

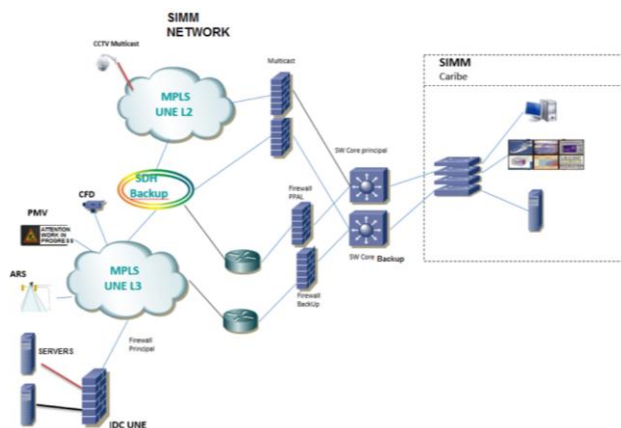
- Closed-circuit television (CCTV)
- Variable messaging panels (VMP)
- Traffic light network support (TLNS)
- Automatic vehicle location (AVL): localization technology installed in all Medellin Mobility Secretariat vehicles.
- Transit incident management system
- Centralized software that enables integrated operation of all of the components

The management model adopted by the TCC is based on the management of warnings originating from its component parts, which trigger the execution of their assignments and, in the integrated operation, optimize the time it takes to react and offer a quality service to the city. For mobility management, it carries out the following processes: detection, verification, dispatch, and transit incident response through the central software. This allows integrated operation of all of the components, thanks to a graphic interface that makes their interaction possible through a georeferenced map on which the management of key warnings and alarms for mobility management is unified and standardized.

3.1.3 System Architecture

The technological solution of the Mobility Control Center is supported by infrastructure that has the specifications required by the manufacturer of each subsystem or peripheral system.

Figure 2. System Architecture



Source: Technical Report SIMM.

For the operation, there are LAN and WAN network services, security platforms, application servers and databases, storage, and monitoring services for each IT element. In addition, there are 40 skilled staff who respond to events in the technological infrastructure 24 hours a day, 365 days a year.

The Mobility Secretariat has different sites, connected through fiber optic cables, where it addresses the needs of the public. This service is implemented over an MPLS network and offers redundancy because it is configured in rings.

All of the critical elements of the network are configured in high availability and have contingency equipment that assumes roles automatically. This applies to switch core, firewall, WLC, and routers.

In terms of IT security, the main headquarters and the various data centers are protected with perimeter firewalls that only allow access to previously authorized personnel and through

ports that are strictly required to operate. There are different security consoles, among them antivirus, anti-spyware, anti-Spam, NAC (Network Access Control), and agents installed in users' computers, all of which generate warnings that facilitate the identification of events. Additionally it has tools that update each element of the infrastructure.

The applications, databases, and network services are configured in clusters. This way, the operation and users are not affected when the equipment fails either physically or logically.

The entire solution is monitored by various consoles that generate warnings when any piece of equipment is not available, when its performance is affected, or when the resources allocated reach defined thresholds.

3.1.4 Information Flow

The following table presents a sample of the data exchanged between the subsystems of SIMM.

Table 3. Information Flow

Subsystems	Subsystem that it communicates with	Type of information
Central software	Photo-detection system	<ul style="list-style-type: none"> • Camera status • Camera description • Camera location
	CCTV system	<ul style="list-style-type: none"> • Events and alarms detected automatically by the cameras • Camera video
	VMP System	<ul style="list-style-type: none"> • Panel status • Panel description • Panel location • Messages displayed on the panels • Panel errors
	Data management system for public transportation	<ul style="list-style-type: none"> • Vehicle location • Configured event and alarms
	Incident response	<ul style="list-style-type: none"> • Type of incident • Incident status • Incident locations • Description and location of resources
	AVL System	<ul style="list-style-type: none"> • AVL status • AVL description • AVL location
Photo-detection system	Traffic light central and/or traffic controllers	<ul style="list-style-type: none"> • Traffic light phases
	Transit Qx	<ul style="list-style-type: none"> • Contravention evidence
PMV System	CCTV System	<ul style="list-style-type: none"> • Event and alarm information
Public transportation data management system	Transportation Company System / Integrators	<ul style="list-style-type: none"> • Public transportation operation parameters
	Transit Qx	<ul style="list-style-type: none"> • Evidence of contraventions
Positron System	CCTV System	<ul style="list-style-type: none"> • Camera location
	AVL System	<ul style="list-style-type: none"> • AVL status • AVL description • AVL location
Traffic lights (detector units and information capture equipment)	Traffic light applications and software	<ul style="list-style-type: none"> • State of detectors and capture equipment • Measurement data of the detectors and capture equipment

Source: Smart Mobility System.

3.3. Security and Emergency Response Control Center

The Security and Emergency Response Control Center is composed of various subsystems and entities that work around the 123 System. It brings together the logistics and technology of over 10 agencies and various security and coexistence subsystems in the following ways:

- The technological subsystems are: 123, video-surveillance, community warnings, cooperators network and the Sectional Police Strategic Information Centers (SPSIC).
- The secretariats of the municipality of Medellín that are part of the system and support the programs of each component are: Security, Transit, Health, Disaster Risk Management Administrative Department (DRMAD), Government, Environment, and Social Wellbeing.
- The institutions that are part of the system's operation are: Aburra Valley Metropolitan Police, Colombian National Army, Colombian National Air Force, Attorney's General Office and Metrosalud. The technological and logistical partner is the USC.
- The Security and Emergency Response Control Center functions thanks to the services provided by various information systems: the Security and Coexistence Information System, SIMM, the Medical Emergency System, the Emergency Regulatory Center, Public Space, Firefighters, Environmental 123, and Social 123.
- The complimentary technological systems used to improve the operation, control, and unification of effort are the following: Interaction of Security Systems, Cooperative Streaming, Automatic Vehicular Control Center, and the Communications, Computing, and Control Center.

3.4 Early Warning System

The Medellín and Aburra Valley Early Warning System (SIATA) is a science and technology project for risk management. The system has as its integrating objective to generate timely and anticipated warnings to the organizations that prevent and respond to disasters facing the vulnerable community with the probability of extreme hydrometeorological conditions in the Aburra Valley that threaten the lives or residences of the population and in general that adversely affect their quality of life. This objective is achieved through the execution of two fundamental macro-tasks: uninterrupted, real-time monitoring of hydrological and meteorological variables and the development of numerical forecasting models.

SIATA is a pioneering project in Colombia. To create this initiative, the Aburra Valley Metropolitan Area and the Office of the Mayor of Medellín joined forces. The project also receives support from Medellín Public Enterprises (Empresas Públicas de Medellín, or EPM) and ISAGEN. Since 2010, the Aburra Valley has had meteorological and hydrological monitoring networks that generate vital information for environmental management. Specifically, it has more than 160 sensors that make up nine monitoring networks. These networks deliver real-time information and cover the area from Barbosa to Caldas. They enable the system to characterize rain events, the water levels of certain streams, atmospheric conditions, and even the humidity and movement of some hillsides.

The information is available to the entire community in the geoportal www.siata.gov.co and in SIATA mobile apps. The information can also be found on social media.

3.5 Field Systems

Following is the general description of the field devices that compose the system. Technical detail can be found in Annex 1.

Table 4. Field Components: Sensors

Mobility
<ul style="list-style-type: none"> • Closed-circuit TV (CCTV) mobility: 80 cameras • Electronic photo detection cameras: 40 cameras installed in 70 spots • Mobile electronic detection camera: 1 for detecting illegally parked vehicles • Variable messaging panels: 22 • Traffic light optimization: 120 DVS type cameras with video analytic software in 21 traffic light intersections • Technological component on buses: GPS and door sensors, passenger and speed count in 3,800 buses • Electronic books: 160 PDA for the electronic recording of fines • AVL Devices for geo-localization of vehicles of the Medellin Mobility Secretariat
Environment – SIATA
<ul style="list-style-type: none"> • Rain gauge network: 71 stations send rain gauge information in real time • Meteorological network: seven sensors that make up this network monitor the temperature, the environment relative humidity, and wind direction and velocity • Water level sensor network: eight sensors located in some of the most important basins of the Aburra Valley. • Soil moisture network: 33 humidity stations • Camera network: seven cameras on clouds • Accelerograph network: 30 sensors in Medellin and its metropolitan area • Other networks: EPM rain gauge network, the Metropolitan Area Air Quality network REDAIRE, and the Water Quality Network REDRIO • Radiometer: monitors the vertical structure of the atmosphere by measuring variables such as temperature, humidity, and amount of water in the atmosphere

Security and emergencies

- 823 CCTV security cameras
- 500 community alarms ²⁶ that facilitate police response. They include sirens and panic buttons to send warning signals to the authorities.
- Automatic vehicle location (AVL): enables automatic location of vehicles and police through GPS, to guarantee better coordination and effectiveness of security in the city's 411 police quadrants.

Source: Author's elaboration.

3.6 Subsystems and Functions

Table 5. Subsystems and Functions

Urban transportation and mobility
<ul style="list-style-type: none"> • Electronic Infraction Detection System (EIDS) • Collective public transportation control • CCTV • Support to traffic light planning • Specialized planning software • Variable messaging panels • Central software • Incident management system • Programming software for transit agents, transit police, transit and logistic resources university managers, and logistical resources
Security and emergency response
<ul style="list-style-type: none"> • 123 Subsystem • Video surveillance subsystem • Community alarm subsystem • Security online.com
Environment
<ul style="list-style-type: none"> • SIATA • Mobile version • Emails, WattsApp and ChatBlackberry

Source: Smart Mobility System.

