CHARACTERIZATION OF THE LIGHTNING SAFETY EDUCATION PROGRAMS
IN THE WORLD AS A FIRST STEP FOR THE CREATION OF
A LIGHTNING SAFETY POLICY IN COLOMBIA

A research-innovation project presented by

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FRANCISCO JOSÉ DE CALDAS

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CHARACTERIZATION OF THE LIGHTNING SAFETY EDUCATION PROGRAMS IN THE WORLD AS A FIRST STEP FOR THE CREATION OF A LIGHTNING SAFETY POLICY IN COLOMBIA

In fulfillment of the requirements for the bachelor degree ELECTRICAL ENGINEER

A research-innovation project presented by DANIEL ESTEBAN VILLAMIL SIERRA

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UNIVERSIDAD DISTRITAL FRANCISCO JOSÉ DE CALDAS FACULTY OF ENGINEERING Bogotá D.C., Colombia 2017
To my Beloved Lord Jesus Christ, the Son of God, whose second coming will be soon as the lightning that flashes and lights up the sky from one side to the other (The Holy Bible, Luke 17:24)
I want to start by thanking my Advisers, Professors Francisco Santamaría and Wilson Díaz, for their guidance, support, enthusiasm, and patience during all the process of this research. I really appreciate all the times they listened to my ideas and encouraged me to seek for excellence.

It has been a great honor for me to be part of the Faculty of Engineering, its Electrical Engineering Career, and the GCEM Research Group. I thank all my professors and my fellow students for their interest in this project.

I am very grateful to Professor Carlos Javier Mosquera, current Rector of the Universidad Distrital Francisco José de Caldas, for being interested in knowing and supporting this project personally.

Certainly this work would not have been possible without the support of my parents, Fabio and Olga, and my brother, Juan Manuel. Their permanent love is a treasure that I ask God to enjoy for many years more.

I would also like to express my gratitude and appreciation for Professor Francisco Román, for his company during this process and for believing in me and encouraging me to dream that I could achieve great things when I thought it would be very difficult to do.

Special thanks are due to Professor Mary Ann Cooper, who reviewed and edited this document with great dedication and enthusiasm. Her comments, advises, and contributions were key to substantially improve the quality of this research-innovation project. I really hope to continue learning from her for a long time.

I want to express my sincere gratitude to the 65 lightning experts, whose names are listed in Appendix 1, for cooperating with this research.

I thank Engineer Pablo Aguirre, my friend and fellow student during my whole career, for his great help in the adequacy of the information presented in the news of Appendix 3.

I also thank my dear friend Anny Reyes, an Industrial Engineer who helped me to process the information obtained from the survey applied in this project.

I would like to finish these acknowledgments in the most special way, by expressing my gratitude to the most wonderful person on the earth for me, my beloved best friend Laura Daniela Calderón, for her company and for being a source of motivation and inspiration during this process. I love you with all my heart.
Abstract

This research-innovation project presents the results of a study on the education programs on lightning safety that have been implemented in the world. The importance of the study of these programs is based on the multiple injuries associated with atmospheric discharges that have been observed in Colombia during the last years. A primary research is conducted to determine which could be the most pertinent diffusion means to spread the lightning safety message among the rural population, in order to have the necessary elements to propose an educational methodology that may be the first step towards the creation of a lightning safety public policy in Colombia.

**Index terms:** Lightning Risk, Lightning Injuries, Lightning Safety, Education Programs, Educational Methodologies, Risk Management, Public Policies

Resumen

En este proyecto de investigación-innovación se presentan los resultados de un estudio sobre los programas de educación en prevención contra rayos que han sido implementados en el mundo. La importancia del estudio de estos programas se fundamenta en las múltiples lesiones asociadas a las descargas eléctricas atmosféricas que se han observado en Colombia durante los últimos años. Una investigación primaria es llevada a cabo para determinar cuáles podrían ser los medios de difusión más pertinentes para transmitir el mensaje de la prevención contra rayos a la población rural, con el fin de tener los elementos necesarios para plantear una metodología educativa que pueda ser el primer paso para la creación de una política pública en prevención y protección contra rayos en Colombia.