²⁶ **Community warnings:** In connection with the Community Police, the good neighborhood networks are established or Citizen Security Fronts. They are composed of neighbors in the neighborhoods, where an alarm system is installed that can be activated with wireless buttons.

3.7 Knowledge Generation: Business Intelligence and Data Analytics System

All of the information processed by the different systems is subject to analysis in the entities, using business intelligence tools, big data, or knowledge management. Medellín still has a long way to go in these areas.

On security, the third generation of online security, using artificial intelligence software, aims to cross-reference information with citizen complaints, to find coincidences in crimes committed through information such as license plates, ID numbers, telephone numbers, and a person's name, among others. It also seeks to support investigators and prosecutors, providing them with information about crimes that are being reported through Security online.²⁷

In the Mobility Control Center, the operation goes beyond online responses to incidents. For this purpose, it has specialized personnel in the transit and transportation area who process the information produced by the different components to conduct traffic light planning studies, detect changes in traffic patterns and road saturation, identify areas where more accidents occur, critical agents, and transit plans, among others, in order to generate proposals that support the Mobility Secretariat in the adoption of sustainable mobility policies. In 2014, 24 traffic light optimization studies were presented, focusing on road safety for all who travel on them. Similarly, 23 studies on transit management strategies were conducted, in which various alternatives were proposed for the solution of the mobility problem in a few important spots in the city. Several of those assessments have been implemented, and it is expected that the coverage of the studies will be expanded to find solutions in accordance with city's organization.

²⁷ USC 2014. Link: - <http://www.esu.com.co>

Early warning system information comes in real time. The sensors of each type of network normalize the variables associated with the models on rain, river basins, flows, and stations. The results obtained comprise a database, processed with smart software, to generate the alerts or corresponding reports. They are interpreted by the team that leads the project. In this way, the final data analysis is the responsibility of the specialized personnel.²⁸

4. Organizational Structure

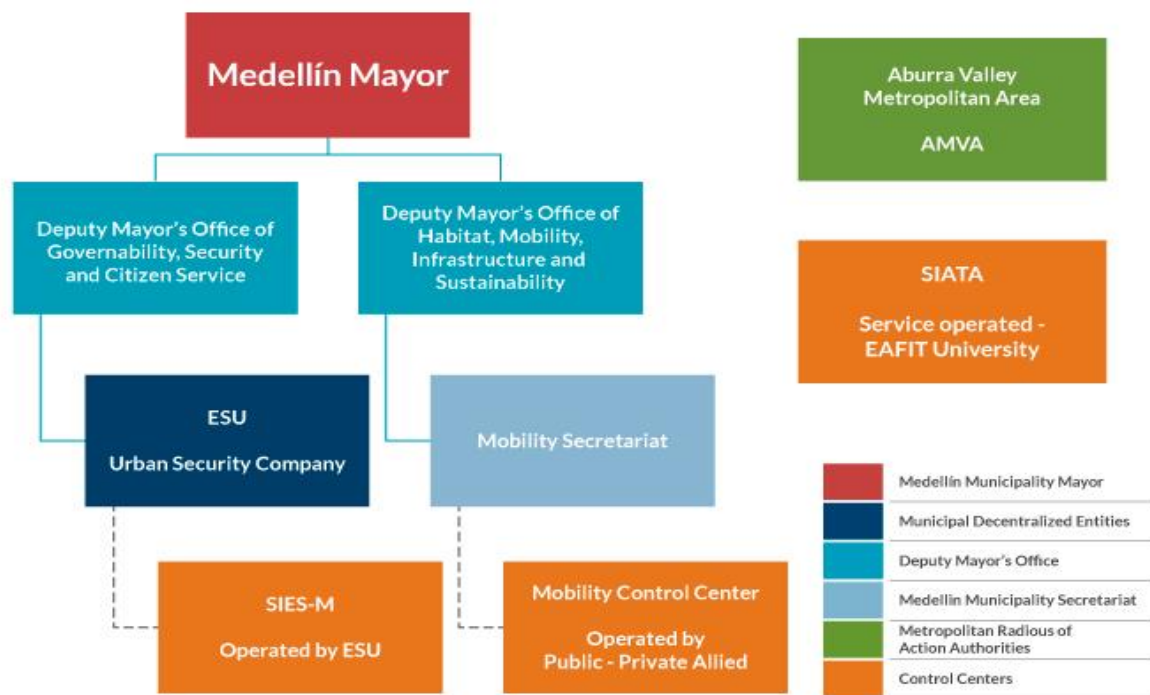
4.1 Government Model

Figure 12 identifies the entities under which the three main smart city service systems fall. Two are municipal (SIMM and the Mobility Control Center), and one (SIATA) covers the metropolitan area.

The Mobility Control Center falls under the Medellín Mobility Secretariat, which is part of the Office of the Deputy Mayor for Housing, Mobility, Infrastructure, and Sustainability, which in turn falls under the Office of the Mayor. The control center is operated by a public-private concessionaire. It has a team of 40 people, distributed among the following areas:

²⁸ SIATA Executive Report. SIATA. 2013. Link: <http://www.sabaneta.gov.co/institucional/DocumentosMunicipio/EWS%20-%20Sistema%20de%20Alerta%20Temprana%20de%20Medell%C3%ADn.pdf>

Figure 3. Public Entities Chart and Hierarchy



Source: Office of the Mayor of Medellín.

(i) research, development, and innovation; (ii) operations; (iii) information; (iv) technology; and (v) administration. They operate in an integrated manner with the Secretariat, which has transit agent supervisors deployed permanently in the control center to coordinate responses to road events.

The SIMM comprises various subsystems and entities that work around the 123 System as a fundamental part of citizen contact with emergency and security entities.

The SIATA is a project of the Aburra Valley Metropolitan Area which is the environmental authority for the municipalities that comprise it (Medellín, Caldas, La Estrella, Itagui, Sabaneta, Bello, Copacabana, Girardota, and Barbosa). The Metropolitan Area delegates to the EAFIT, a private university in Medellín, the operation of SIATA, designating 15 experts in the following areas: (i) maintenance, (ii) integrated information systems, (iii) development of sensors and telemetry, (iv) quality, (v) operations, (vi) meteorological modeling, (vii) hydrologic modeling, and (viii) education and communications.

The secretariats of the municipality of Medellín that are part of the system and support the programs of each component are: Security, Transit, Health, DAGRED, Government, the Environment, and Social Wellbeing. These areas have experts in the areas of: (i) automatic vehicular location systems; (ii) online security portals; (iii) closed circuit TV solutions; (iv) access/visitor control centers; (v) asset and intrusion control system; (vi) fire detection/extinguishing solutions; and (vii) building automation and management.

4.2 Cost System: Annual Budget, Investments, and Operating Costs

The initial investment of the Medellín Smart Mobility System project was \$34.780 billion pesos (US\$11.2 million). This investment covers mainly the electronic detection component (43 percent) and the control center (24.4 percent).

In the 15 years of the SIMM project, the investment will reach \$79.600 billion pesos in net present value (US\$27.4 million).

The annual operating costs of the SIMM in 2014 were about \$25.251 billion pesos (US\$8.13 million). Project expenditures increase by an average of 4 percent annually.

Although the value of this type of contract is undetermined, it can be calculated. This is because the source of income used is the percentage of the economic rights of the fees granted by the city to the private sector during the operation, updating, and maintenance phase of the contract.

This effective value remunerates all costs and expenses—both direct and indirect—incurred by the concessionaire in carrying out the contract, including the taxes, fees, and contributions caused by its execution (or on the occasion of the subscription), financial costs, remuneration of capital invested, profits of the concessionaire, and in general, the value in return for compliance with all the obligations that the concessionaire acquires by virtue of the contract.

The monitoring component through SIATA has contributions of US\$1 million for five years from public and private companies such as EPM and ISAGEN, which have joined the system as part of their corporate social responsibility.²⁹

For the SIMM, the Office of the Mayor, with the participation of the City's Security Secretariat, has an annual budget of 4.350 billion pesos (US\$1.4 million) for infrastructure and implementation of the security strategy designed by the control center. The project's investments reached approximately 12 billion pesos (US\$3.8 million) in 2010.³⁰

²⁹ SIATA Budget, Aburra Valley Metropolitan Area, 2013. Link: http://www.wcdrr.org/uploads/37131_candidateinformationspanish.pdf

³⁰ Investment Budget by Results, Office of the Mayor of Medellin, 2013. Link: https://www.medellin.gov.co/irj/go/km/docs/wpcontent/Sites/Subportal%20del%20Ciudadano/Plan%20de%20Desarrollo/Secciones/Instrumentos%20de%20Seguimiento_0_/Documentos/2012-2015/PresupuestoPorResultados/PresupuestoPorResultados_2013.pdf

5. Monitoring and Control

5.1 General Description

In the evaluation, no evidence was found of a specific system of indicators to measure in an integrated way the management of the smart city. Each dependency—the SIATA, the SIMM, and the Mobility Control Center—has specific indicators to measure the effectiveness of its operations, the impact of the use of devices in the field, and comparators with incidents in previous years.

Medellin has an indicator reporting system that measures the city's management, called the “Medellin como vamos” portal.³¹ It is an integrated site that shows administrative results. In the future, it could include a special chapter on smart city services and integrate the impact of the technologies and applications in the service of the citizens.

5.2 General Benefits of the Medellin Smart City Strategy

The 2014 management report of the Office of the Mayor of Medellin highlights the following data:

- 59 percent of Medellin's population are Internet users thanks to 510 public sites connected to free Internet in the city.
- There are 48 community centers with access to ICT, known as Telecentros.³² They allow citizens to access both the Internet and training through

Operative annual plan of investments, Office of the Mayor of Medellin, 2015. Link:

https://www.medellin.gov.co/irj/go/km/docs/pccdesign/SubportaldelCiudadano_2/PlandeDesarrollo_0_17/Publicaciones/Share%20Content/Documentos/2015/POAI%202015.pdf

³¹ Medellin Como Vamos Portal. Medellin Como Vamos Report, 2014. Link: <http://www.medellincomovamos.org>

³² Digital Inclusion in Telecenters. Link: <http://tecnayudas.com/index.php/inclusion-digital-telecentros>

- classroom courses in office automation and virtual training courses for work.
- More than 93,000 people have participated in workshops and courses in appropriate technology subjects in the city's townships and neighborhoods.
- Four smart city services have been deployed, 10 applications for access, participation, transaction, and interaction with citizens, and 12 city portals are operating in virtual spaces devoted to collaboration and exchanges between communities.
- 340,000 citizens have connected to free Internet, which is available in 61 public places throughout the city.

5.3 Qualitative and Quantitative Measures for the Analysis of the Benefit

5.3.1 Transportation, Urban Mobility, and Incident Response

Since the implementation of the Smart Mobility System in 2010, a series of results have been recorded, which are presented below. They can still be improved upon, and they should be integrated with policies designed to reduce the use of private cars and significantly improve the use of public services under optimal conditions for all. The current experience has yielded the following results:

- A 24 percent reduction in the rate of traffic accidents for per 10,000 vehicles in the areas covered by the variable messaging panels (compared to 2011–14)
- A 35 percent reduction in the traffic accident rate for every 10,000 vehicles in the areas covered by the photo-detection cameras (compared to 2010–14)

- A 14 percent reduction in the accident rate for every 10,000 vehicles in Medellin. (compared to 2010–14)
- A 7 percent reduction in response time to traffic incidents (compared to 2010–14).
- An 18 percent reduction in the percentage of negative incidents (responses to false alarms) (compared to 2010–14).
- 74 percent fewer drivers fined for exceeding the speed limit (compared to 2010–13)
- 193,840 hours of congestion saved in 2014 as a result of the reduction in response times over 2010
- 27 percent fewer photo-detections were made for speeding (compared to 2012–13)
- 24 of every 1000 vehicles were subject to photo-detection; now only 4 of every 1000 (compared to 2011–14)
- An 8 percent increase in the response time of under 15 minutes to accidents (compared to 2010–14)
- 69 percent fewer drivers were fined for running red lights (compared to 2010–13)

5.3.2 Citizen Protection and Security

In 2014, 12,500 cases were responded to through the emergency line and the video surveillance monitoring system. This is due to an improvement in reported emergency or incident response times. The web platform Seguridadenlinea.com now serves 20,000 users.

The following results in security cannot be attributed solely to the SIMM management and the video surveillance network. Clearly, however, these mechanisms have supported the integration of the efforts to reduce crime rates. The results presented by the Office of the Mayor for 2014 are the following:

- Ostensible reduction in the homicide rate, which registered 69.6 per 1000 residents in 2011, 52.3 in 2012, 38.3 in 2013, and 27.0 in 2014.
- A 20 percent decrease in domestic violence cases, compared to the baseline. The number of cases fell from 5,658 in 2011 to 4,524 in 2014.
- A 40.8 percent reduction in the number of car thefts, compared to the baseline. The number fell from 2,000 cases in 2011 to 1,185 in 2014.
- 50 percent fewer thefts of financial entities, falling from 8 cases in 2011 to 4 cases in 2014.
- A 60 percent reduction in the number of homicides, compared to the baseline. The number of homicides fell from 1,649 in 2011 to 659 in 2014.

5.3.3 Emergency and Response

Modernization of the technologic platform for the 123 System in 2014 led to a larger percentage of calls received and greater system integration. Eighty percent of calls received in 2014 were responded to, compared to 57 percent in 2013.

In 2014, the timeliness of pre-hospitalization emergency and disaster responses remained 14 minutes. With the support of the SIMM, the development of the system that supports the response networks in health with emphasis on emergencies and disaster network, and with an investment in 2012–14 of 42.643 billion pesos, both the response time and the quality of pre-hospitalization care improved. Better coordination was achieved between public and private emergency networks, reducing the preventable mortality rate in Medellin.

5.3.4 Environment³³

Currently, the municipality of Medellin monitors the concentration of particulate material (PM2.5) in the air through stations run by the Aburra Valley Metropolitan Area Air Quality Monitoring Network. In 2014, the concentration of suspended particles in the air smaller than 2.5 (mg/m3) was 17.9 micrograms per cubic meter. This result represents an improvement of 128.5 percent over the goal for 2014.

5.3.5 Interaction with Citizens

5.3.5.1 The Media³⁴

The Metropolitan Area, the municipality of Medellin, and Teled Medellin joined together to create the first integrated real-time weather information system in Colombia, using scientific information produced by SIATA and other meteorological agencies as input. By 2014, all of the daily reports were done in an uninterrupted manner in the spaces destined for this purpose, that is, TV, web page, social networks, and special applications on mobile devices such as smart phones and tablets. Alliances were also established with radio stations to broadcast the reports produced by climate reporters 24/7 throughout the day. This information is also updated in real time on the web page www.clima247.gov.co.

5.3.6 Energy Efficiency

Starting in 2014, the policy of using new technologies in the city's public illumination has intensified, especially with the expanded use of LED technology for illumination of the main parks and plazas. This enables:

- A commitment to the environment: LED lights do not contain mercury or

³³ Management Report, Office of the Mayor of Medellin 2014. Link:

https://www.medellin.gov.co/irj/go/km/docs/pccdesign/SubportaldeCiudadano_2/PlandeDesarrollo_0_17/Publicaciones/Share%20Content/Varios/Informe%20de%20Gesti%C3%B3n%20-AlcaldiadeMed.pdf

³⁴ Management Report, Office of the Mayor of Medellin 2014. Link:

https://www.medellin.gov.co/irj/go/km/docs/pccdesign/SubportaldeCiudadano_2/PlandeDesarrollo_0_17/Publicaciones/Share%20Content/Varios/Informe%20de%20Gesti%C3%B3n%20-AlcaldiadeMed.pdf

hazardous materials, which is why disposing of them does not require plans or procedures applicable to the type of materials contained in conventional light bulbs.

- Energy saving: replacing 70W bulbs that expend 81W with 40W LED bulbs yields 50 percent more energy.

5.3.7 Other Benefits

The benefits transferred by the private operator to the city are translated into a percentage of the total collected according to the conditions of the public-private partnership. In the case of the Mobility Secretariat, the city receives a percentage of the income from the management of each transaction of registering drivers, automobiles, transportation, and manual infractions, as well as those generated by the photo-detectors. As can be observed, the Secretariat has had a steady improvement in its earnings, from around 29 billion pesos (US\$9.3 million) in 2011 to more than 44 billion (US\$14.19 million) in 2014.

6. Lessons Learned

6.1 Social Innovation: The Next Step in Appropriation of Technology

In addition to implementing services, technology, and control centers that centralize the operation of the city, Medellín supports social innovation. Through open government strategies, citizen participation, social innovation, and sustainability, with MDE: Medellín Smart City,³⁵ it hopes to advance a program that is both technological and social. Through strategies such as free hotspots, the co-creation MIMedellin, and content creation, among others,³⁶ the idea is to view technology as a tool that people should know how to use

and enable residents to live better in their surroundings.

6.2 Partnerships among Government Entities for the Integration of Services in Shared Territories

One of the fundamental factors in creating synergies and providing integrated services is collaboration among municipal, departmental, metropolitan, and national administrative entities. Thus, the Medellín Municipal Partnership with the Aburra Valley Metropolitan Area³⁷ enables them to monitor the environment in Medellín and the surrounding municipalities, integrating SIMM into emergency response. This partnership has boosted efficiency in the management of field devices maintained by the Mobility Control Center that require constant support to comply with environmental regulations. Likewise, the collaboration between the National Police, the emergency network and the decentralized entities has been successful thanks to the will and joint participation of the different entities, even though they fall under different government jurisdictions.

6.3 Modernization of the City's Administrative Services Necessary to Implement a Smart Cities System such as that of Medellín

The main point of contact for the citizens of the municipality of Medellín is the administrative services that it provides. This implies that the level of trust in the government is affected by people's impression of the service they receive when transacting with it.

Medellín made important advances in modernizing transactions with the State, such

³⁵Medellín Smart City. Link: <http://mdeinteligente.co/estrategia/>

³⁶Medellín Smart City – Content creation. Link: <http://descubre.mdeinteligente.co>

³⁷Aburra Valley Metropolitan Area. Link: <http://www.metropol.gov.co/>

as the public-private partnership within the Mobility Secretariat, decentralization of technical services, innovation in the USC, and implementation of a one-stop shop for handling transactions in the decentralized branches of the municipality and through the web page, among others. All of this makes the processes and databases of the municipality more organized, which enhances its capacity to manage and integrate smart city services with reliable information for its correct functioning.

6.4 Change Management, Socialization Campaigns, and Citizen Awareness

Before implementing any service that involves interaction with citizens, it is indispensable to identify the social objectives of the project and the benefits that will accrue to the citizens, and to determine the possibility of quantifying them. In implementing the SIMM, for example, an awareness campaign was needed to educate citizens on the importance of electronic detection cameras. Thus, despite the fact that they were pioneering technologies in the country and they encountered resistance, citizens have identified benefits in terms of protection of life and culture. Despite this positive experience, currently some online security services and the benefits of the SIATA system are not broadly understood by the citizens. This sometimes prevents them from taking advantage of all of the positive effects that these initiatives can generate in their everyday lives.