**Palabras clave:** Riesgo por Rayos, Lesiones por Rayos, Prevención contra Rayos, Programas Educativos, Metodologías Educativas, Gestión del Riesgo, Políticas Públicas
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Introduction

Lightning is considered as a prominent topic of research among physicists and electrical engineers worldwide. Many studies have been done to understand the physics of lightning, as well as how to get protection against its negative effects. The latter have been focused on ensuring security facing Electromagnetic Interference (EMI) due to lightning, both conducting and radiating interferences, which may affect living beings, devices, and structures. Many years of work performed by technical committees around the world have produced comprehensive technical standards where the knowledge about lightning is available by presenting terms, definitions, and methodologies related to lightning protection. The European Standard IEC 62305 of the International Electrotechnical Commission (IEC) and the North-American Standard NFPA 780 of the National Fire Protection Association (NFPA) are the most outstanding ones, in which the installation of lightning protection systems is the central issue.

Many countries and agencies within them have also published their own lightning protection codes and standards. For the case of Colombia, the Technical Standard NTC 4552 (acronym of Norma Técnica Colombiana 4552), since its first edition in 2004, has provided guidance regarding criteria for the design, installation, and maintenance of lightning protection measures. NTC 4552 incorporates the principles of IEC 62305 and also takes into account the specific lightning parameters of tropical zone, where Colombia is located (Sánchez et al., 2014). NTC 4552 is the current road map for those who promote lightning protection in Colombia.
While these standards prescribe lightning protection of buildings and other structures, of great concern is the fact that none offer guidance for the protection of those people who live in rural areas. Rural dwellers are especially exposed to be affected by lightning due to daily factors such as labor-intensive agricultural practices in open fields, vast distances between places, and lack of quality medical services, thunderstorm warning information, and immediate emergency response (Gomes and Ab Kadir, 2011). The most important fact is the lack of ‘lightning safe’ areas including substantial buildings, which have plumbing and wiring running through the walls, and fully enclosed metal vehicles, leaving the population vulnerable 24/7 (Gomes et al., 2012). For these reasons, in recent years the research on lightning safety for rural populations has often been oriented towards socio-demographic factors, seeking to find new ways of helping people from the perspective of the social sciences (Trengove and Jandrell, 2011; Holle, 2012; Aini et al., 2014; Cardoso et al., 2014; Elistina et al., 2014; Trengove and Jandrell, 2015).

More than two decades of research attempting to unite social studies with lightning protection have caused researchers to conclude that launching adequate public education programs about lightning safety to all people, within their own contexts, is the key to mitigating risk from lightning, even when there is no technical possibility of applying lightning protection standards (Cooper and Holle, 2005a; Gomes et al., 2006; Cooper and Holle, 2012b; Jayaratne and Gomes, 2012; Gomes and Gomes, 2014; Mary and Gomes, 2014; Villamil et al., 2015).

This research-innovation project is intended to study the education programs on lightning safety that have been conducted to spread the lightning safety message among people in different countries, in order to answer the following research question: which would be the characteristics that a lightning safety education program should have for the Colombian population?

It is hoped that this study will be useful in devising a lightning safety educational methodology proposal that takes into account the particular characteristics and the specific needs of Colombia related to lightning hazard,
especially in areas where people have high risk of disaster (Cruz et al., 2013; Navarrete et al., 2014; Holle, 2015), in order to start the creation of a lightning safety policy in the country (Villamil et al., 2016).

i. **Acronyms and Abbreviations**

The acronyms and abbreviations used throughout the document are:

- AACLENet: African Centres for Lightning and Electromagnetics Network
- CG: Cloud to Ground Flashes
- DRM: Disaster Risk Management
- EMI: Electromagnetic Interference
- GC: Ground to Cloud Flashes
- GFD: Ground Flash Density
- ICLP: International Conference on Lightning Protection
- LLS: Lightning Location System
- LPS: Lightning Protection System
- LRM: Lightning Risk Management
- LS: Lightning Safety
- LSA: Lightning Safety Awareness
- LSR: Lightning Safety Rules
- LSW: Lightning Safety Week
- SALAP: South Asian Lightning Awareness Program
- SNGRD: Sistema Nacional de Gestión del Riesgo de Desastres
- TD: Keraunic Level
- UNGRD: Unidad Nacional para la Gestión del Riesgo de Desastres
ii. Objectives

The primary research objective proposed to be achieved in this research-innovation project is:

**To determine the characteristics of the lightning safety education programs that have been implemented around the world in order to make an educational methodology proposal on lightning safety for Colombia.**

The proposed specific objectives are:

- To describe risk scenarios, related to mortality and morbidity, from atmospheric electrical discharges within Colombian population.