6.5 Self-sustaining Projects with Public-Private Partnerships

Medellin took on the challenge of implementing a project such as the SIMM with three national companies, only one of which had expertise in transit and transportation. In every case it is necessary to have partners that have the knowledge and the strategies to implement them, and that have a firm

commitment with the citizenry and with public resources and the principles of their usage.

When structuring the project, it is important to keep in mind the following:

- Identify projects that have their own sources of income, that is, that do not require additional contributions from the government, such as mobility in Medellin.
- Structure projects in such a way that the private operator finances all of the investment and covers the expenses incurred by the project.
- Include in the contracts funds for research and development to seek efficiencies and modernization of the components.
- The long term stimulates public-private partnerships for the construction of projects that are coherent and self-sustaining over time. During the planning phase, the concessionaire should develop and present a work plan that meets their obligations in the contract. In the execution phase, the concessionaire must implement the solution in accordance with the levels of service of each process.

6.6 Building Smart Cities

A city that wishes to become a smart city should take other world cities that have been successful at this as a point of reference. It should analyze their transportation systems, road infrastructure, and culture, among other aspects, and if possible request the collaboration of outside entities and experts in this area.

It is important to work together, involving the municipality as well as civil society, academia, and the private sector, to establish development objectives for the city and plan the future in a sustainable manner, learning

from past mistakes and prioritizing people and the environment.

It is important to plan holistically. To do so, some aspects that should be taken into consideration are mobility and transportation, use of the soil and zoning, the environment and climate change, fiscal management, and citizen security. Additionally, cities should exchange knowledge and open themselves up to constructive criticism by the citizens.

7. Conclusions

- Smart cities are a great way to stimulate social and economic growth. They seek to optimize service delivery to citizens, such as the management of the supply and consumption of energy and water, improvement of transportation and mobility, citizen security, and civil protection, among others. Improving these services will transform the city.
- Among Medellín's goals is to become a smart city in the medium term. Within that transformation process, it has centralized efforts to improve citizen mobility by including companies that have experience managing control centers, technological infrastructure and optimization, and management software. The fact that transactions are more efficient and that driver education and security are promoted has meant that the improvement in the quality of life indicators for residents of Medellín has proportionally advanced smart city objectives.
- Not everything along this path has been easy: the integration of service-operation entities has been slow in the absence of inter-administrative agreements that enable information sharing. Technological delays in some components have hindered their integration, and the lack of resources in some entities has prevented a more vigorous campaign to publicize the availability of services.
- The increase in the number of vehicles in

large cities such as Medellín and other similar cities has accorded an important role to mobility and transit management in the development of smart cities. For that reason the city's Transit Control Center has been the fundamental pillar that has enabled it to integrate a great deal of information and the extensive and intensive application of ICTs. This has made this solution a role model to be followed and has allowed the region to advance as a smart city.

- In Medellín, the priority has been to emphasize the mobility system as the first achievement. Barcelona, which has a similar economy and population size as Medellín, and which is one of the first smart cities, has also based its strategy on sustainable mobility by implementing messaging panels, electronic mobility, and the use of bicycles with the construction of bicycle routes and control centers. If these two experiences are compared, it is evident that Medellín does not have far to go to reach the same horizon as Barcelona.

Appendix A.

Advanced Technical Specifications

1. Central System (Integrated Operation and Control Center) and Communications Solution

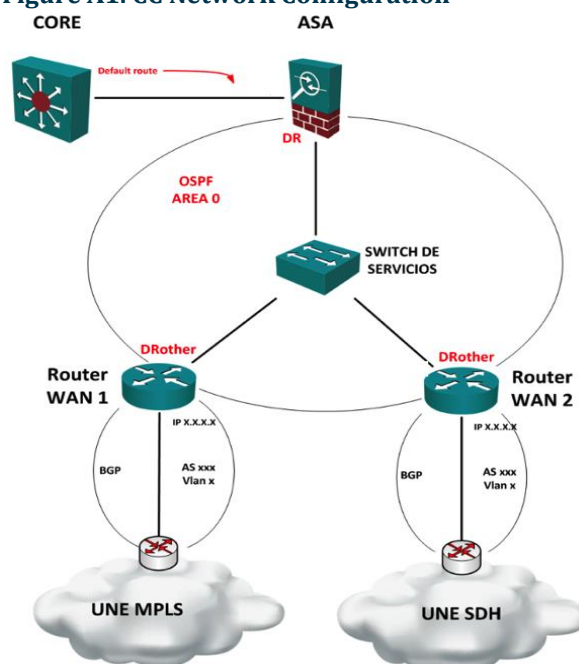
The SIMM technological solution is based on highly redundant infrastructures having specifications required by the manufacturer of each subsystem or peripheral system.

For the operation of the SIMM, LAN, and WAN services, security platforms, application servers and databases, storage services, and monitoring of each element of the IT network have been implemented. Additionally, there are trained staff members to address issues in the technological infrastructure 24 hours a day, 365 days a year.

The SIMM has different help desks for citizens that are connected via fiber optics. This service is implemented on UNE's MPLS network and provides redundancy because it is configured in rings, allowing information to reach its destination even when some MPLS network equipment is not available. This is achieved because the network traffic takes another path.

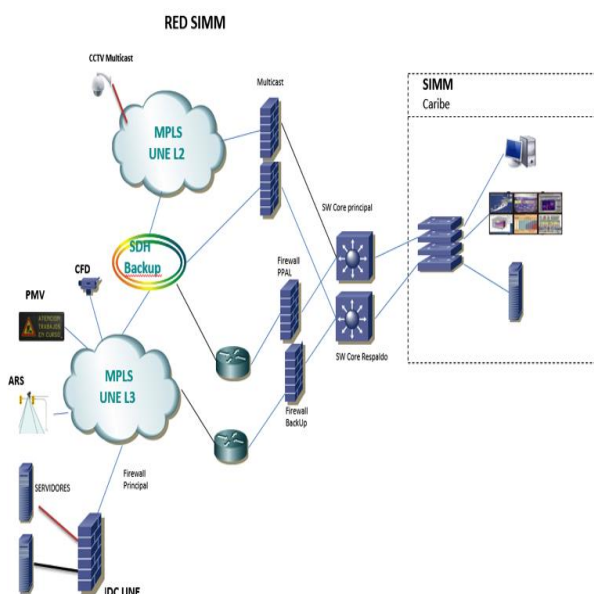
The headquarters of the Mobility Secretariat of Medellín has a configuration that provides greater availability to communicate with UNE's data center. Apart from having an MPLS link with ring configuration, it also has an SDH link, also configured in rings, with fiber and fully independent equipment wired through different routes.

Figure A1. CC Network Configuration



Source: Technical Report SIMM.

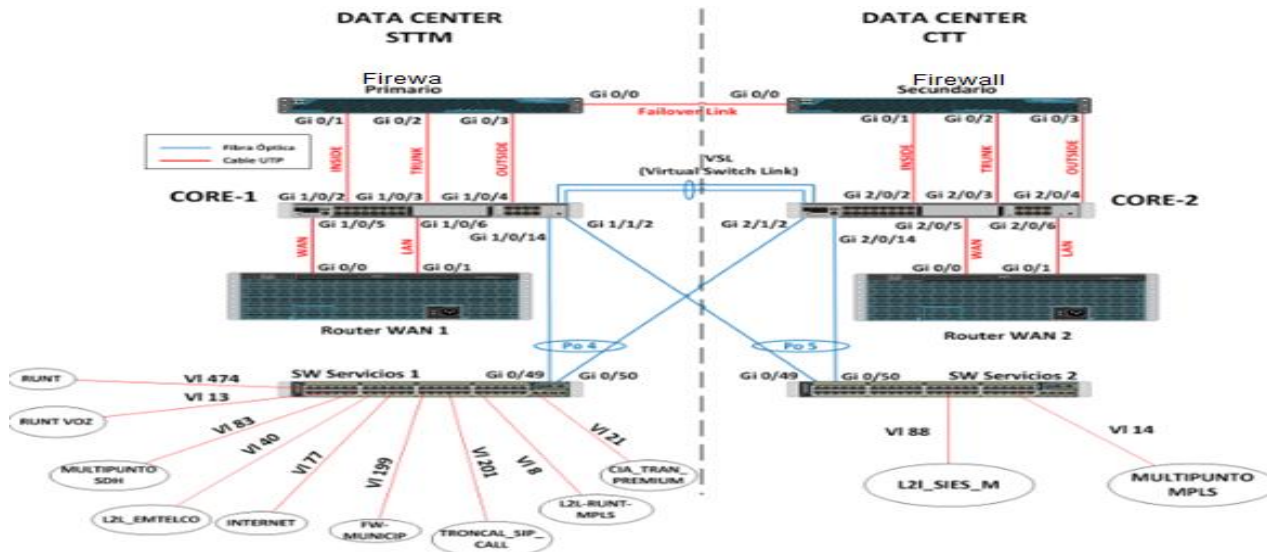
Figure A2. Control Center Network Configuration 2



Source: Technical Report SIMM.

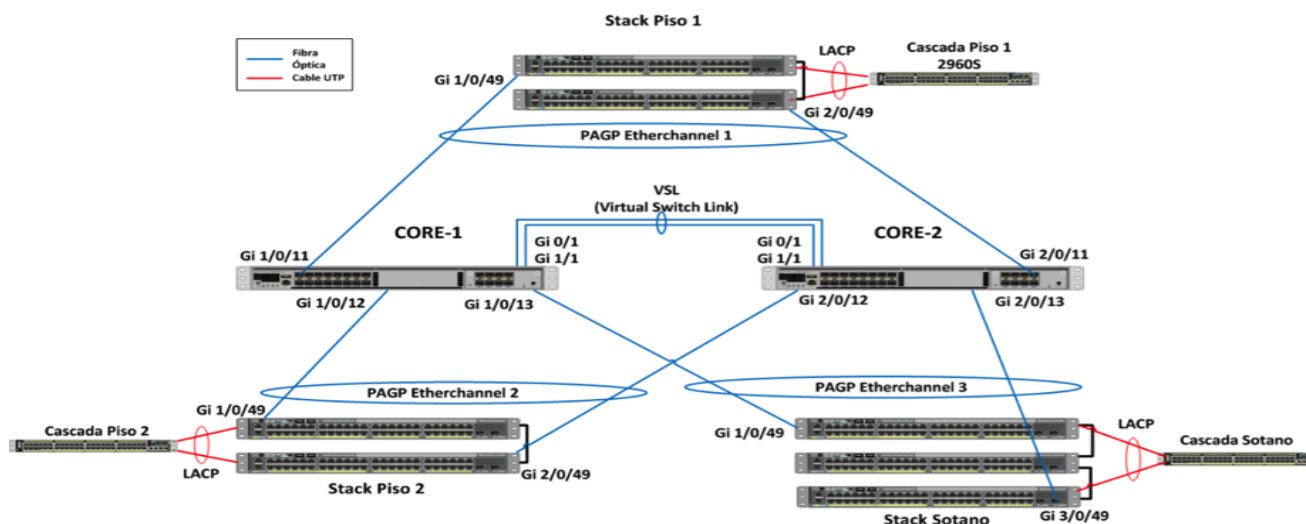
All network elements are configured in high availability and contingency teams assuming roles automatically. This applies for Core Switch, Firewall, WLC, and Routers. The edge switches are set to Stack and tolerate a fiber disconnection or disconnection from cables that are part of them.

Figure A3. Control Center Network Configuration 3



Source: Technical Report SIMM.

Figure A4. Control Center Network Configuration 4



Source: Technical Report SIMM.

In terms of IT security, the headquarters and the different data centers are protected with a perimeter firewall that only allows access to previously authorized staff and through ports strictly required to operate. There are different security consoles, including antivirus, anti-spyware, anti-spam, NAC, and agents installed on the users' computers, all of which generate alerts that facilitate the identification of events. Additionally, there are tools that conduct controlled updates of each of the elements in the infrastructure.

All servers and storage are hosted in the data center, which features fingerprint devices to control entry. The air conditioning system is configured to deliver the temperature recommended by the factory; there is back-up air conditioning so that, in case of failure of the main air conditioning system, the platform does not become affected. There is a fire protection system, and electrical redundancy comprising a double circuit, substations, plants, and UPSs.


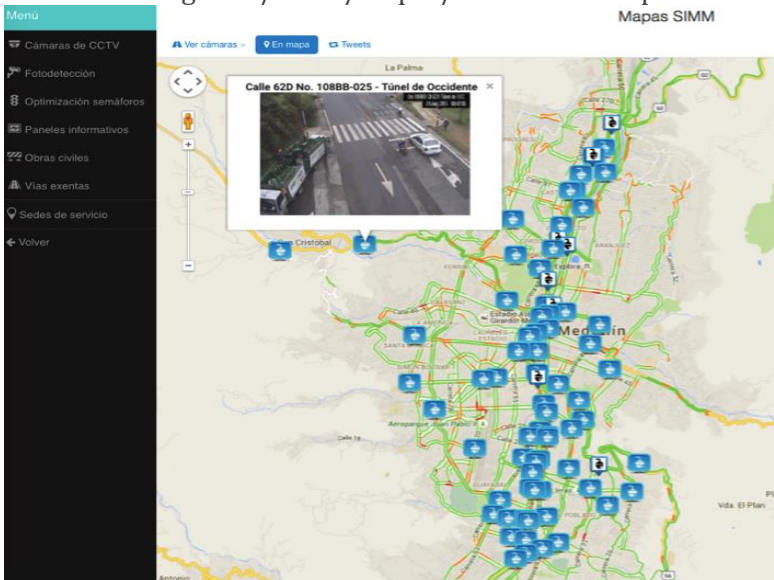
The applications, databases, and network services are configured in a cluster. This is done so that the operation and users will not be affected when there is a logical or physical equipment failure.

Different consoles monitor the entire solution, sounding alarms when a computer is not available, when performance is affected, or when the resources provided reach the defined thresholds.

2. Field Systems

2.1 CCTV- Closed Circuit Television - Mobility


Table A1. CCTV Circuit

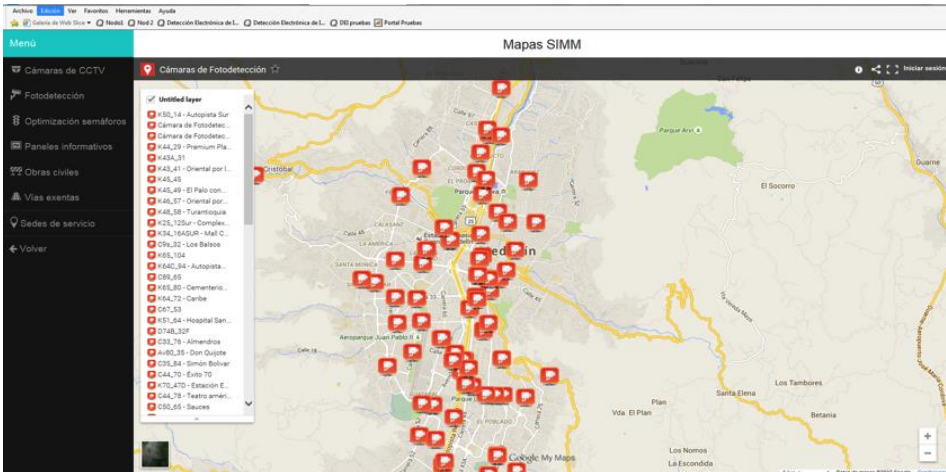
Field device	
Functions	<p>The CCTV system has specialized cameras used exclusively for mobility, located in strategic mobility points of the city such as roundabouts and intersections on the main routes, with a monitoring center in the STTM. Online display at the portal.</p>
Technical specifications: hardware	<p>Hardware:</p> <ul style="list-style-type: none"> • IP video camera, PTZ (Pan / Tilt / Zoom) type with vertical and horizontal motion and zoom and 360-degree rotation • Color camera with day/night vision, manual and automatic focus, and lens with automatic lighting adjustment • Different compression format settings (H.264, EPMG-4 and MJPEG)
Reference and amount	<p>80 CCTV cameras for mobility monitoring</p>
Map and location	<p>Map: https://www.medellin.gov.co/simm/mapas/index.html?map=camarasCctv :</p> 

Source: Smart Mobility System.

2.2 Cameras for Electronic Photo-detection

Table A2. Field Devices for Photo-detection

Field device	
Functions	<ul style="list-style-type: none"> • Electronic detection of the following offenses: • Failure to stop at a red light or yellow light, a STOP sign or a flashing red light • Driving a vehicle exceeding the speed limit • Driving through restricted places or at hours prohibited by the competent authority • Driving vehicles weighing 3.5 tons or more in the left lane of the road when there is more than one lane • Parking a vehicle in prohibited places • Disregarding pedestrians crossing a road in an area allowed for them or not giving them priority in the crossings established for that purpose • Required documents expired: compulsory insurance and technical and mechanical inspection • Vehicle count and classification • Management of black lists and white lists
Technical specifications: hardware	<p>Fixed inductive loops or laser-type radar detector</p> <p>Components:</p> <ul style="list-style-type: none"> • Video and snapshot unit • Certified speed • Detection unit • Processing unit • Energy unit and connection to peripherals • Energy unit and connection to peripherals • Dim infrared lighting unit • Cabinets • License plate reader with OCR recognition in all cameras
Reference and amount	40 Cameras at 70 points

Map location	and	https://www.medellin.gov.co/simm/mapas/index.html?map=camarasFotodeteccion 
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Source: Smart Mobility System.

2.3 Mobile Cameras for Electronic Detection


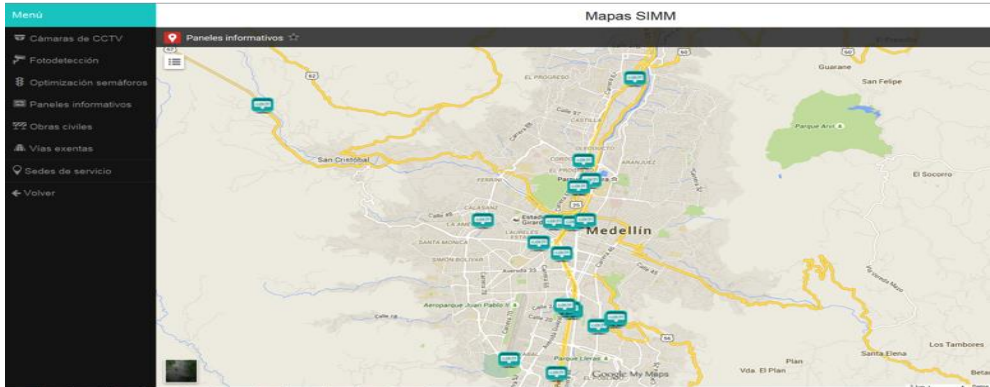
Table A3. Field Devices for Mobile Cameras

Functions	The portable automatic speed surveillance equipment is normally used in roads and streets and is very effective in reducing accidents. All vehicles passing by the camera are audited, whether they are exceeding speed limits or not, allowing statistical analysis that assists in traffic management processes.
Technical specifications: hardware	<p>It has a high-quality camera especially developed for transit operations, taking an irrefutable recording of the offense.</p> <p>Uses glare-free (infrared) illuminator for operations with low lighting</p> <p>Protected from bad weather and electrostatic charges</p> <p>Complies with all regulatory metrology</p> <p>Performs simultaneous control in roads having up to four lanes</p> <p>On-line operation with the processing center</p> <p>Quick and easy operation, and can be installed by one technician</p>

Source: Smart Mobility System.