- To depict the main components and indicators of the lightning safety education programs implemented in the world.

- To propose a recommendation for the formulation of a lightning safety policy oriented to the Colombian population.

iii. Organization of the Project

The structure of this research-innovation project is:

- Chapter 1 provides a contextualization of lightning and its associated risk. The basic parameters of lightning and lightning injury mechanisms are presented.

- Chapter 2 describes common lightning risk scenarios from news reports about lightning injuries occurred in Colombia. Recommendations for lightning safety under similar circumstances are given.

- Chapter 3 presents the elements pertaining to the comprehensive education programs and isolated initiatives on lightning safety implemented worldwide. The components of the programs are identified and their impact indicators are analyzed.
• Chapter 4 depicts the design and application of an instrument implemented to determine the most pertinent diffusion means for delivering the lightning safety message to the rural population. The results are presented and analyzed.

• Chapter 5 introduces an overall recommendation for the creation of a lightning safety educational methodology for the Colombian rural population, which is intended to be the first step towards the establishment of a lightning safety policy in Colombia. Both recent national and international changes and new courses that have taken place in the field of disaster risk management are considered.

• Conclusions section presents the main conclusions obtained from the work performed.

• Appendix 1 introduces the 65 lightning experts that cooperated with this work.

• Appendix 2 provides a general insight into the main components of the existing comprehensive education programs on lightning safety and the isolated initiatives on the subject considered in Chapter 3.

• Appendix 3 presents quotations from 100 news reports of lightning injuries occurred in Colombia from 2011 to 2016.

• Appendix 4 presents the publications made from this research-innovation project.
Chapter 1: Lightning and Its Associated Risk

Lightning is a natural phenomenon whose features have not been completely understood yet. Since the famous kite experiment of Benjamin Franklin lightning protection systems have been developed and there has been an increasing comprehension of the electrical nature of lightning. Learning more about the physics of lightning and its global and local effects is a challenge for many, especially for those concerned with the high risk that it poses to human beings.

Recent research and technology advances have led to great improvements in the characterization of the geographic regions where lightning risk to populations is more likely. Likewise, different ways in which humans and animals can be injured by lightning have been identified, namely: direct strike, contact injury, side flash, ground current, upward streamer, and barotrauma.

1.1 Lightning Ground Flashes

While better understood now, lightning is a very complex phenomenon. Lightning flashes that hit the ground (CG) are about 25% of total lightning discharges (Rakov, 2007). Cloud to ground flashes are a consequence of the dielectric breakdown of air that results when an intense electric field between clouds and ground causes an arc discharge through air, making the air conductive for a very short time (Young and Freedman, 2012). The distribution of the electrical charge within a cloud is complex. In general, storm clouds are negatively charged on the lower level and positive higher up (Cooray, 2015).
Chapter 1: Lightning and Its Associated Risk

**Lightning Ground Flash Classification**

Typical classification for this kind of lightning flashes is made according to the following two parameters, both related to its initial leader\(^1\): (i) the direction of propagation and (ii) the polarity of its charge (Dwyer and Uman, 2014). The direction may be *downward* (or *cloud-to-ground*, CG) or *upward* (or *ground-to-cloud*, GC), while the polarity categorizes them as *positively-charged leader* (or *positive*) and *negatively-charged leader* (or *negative*). The combinations of these parameters are illustrated in Figure 1.1.

**Negative Ground Flashes Parameters**

Downward negatively-charged leader flashes are the most frequent cloud-to-ground lightning (90% or more) (Rakov and Uman, 2003), in part because require less energy than the downward positively-charged flashes due to the gap distance between the negative charge center of the cloud and ground is shorter (see Figure 1.1, parts a and c). Table 1.1 lists the typical parameters of negative ground flashes. While all the parameters of Table 1.1 are studied in the field of lightning physics, only a few are directly applied in the field of lightning protection.

1.2 **Lightning Protection Parameters**

Standard IEC 62305-1 defines lightning protection as a “complete system protection of structures against lightning, including their internal systems and contents, as well as persons, in general consisting of an LPS (*Lightning Protection System*) and SPM (*System Protection Measures*)” (International Electrotechnical Commission [IEC], 2010a, p. 12). Table 1.2 presents the lightning parameters for lightning protection engineering applications.