2.4 Variable Messaging Panels

Table A4. Field Devices of Variable Messaging Panels

Field device	
Functions	<p>The variable messaging panels (VMP) are traffic control devices that, through different dynamic messages with letters, symbols, and figures, provide drivers with information about traffic accidents, the state of vehicle circulation, and different traffic circumstances, enabling them to select the best routes to reduce travel times, traffic volume, and accident rates caused by conditions that can be forewarned.</p>
Technical specifications: hardware	<p>Hardware:</p> <ul style="list-style-type: none"> • Based on high-resolution light emitting diodes (LED). At least 64x64 pixels. Each character matrix of at least 7x5 pixels. At least 12 LEDs per pixel. • At least 6.1 m by 2 m for entrances to the city (Type 1) and at least 4.5 m by 1.5 m (type 2) to other areas within the city. For different dimensions, the length defined by the abovementioned measures for each type of VMP must be respected. • Useful life demonstrable by experience of at least 10 years • Power consumption of 150 W per square meter of panel at the most • Panel day and night visibility at distances of 250 mts, assessing that distance with 450-mm letters with a minimum angle of 30°
Reference and amount	22 panels
Map and location	<p>https://www.medellin.gov.co/simm/mapas/index.html?map=panelesInformativos</p> 

Source: Smart Mobility System.

2.5 Optimizing Traffic Lights

Table A5. Optimizing Traffic Lights

Field device	
Functions	The traffic optimization field device features a technological system that optimizes the operation of the city traffic light network, using tools that provide information about the number of vehicles on the road, average speeds, and road occupancy, among other indicators. It consists of 120 DVS cameras (Vehicle Detector Center) with video analytics software in 21 intersections with traffic lights. Additionally, there is a specialized traffic light planning software that allows technical staff to evaluate different optimization scenarios and response of road intersections for better mobility.
Map and location	<p>https://www.medellin.gov.co/simm/mapas/index.html?map=optimizacionSemaforos</p> 

Source: Smart Mobility System.

2.6 Technological Component on Buses

Table A6. Technological Components for Buses

Functions	Central electronic device that enables the concentration, unification, and transmission of positioning information, speed, door states, monitoring of passengers, among others, transmitted from vehicles providing public transport
Technical specifications: hardware	<p>Hardware:</p> <ul style="list-style-type: none"> • Global positioning system • Microprocessor that allows and ensures the correct acquisition and transmission of information by processing, storing, communicating, encrypting, and centralizing data provided by the global positioning system • Bidirectional and wireless telecommunications that guarantee online or batch sending and receiving • Storage media: SD Card, MiniSD, MicroSD or SDHC • Battery for devices

	<ul style="list-style-type: none"> Designed to ensure at least 95 percent availability and operability, considering operating conditions in the vehicle, such as vibration, dirt, moisture and temperature <p>Software:</p> <ul style="list-style-type: none"> Allows and ensures proper acquisition and transmission of information by processing, storing, communicating, encrypting, and centralizing data provided by the global positioning system, the telecommunications module, and the automatic counting sensors of passengers and closed/open door state sensors Centralized data reception Control of telecommunications processes and the particular application of each of the rules resulting from the events, states, instances, and time required Tasks ensuring the integrity, reliability, data security and detailed record of each data reception, data delivery, and data processing transaction, device status, errors arising from the operation, storage, event recording, and registration changes in the program (version and date of last update) Tasks ensuring management of the input and/or output components, memory management and, in general, controlling the integration of all the equipment on board in the vehicle
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Source: Smart Mobility.

2.7 Mobile Computers for Traffic Fines

Table A7. Devices for Mobile Computers for Traffic Fines

Functions	An electronic device that enables the issuance of traffic fines in digital form allowing automatic printing of the fine, its registration, and transmission to the central traffic system via Internet
Technical specifications: hardware	<p>Hardware:</p> <ul style="list-style-type: none"> Bright 4-inch WVGA multi-touch screen For industrial environments Readability of barcode WAN radio options with voice and data Improved battery technology Equipped with efficient dual-core multiprocessor architecture GPS and GPRS support Software Allows recording information of a traffic fine Allows printing the traffic fine Sends the information to the mission traffic system Allows registering the location of the mobile computer at any time Allows recording of evidence to substantiate the fine, such as photos and videos
Reference and amount	160

Source: Intelligent Mobility System.

2.8 AVL System


Table A8. AVL System Components

Functions	The AVL system is intended for geo-positioning activities of STTM vehicles
Technical specifications: hardware	<p>Hardware:</p> <ul style="list-style-type: none"> • High-sensitivity module • Global positioning system • Communication GSM/GPRS/SMS, four bands (850/900/1800/1900 MHz) • Functions control via the Internet (TCP/IP or UDP) • Geo-reference reports with individual settings • Automatic troubleshooting of report transmission • Digital inputs with status change report • Individually controllable digital outputs • Configurable firmware update online • Software • Configurable reports • Position and speed, programmable distance and/or time • Total distance traveled, configurable by time • Exceeded and normal speed with configurable speed limit • Input status change • Off and ignition • Unit reset • Panic button • Synchronized GPS • Position request

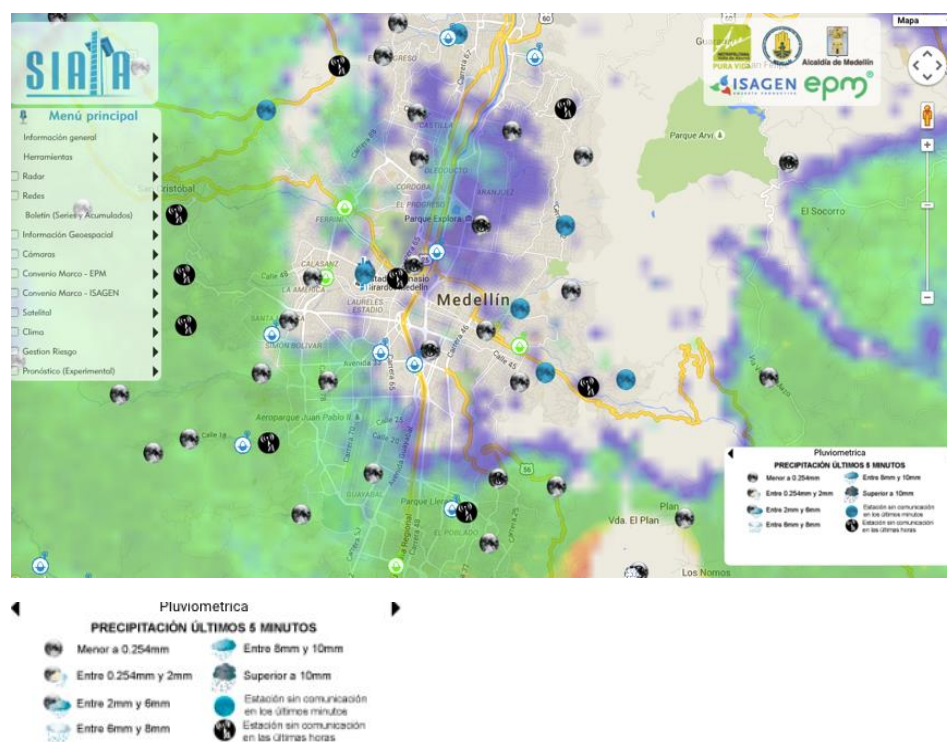
Source: Intelligent Mobility System

2.9 SIATA - Rainfall Network

Table A9. SIATA - Rainfall Network Components

Field device		
Functions	It is the strongest network that SIATA currently has. The stations send real-time rainfall information, which is continuously updated and displayed to the community through the geo-portal and other tools designed to disseminate information (Twitter, social networks and emails).	
Reference and amount	71	

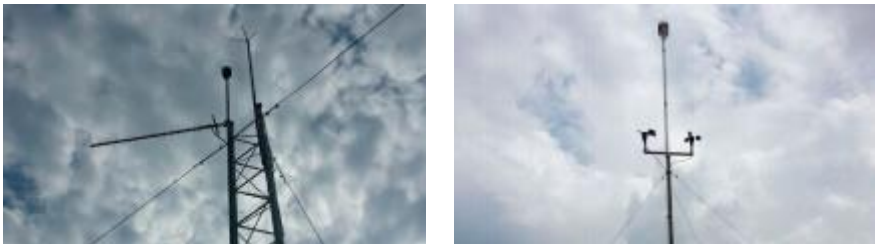
Map and location

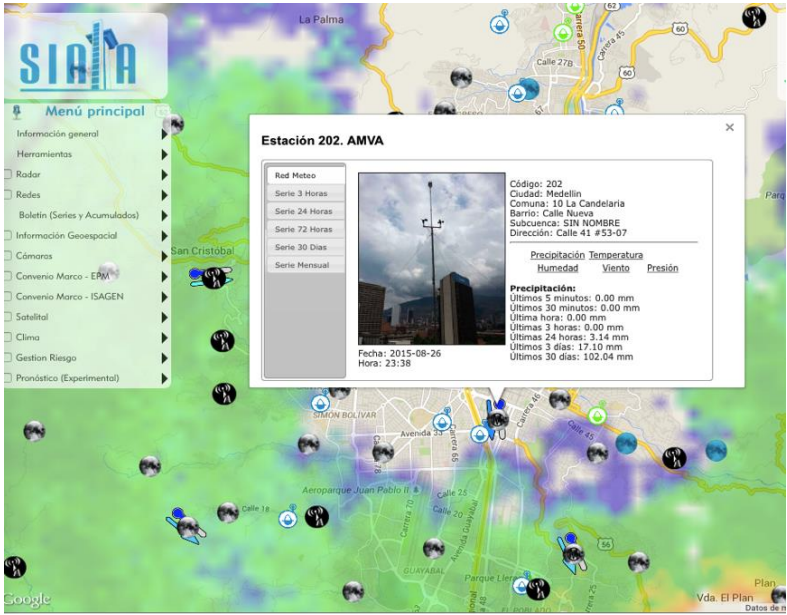


Source: SIATA.