---

\(^1\) “The leader is the initial step in the lightning flash and establishes the conductive channel that the electrical discharge (lightning) will take” (United States National Weather Service (NWS), www.lightningsafety.noaa.gov/science/science_types_flashes.shtml)
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<table>
<thead>
<tr>
<th>Polarity</th>
<th>Direction</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Downward</td>
<td>Upward</td>
</tr>
<tr>
<td>Negative</td>
<td>a)</td>
<td>b)</td>
</tr>
<tr>
<td></td>
<td><img src="image1" alt="Downward negatively-charged leader" /></td>
<td><img src="image2" alt="Upward negatively-charged leader" /></td>
</tr>
<tr>
<td>Positive</td>
<td>c)</td>
<td>d)</td>
</tr>
<tr>
<td></td>
<td><img src="image3" alt="Downward positively-charged leader" /></td>
<td><img src="image4" alt="Upward positively-charged leader" /></td>
</tr>
</tbody>
</table>

Figure 1.1. Four types of lightning ground flashes:
- a) downward negatively-charged leader,
- b) upward negatively-charged leader,
- c) downward positively-charged leader,
- d) upward positively-charged leader

Adapted from Dwyer and Uman (2014)
### Table 1.1. Typical parameters of negative ground flashes

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TYPICAL VALUE OR RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of lightning flash</td>
<td>200–300 ms</td>
</tr>
<tr>
<td>Number of return strokes per flash</td>
<td>3–4</td>
</tr>
<tr>
<td>Time interval between strokes</td>
<td>40–60 ms</td>
</tr>
<tr>
<td>Percentage of flashes with single strokes</td>
<td>20 %</td>
</tr>
<tr>
<td>Speed of stepped leaders</td>
<td>3 × 10^5 m/s</td>
</tr>
<tr>
<td>Length of steps of stepped leaders</td>
<td>10–100 m</td>
</tr>
<tr>
<td>Time interval between steps of stepped leaders</td>
<td>10–100 μs</td>
</tr>
<tr>
<td>The charge per unit length on the stepped leader (close to ground)</td>
<td>0.001 C/m</td>
</tr>
<tr>
<td>Peak current in first return stroke</td>
<td>30 kA</td>
</tr>
<tr>
<td>Rise time of current of first return strokes</td>
<td>5 μs</td>
</tr>
<tr>
<td>Rate of change of current of first return strokes</td>
<td>10–20 kA/μs</td>
</tr>
<tr>
<td>Charge associated with first return stroke</td>
<td>5 C</td>
</tr>
<tr>
<td>Speed of dart leaders</td>
<td>10^7 m/s</td>
</tr>
<tr>
<td>Length of dart of dart leader</td>
<td>10–70 m</td>
</tr>
<tr>
<td>Charge on dart leader</td>
<td>1 C</td>
</tr>
<tr>
<td>Peak current of subsequent strokes</td>
<td>12 kA</td>
</tr>
<tr>
<td>Rise time of current of subsequent strokes</td>
<td>0.5 μs</td>
</tr>
<tr>
<td>Rate of change of current of subsequent strokes</td>
<td>50–100 kA/μs</td>
</tr>
<tr>
<td>Charge associated with subsequent strokes</td>
<td>1 C</td>
</tr>
<tr>
<td>Percentage of flashes with continuing currents</td>
<td>30–50 %</td>
</tr>
<tr>
<td>Duration of continuing currents</td>
<td>100 ms</td>
</tr>
<tr>
<td>Amplitude of continuing currents</td>
<td>100–200 A</td>
</tr>
<tr>
<td>Peak current of M-components</td>
<td>100–200 A</td>
</tr>
<tr>
<td>Rise time of M-component current</td>
<td>400 μs</td>
</tr>
<tr>
<td>Duration of M-component current</td>
<td>2 ms</td>
</tr>
</tbody>
</table>

Adapted from Cooray (2015)
Table 1.2. Lightning parameters for lightning protection engineering applications