2.10 SIATA - Weather Network

Table A10. SIATA - Weather Network Components

Field device		
Functions	<p>Sensors comprising this network monitor temperature, humidity in the environment, and wind direction and speed at seven points in the Aburra Valley. The stations are located from north to south as follows: Parque de las Aguas, Botanical Garden, Building The Metropolitan Area of the Aburra Valley, National University (Agronomy campus), SIATA Tower (Stadium Sector), RADAR Tower (Santa Elena), and Itagui Council Educational Institution.</p>	
Reference and amount	7	

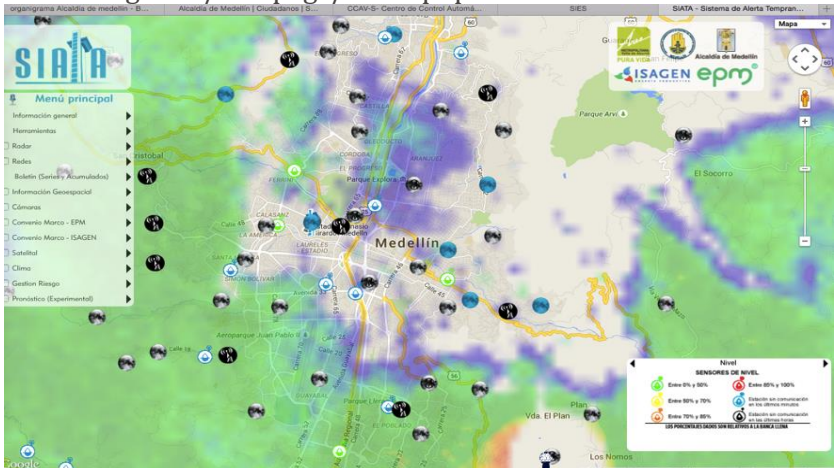
Map and location	
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Source: SIATA.

2.11 SIATA - Level Sensor Network

Table A11. Level Sensor Network Components



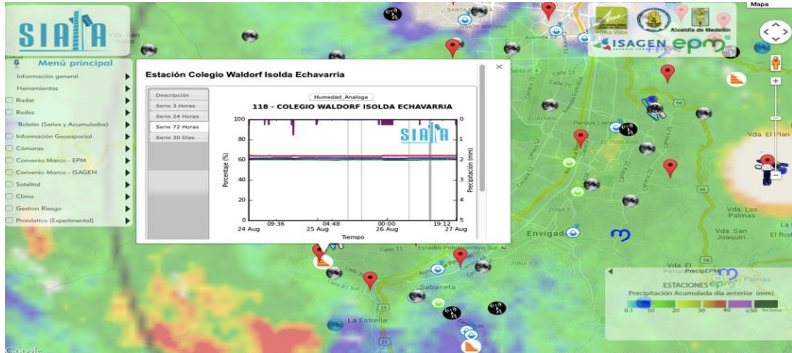
Field device	
Functions	<p>As of this date, the network comprises eight sensors located on some of the most important watersheds of the Aburra Valley (Medellin River, La Presidenta Gorge, La Hueso Gorge, Altavista Gorge, La Gomez Gorge). This network is responsible for monitoring the level of streams and generating real-time information to the community. There are four stations installed on the Medellin River: the Bridge on the Aguacatala River, the Bridge at Calle 33, the Environmental School Paseo del Rio and Parque de las Aguas. The network will consist of 27 radar-type level stations, with technology that detects fluctuations in the levels of the main gorges of Medellin and the metropolitan area.</p>
Reference and amount	27a

Map and location	http://www.SIATA.gov.co/newpage/index.php 
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Source: SIATA.

2.12 SIATA - Soil Moisture Network

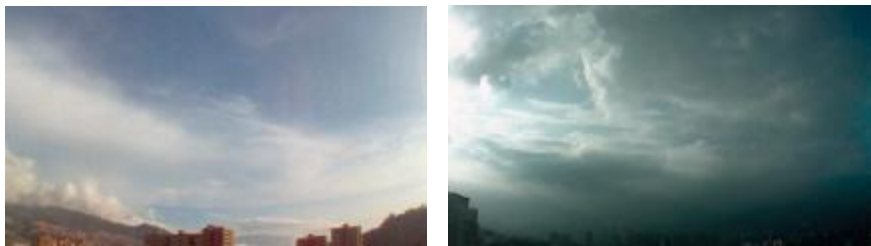
Table A12. Soil Moisture Network Components

Field device	 
Functions	<p>This network will comprise 33 moisture stations to be located on the slopes of the city, which will indicate the level of saturation of the soil and determine, based on studies and hydrological models where work is underway, the level of risk on different slopes. The devices monitor humidity, temperature, and electrical conductivity at the point of study.</p>
Reference and amount	33
Map and location	

Source: SIATA.

2.13 SIATA - Camera Network


Table A13. Camera Network Components

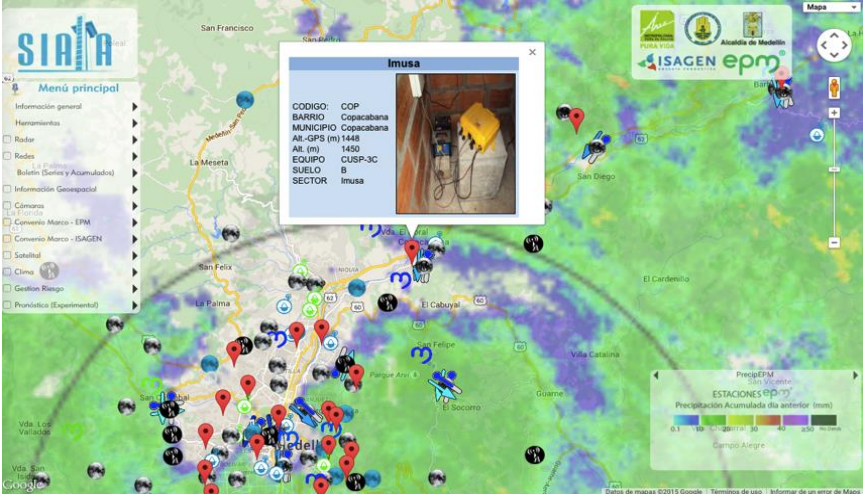
Field device	
Functions	Seven video cameras film the skies of Medellín in real time. Through the images, first-hand information is obtained on the formation of clouds and rain systems in the Aburra Valley. Five cameras are located on the SIATA Tower overlooking different directions, and two are in the Radar Tower (village of Santa Elena) overlooking the west of the valley.
Reference and amount	7

Source: SIATA

2.14 SIATA - Accelerograph Network

Table A14. SIATA - Accelerograph Network Components

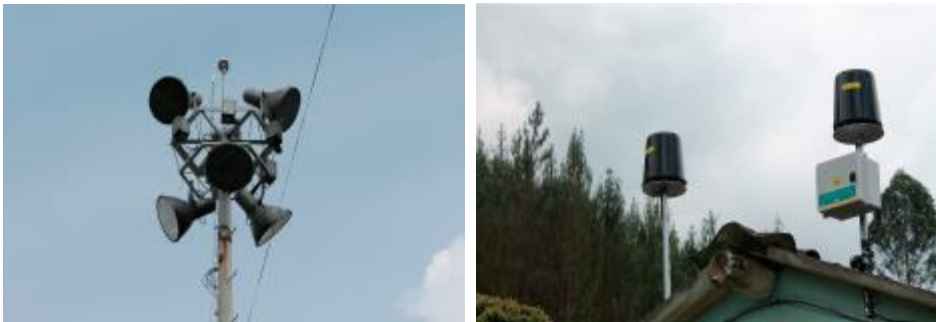
Field device	
Functions	The Accelerograph Network of Medellín - RAM and Metropolitan Area - RAVA were installed by the Seismology Group of Medellín. The accelerograph network of the Aburra Valley - RAVA starts in 2000 with a micro-zoning project of the Metropolitan Area, which enabled equipment to be installed in Bello and Itagui. In 2008, the Project was supposed to zone the other municipalities that were missing (Caldas, La Estrella, Sabaneta, Envigado, Copacabana, Girardota and Barbosa). There are 30 teams from both RAM and RAVA networks, jointly operated by SIATA.
Reference and amount	30

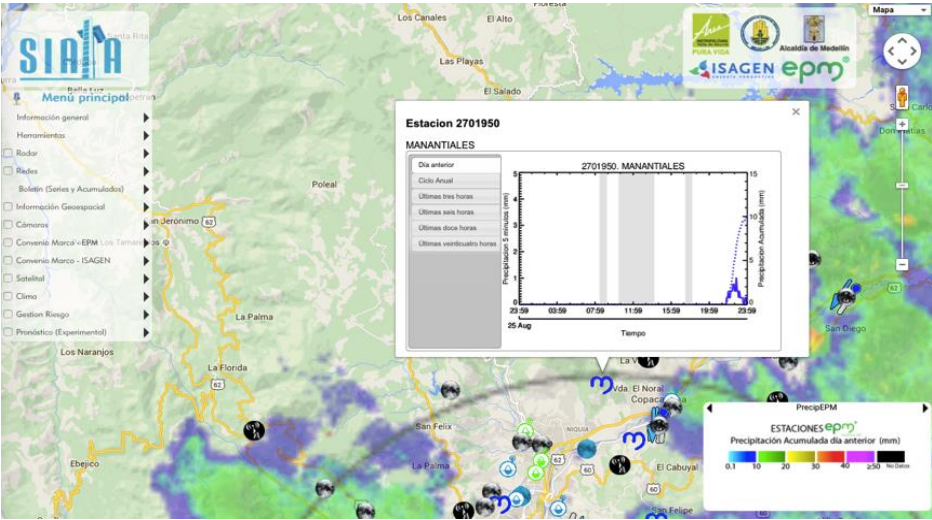
Map and location	
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Source: SIATA.