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MAGNITUDES AND COMMENTARIES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Of Incidence</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Keraunic Level TD</strong></td>
<td>Thunderstorm days per year. This parameter is used when direct measurements of Ground Flash Density are not available</td>
</tr>
<tr>
<td><strong>Ground Flash Density GFD</strong></td>
<td>Number of lightning per square kilometer - year</td>
</tr>
<tr>
<td><strong>Flash Polarity</strong></td>
<td>Positive or negative</td>
</tr>
<tr>
<td><strong>Multiple Stroke Flashes</strong></td>
<td>Number of strokes per flash</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td>In milliseconds. Lightning total duration or interval between strokes</td>
</tr>
<tr>
<td><strong>Lightning Peak Current Amplitude</strong></td>
<td>In kilo-Amperes. Frequently referenced as the most important parameter in engineering applications</td>
</tr>
<tr>
<td><strong>Charge</strong></td>
<td>In Coulombs. Total, first stroke and subsequent strokes</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td>In A²-s or kJ/Ω. Integral (∫ I² dt), W/R</td>
</tr>
<tr>
<td><strong>Stroke Current Impulse Shape</strong></td>
<td>kA/µs. In which are taken into account the characteristics dependent of the time, with emphasis in the characteristics of the Lightning Current Rate of Rise</td>
</tr>
</tbody>
</table>

Adapted from Torres (2010)

Among the parameters presented in Table 1.2, Keraunic Level (TD) and Ground Flash Density (GFD) are of special importance because they are useful not only in protection applications but also for prevention purposes, inasmuch as these parameters of incidence provide historic information about the number of lightning ground flashes that occur during one year over a specific area.

**Keraunic Level (TD)**

A thunderstorm day is “a day in which thunder is heard by meteorological observers” (Cooray, 2003, p. 131). The idea of this concept was formally established by
the International Meteorological Committee (IMC) after the First International Meteorological Congress, held in 1873, by giving answer to the question ‘In counting Thunderstorms, should the Storms as such or the Days of Storm be given?’ through the following statement:

In order to obtain values which admit better of comparison it is recommended only to count the Days of Thunderstorms ... As days of thunderstorms only those are to be noted on which both Lightning and Thunder have been observed. If only Lightning without Thunder has been noticed the entry for the day must be Sheet Lightning.

(International Meteorological Committee [IMC], 1873, p. 14)

The first isokeraunic maps were made near the end of the 19th century, with plotted contours indicating equal keraunic levels (equal number of thunderstorm days). Figure 1.2 shows the global distribution of annual thunderstorm days registered from the year 2002 to the year 2009 (contours made with color scale); whereas Figure 1.3 presents an isokeraunic map of Colombia for the year 1999 provided by the Standard NTC 4552-1 (contours made with lines).

*Ground Flash Density (GFD)*

The technique of counting thunderstorm days used to determine the Keraunic Level is totally based on human observations, so that measurements can vary among observers. Estimating the number of cloud-to-ground lightning striking an area of one square kilometer in the period of one year by more reliable methods of observation is preferred as more accurate. According to Torres (2010), this estimation has been traditionally made by two methods: (i) direct measurements with lightning flash counter equipment, lightning location systems or, more recently, through satellite systems (Figure 1.4 shows a recent ground flash density map for Colombia), and (ii) empirical equations relating the ground flash density with the keraunic level. Unfortunately, the required technology to develop GFD maps with the first method is not available in many regions, making the latter method the only option in those cases.
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Figure 1.2. Global distribution of thunderstorm days (period 2002–2009).
Taken from Cooray (2015)

Relation between Ground Flash Density and Keraunic Level

As stated in the Standard IEC 62305-2, the GFD in temperate regions, when GFD maps are not available, is calculated as approximately one-tenth of the Keraunic Level (International Electrotechnical Commission [IEC], 2010b):

$$GFD \approx 0.1 TD$$  \hspace{1cm} (1.1)

Regarding tropical regions, the mathematical expression to calculate the GFD is not unique. In the case of Colombia, the Standard NTC 4552-2 states the following equation (Instituto Colombiano de Normas Técnicas y Certificación [ICONTEC], 2008b):

$$GFD = 0.0017 TD^{1.56}$$  \hspace{1cm} (1.2)
Chapter 1: Lightning and Its Associated Risk

1.3 Global Distribution of Total Lightning

More modern methods have been implemented to detect the frequency of global and local lightning discharges. For instance, satellites are being used to record lightning

Figure 1.3. Isokeraunic map of Colombia for the year 1999. The keraunic level was evaluated in areas of 30 km². Taken from ICONTEC (2008a)
flashes through the optical signals from lightning, in order to observe both their distribution and variability. Unfortunately, according to Cooray (2015), this technology cannot distinguish between ground flashes and the other types of flashes because lightning channels are obscured by clouds.