2.15 Other Networks

Table A15. Other Network Components


Field device	
Functions	<p>In addition to the three major networks, the geo-portal shows not only the radar information and the above-named networks, but also the rainfall data generated by EPM network, the air quality network of the metropolitan area (RED AIRE) and the water quality network (REDRIO).</p> <p>There is also an online newsletter, which publishes rainfall accumulation in the last three, 24, and 72 hours.</p> <p>Users can access geospatial information of the limits of the municipalities of the metropolitan area and Antioquia. In the risk management menu, the staff and the community in general can access different environmental studies, such as the study for threat, vulnerability, and risk for landslides, torrential floods and floods in the Aburra Valley and the Land Use Plan and Management Plan of the Aburra River–POMCA. It also generates reports on Microzoning and Seismic Risk Evaluation of the Aburra Valley 2007 and the Second Integrated Survey of Hydrological Sub-basins of Medellín, 2011. These studies, integrated into the RADAR and rain information of SIATA, produce vital firsthand information for CMGR officers.</p>

<p>Map and location</p>	<p>EPM Rainfall Network</p> 
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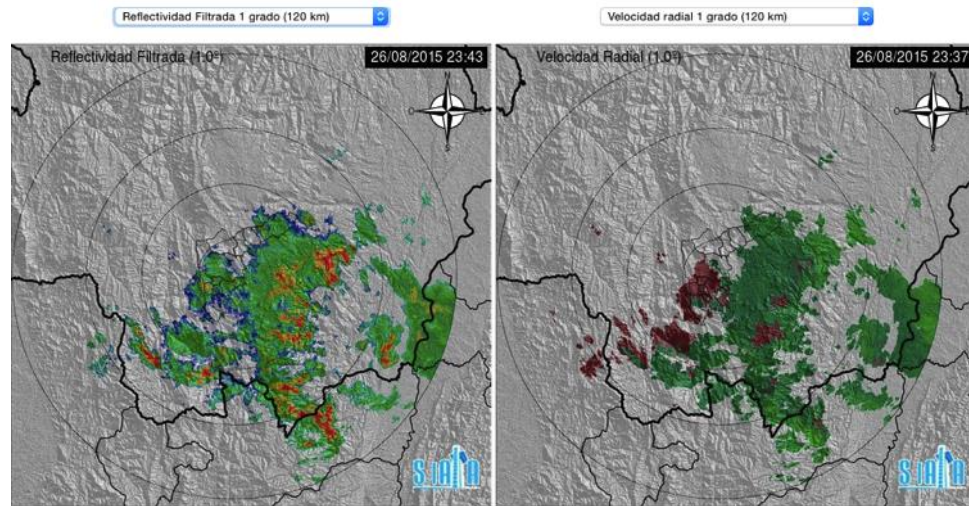
Source: SIATA

2.16 SIATA – Radiometer

Table A16. SIATA - Radiometer Components

<p>Field device</p>	
<p>Functions</p>	<p>The radiometer is responsible for monitoring the vertical structure of the atmosphere, measuring variables such as temperature, humidity, and amount of water in the atmosphere. In Latin America, there are only three: one in Mexico, one in Brazil, and the latest installed in Medellín. Medellín is the first city in Colombia to have this equipment. It is key to short-term weather forecasting and crucial to understanding the phenomena generated in the valley, including the detection of the degree of atmospheric instability and the influence of the state of the atmosphere on air quality.</p>

Map and location



Source: SIATA.

Appendix B.

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2. Stakeholders and Contact Information





Table A17. Stakeholders and Contact Details

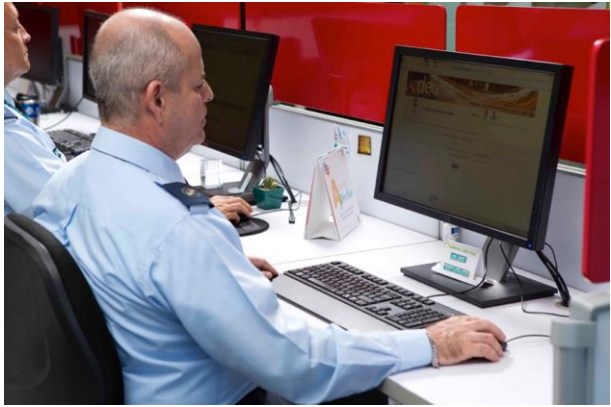



Entity	Contact
Sistema Integrado de Movilidad de Medellín (SIMM)	Traffic Secretary Omar Hoyos Legal and Administrative Deputy Secretary Carlos Lema
SIATA (Sistema Integrado de Movilidad de Medellín)	SIATA Press Assistant Alejandra Parra Goez SIATA Press Assistant Daniela Garcia Londoño
EPM (Empresas Publicas de Medellín)	Project leader for the internal renewal of EPM Building Diego Leon Salazar Vargas
Office of the Mayor of Medellin	Press Secretary Juan Quiceno
Empresa de Seguridad Urbana (ESU)	SIES General Coordination Colonel Ramon Pelaez
Une	Corporate Services Director Rafael Fernando Roldan Cadavid
XM	New Businesses Manager Ricardo Arango
Consortio ITS	General Manager - Consortio ITS Carlos Marquez



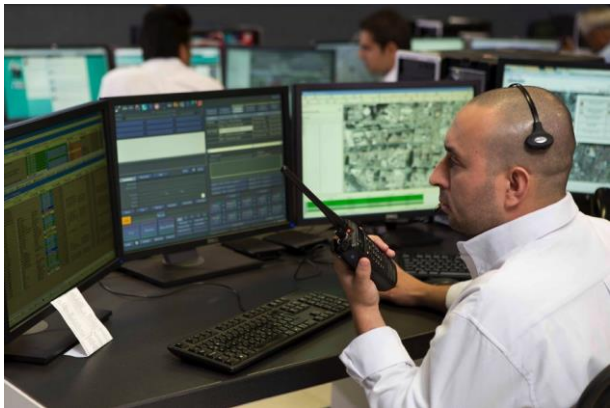

Appendix C. Images


Table A18. Images of the Control Center, Equipment, and City Services

Author	Source	Section	Picture
Medellin Travel	http://medellin.travel/	General Vision of the City	
			
			

Author	Source	Section	Picture
Traffic Secretariat of Medellin	https://www.medellin.gov.co/simmm/	Intelligent Mobility System	
Traffic Secretariat of Medellin	https://www.medellin.gov.co/simmm/	Intelligent Mobility System	
Traffic Secretariat of Medellin	https://www.medellin.gov.co/simmm/	Variable Messaging Panels	
Traffic Secretariat of Medellin	https://www.medellin.gov.co/simmm/	Electronic detection of traffic offenses	

Author	Source	Section	Picture
			
Traffic Secretariat of Medellin	https://www.medellin.gov.co/simmm/	Closed Circuit TV	
Traffic Secretariat of Medellin	https://www.medellin.gov.co/simmm/	Control Center	 

Author	Source	Section	Picture
			
<p>Traffic Secretariat of Medellin</p>	<p>https://www.medellin.gov.co/simm/</p>	<p>Traffic Light Control Center</p>	
			
			

Author	Source	Section	Picture
Traffic Secretariat of Medellin - Consorcio ITS	https://www.medellin.gov.co/simmm/	Control of Collective Public Transportation Fleet	
Traffic Secretariat of Medellin	https://www.medellin.gov.co/simmm/	Information System for Users	  

Author	Source	Section	Picture
			
Traffic Secretariat of Medellin	https://www.medellin.gov.co/si/mm/	Urban Security System- SIES M	
Early Warning System	http://siata.gov.co/newpage/web/nosotros.php	Early Warning System	

Appendix D. Template for Development Stage of Different Services

Table A19. Template for Development Stage of Different Services

Service range		Smart city functions and means				
Service domain	Service system	Data collection and monitoring	Control	Information production and data processing	Information reporting for citizens	Exchange of information between services
		Signal controller, image detector, BIS, closed circuit television		Smart city operations center	VMS, VDS, BIS, Internet, mobile devices, call center, e-government, Open-API, broadcasting, and media	Information platform (ownership, control, and monitoring system)
Transport and urban mobility	Adaptive traffic light system	2	1	2	0	2
	Advanced driving systems	2	0	2	3	2
	Public transport information system	3	3	3	1	2
	Incident management system	4	3	3	2	2
	Parking information system	5	4	4	4	3
	Limited time parking	2	2	2	1	1
Citizen safety	Crime management system	4	3	4	2	2
Emergencies and civil protection	Disaster management system	4	2	3	2	4

Environment	Aqueduct management system	3	3	3	2	2
	Waste management system	2	3	2	2	2
	Environmental control (noise, air quality, weather)	4	4	4	3	3
Energy efficiency	Energy management system	3	3	3	2	3
Interaction with citizens and means of communication	Communication with citizens	2	2	2	3	2

Note: The numbers refer to levels of performance according to the following references: 4: advanced, 3: moderate, 2: basic, 1: to be introduced in the future, and 0: absent.