The global distribution of total lightning flashes and a zoom over the Colombian territory from satellite data between January 2012 and December 2014 are displayed in Figure 1.5. This map is result of the data obtained from the Global Lightning Dataset GLD360, where 80% of registered events are cloud-to-ground strokes (Holle, 2015).

From the current global distribution of total lightning, it is possible to observe a high lightning activity concentrated over the areas close to the equatorial zone. This fact is in part a consequence of “the amount of sunshine received by those areas which contributes to the large amount of the vertical updraft which produces cold fronts, sea and lake breezes and afternoon heating of warm, moist air” (Ab Kadir et al., 2010, p. 1).

![Figure 1.4. GFD in Colombia (period 2012–2013).](image)

A maximum value of 60 flashes/km²-year was found in the Catatumbo region. Taken from Torres et al. (2015).
Figure 1.5. a) Global distribution of total lightning flashes for the period from January 2012 to December 2014, b) Zoom over the Colombian territory, where a substantial lightning activity is observed in the northern zones of the country
Adapted from Holle (2015).

1.4 Lightning Injury Mechanisms

The ways in which lightning interacts with living beings are known as lightning injury mechanisms. By studying these mechanisms of injury – direct strike, contact injury, side flash, ground current, upward streamer, and barotrauma (blunt or penetrating injury) – the research on lightning injury in medicine, physics, and electrical engineering has been taken further. Illustrations of the lightning injury mechanisms are shown in Figure 1.6, while some general aspects of them are presented in Table 1.3.
Figure 1.6. Illustrations of the lightning injury mechanisms: a) Direct strike, b) Contact injury, c) Side flash, d) Ground current, e) upward streamer, f) Lightning explosive barotrauma. Adapted from Blumenthal (2012).
### Table 1.3. Some general aspects of the lightning injury mechanisms

<table>
<thead>
<tr>
<th>MECHANISM</th>
<th>GENERAL ASPECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct Strike</strong></td>
<td>Whereas direct strike is most commonly described as the mechanism of injury, studies show that it accounts for a very small proportion of injuries and deaths.</td>
</tr>
<tr>
<td><strong>Contact Injury</strong> (Touch Voltage)</td>
<td>Injury from contact occurs when the person is touching an object that is part of the pathway of lightning current, such as a tree, metal fence, indoor plumbing, or wiring.</td>
</tr>
<tr>
<td><strong>Side Flash</strong></td>
<td>Side flash or splash occurs as a portion of lightning jumps from its primary strike object to a nearby person on its way to the ground.</td>
</tr>
<tr>
<td><strong>Ground Current</strong> (Step Voltage)</td>
<td>Step voltage, a difference in electrical potential between a person's feet, may occur as lightning current spreads radially through the ground. A person who has one foot closer than the other to the strike point has a potential difference between the feet so that a portion of the lightning current flows through the legs and body rather than the ground.</td>
</tr>
<tr>
<td><strong>Upward Streamer</strong> (Connecting Leader)</td>
<td>Cloud-to-ground lightning approaches the earth as a downward stepped leader. As the leader approaches, the large electrical field induces opposite charges that surge through trees, buildings, people, and any other object near the thunderstorm. If one of these upward streamers connects with a downward leader, a completed lightning strike occurs. Individuals in the path of an upward streamer may be injured even in the absence of a completed lightning strike.</td>
</tr>
<tr>
<td><strong>Blunt Injury</strong> (Shock Waves)</td>
<td>Blunt injury from lightning can occur from at least two mechanisms. First, the person may be thrown a considerable distance by the sudden, massive contraction caused by current passing through the body. Second, a concussive injury caused by explosive or implosive force occurs as the lightning pathway is instantaneously superheated then rapidly cooled after the passage of the lightning.</td>
</tr>
</tbody>
</table>

Adapted from Price and Cooper (2014)
Reports of each Injury Mechanism from the Literature

Roman et al. (2005) present an electromagnetic analysis of an incident involving a young girl who was impacted by a direct lightning strike in a small village located close to the city of Gavle, Sweden. The girl was a goalkeeper in a soccer match. Though the victim was seriously injured, she survived.

Similarly, the death of a 50-year-old man due to lightning touch voltage is reported by Kumaran et al. (2014). Lightning impacted the motorcycle of the victim while he was riding it near his village under rainy weather. Based on the autopsy, it was concluded that a high current had passed through the victim and the cause of death was the extensive burns produced by it. According to Cooper (2012a), direct strike and contact injury are the least frequent mechanisms of injury in developed countries (see Table 1.4).

Table 1.4. Distribution of lightning injury by mechanism in developed countries.

<table>
<thead>
<tr>
<th>MECHANISM</th>
<th>PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Strike</td>
<td>3–5%</td>
</tr>
<tr>
<td>Contact Injury</td>
<td>3–5%</td>
</tr>
<tr>
<td>Side Splash / Flash</td>
<td>30–35%</td>
</tr>
<tr>
<td>Ground Current</td>
<td>50–55%</td>
</tr>
<tr>
<td>Upward Streamer</td>
<td>10–15%</td>
</tr>
<tr>
<td>Blunt Injury</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

Adapted from Cooper (2012a)

A forensic report of the death of a man due to lightning in Kuala Lumpur, Malaysia, is presented by Murty (2009). The victim was a laborer who was traveling home by walking down a road where there were tall trees on its side. Post-mortem examination evidence showed that the lightning current entered the body through the
right side, close to the waist. This case is a typical example of side flash mechanism, in which trees are often involved as lightning primary strike objects.

On the other hand, more than a half of the lightning injury reported cases in humans are related to step voltages, and many of the incidents in which animals are affected in large groups are also associated with ground current. For instance, 22 cattle died in South Africa after lightning struck the place where their enclosure was located. The analysis of the incident was performed considering only the step potential calculations (Dickson, 2014).

In the case of upward streamer and blunt injury, these mechanisms were recently introduced formally in the field of lightning safety. The former, also known as the fifth mechanism, was proposed by Anderson after analyzing an incident occurred in a rural zone of South Africa, in which lightning hit the tent where 26 young girls, two adults and seven dogs were sleeping, resulting in the death of four of the girls and four of the dogs (Carte et al, 2002), Anderson concluded:

Even though it is highly speculative, the author has attempted to explain how lightning could have affected the occupants of the tent on that fateful night. Although some of the evidence is not precise (for example, the positions where each of the victims had actually been sleeping), the sheer quantity of the data at least tends to support considerations of possible alternative mechanisms that could have taken place. The author is satisfied that some of the more conventional mechanisms for lightning discharges reported in the literature played a part, but there is sufficient evidence that not all the observations could be reasonably explained by them. ... in the event of a close flash of lightning, the initiation of upward streamers from bodies, whether standing or reclining, poses dangers that are not due to step voltages, and thus would require different protective measures to prevent injuries.

(Anderson, 2001, pp. 111-112)

Finally, regarding blunt injury, Figgis and Alvarez (2012) presents a case report of a Caucasian man who suffered esophageal rupture caused by lightning strike blunt
force trauma. Despite the man was thrown away two meters, he did not lose consciousness in that moment, but he died one month later because of the mentioned trauma. A remarkable thing in this case is the fact that the lesion was discovered four days after the patient was hospitalized. The main recommendation from this report is always to suspect and examine for blast injury in those who have been injured by lightning, no matter the injury mechanism they were affected by.
Chapter 2: Lightning Risk Scenarios

This chapter presents the available statistics of lightning deaths by country, including Colombia, to provide an overview of the annual fatality rates associated with lightning in the last decades. Lightning incidents reported within the Colombian National Army are also presented.

Additionally, taking into account the lightning features introduced in Chapter 1, one hundred reports of lightning incidents occurred in Colombia are reviewed and analyzed by emphasizing aspects associated with the behavior of people. All the incidents are classified into the following eight population groups: school population, sports and recreation, camps and park agencies, rescue teams, rural population and agricultural workers, urban and semi-urban population, army forces, and livestock.

2.1 Deaths by Lightning Reported Worldwide

There is still no a unified estimate of the annual number of worldwide lightning casualties in the lightning literature. The first estimate formally presented was for 24,000 fatalities, with a suggested number of non-fatal events ten times higher (Holle and Lopez, 2003). Another study proposes the annual number of worldwide lightning deaths at 6,000 (Cardoso et al., 2011). Demographic factors vary between developed and developing countries, which has great influence when attempting to make an accurate global estimate (Gomes and Ab Kadir, 2011).
Population-weighted lightning fatality rates are a key factor for identifying the magnitude of lightning hazard to which each country is really exposed. However, many of the daily lightning-related casualties are not reported because of the difficulty in obtaining updated information about them. The lack of this data hinders greatly the process of understanding and facing the lightning risk presented in the previous chapter, particularly in developing countries with high GFD. For this reason, some studies have been performed in order to get as much information as possible about the number of lightning injuries in a given country during a given period.

Holle (2016a) presents the most recent and comprehensive summary of the available statistics by country of the annual fatality rate per million people, having a total of 26 countries (see Table 2.1). It is noticeable from Table 2.1 that in this summary the type of data collection is also indicated, providing thus specification about the different kinds of sources from which the quantity of lightning fatalities per year has been documented. These sources are meteorological agencies (letter A), medical records (letter B), personal data collection (letter C), print media (letter D), national hazards databases (letter E), and mixture of the aforementioned data sources (letter F). An estimate of 4176 lightning deaths per year was obtained for the 26 countries.

2.2 Lightning Deaths in Colombia

As seen in Figure 1.4 and Figure 1.5, Colombia possesses high lightning activity. During several years the municipality of Ocaña, located in the Department of Norte de Santander, was documented as the ninth area with the highest lightning density in the world (Christian, 2003a) and the second in the South American continent, with a value of 39.9 flashes/km²-year (Christian et al., 2003b). Moreover, a GFD value of 60 flashes/km²-year has been recently registered in the Catatumbo region, on the border with Venezuela (Torres et al., 2015). Additionally, in the case of Bogotá, the capital city, data from LLS shows lightning activity much higher in comparison to adjacent rural areas, probably associated with Urban Effect (Del Rio et al., 2015). In general, lightning
occurrence over Colombia may be increasing because of the effect of greenhouse gases (Diaz and Roman, 2015).

Despite this situation, there is still a lack of studies about the number of people affected by lightning in Colombia. Currently, there are available just two national-scale reports, one regarding every kind of cases (Navarrete et al., 2014) and another considering the incidents related to the Army (Cruz et al., 2013).

**National-Scale Report**

As observed in Table 2.1, the annual lightning fatality rate per million people in Colombia was 1.8 for the period 2000-2009. This rate was obtained from the first comprehensive national scale report of annual lightning deaths in Colombia, presented by Navarrete et al. (2014). Seven hundred fifty seven lightning-related deaths were counted during this period by reviewing death certificates from the National Institute of Legal Medicine and Forensic Sciences (ICMLCF in Spanish), using the codes associated with lightning of the International Classification of Diseases ICD-10 (codes are specified in Table 2.2). The statistics were performed by the National Administrative Department of Statistics (DANE in Spanish) and include the year, month and location in which the events took place, as well as gender and age of the victims.

The number of deaths and the annual lightning fatality rate per million people for each Colombian Department for the period of study, including the average population and the percentage of rural population, are shown in Table 2.3.

**Report about the National Army**

A detailed report concerning lightning casualties within the Colombian Army was presented by Cruz et al. (2013). A total of 72 deaths and 210 injuries were reported for the period 2003-2012 (years 2008, 2011, and the final third of 2012 were excluded due to lack of information). In this case, statistics were provided by the Direction of Integrity Preservation and Security of the Colombian Army (DIPSE in Spanish). Summary of the number of reports, fatalities, injured persons, and total lightning casualties by Department is shown in Table 2.4.
Chapter 2: Lightning Risk Scenarios

Table 2.1. Published annual lightning fatality rates per million people and number of fatalities by country ending in 1979 or later

<table>
<thead>
<tr>
<th>Country</th>
<th>Period</th>
<th>Annual fatality rate per million</th>
<th>Fatalities per year</th>
<th>Data collection type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burundi</td>
<td>2012-2013</td>
<td>2.5</td>
<td>26</td>
<td>C</td>
</tr>
<tr>
<td>Malawi</td>
<td>2007-2010</td>
<td>84.0</td>
<td>1008</td>
<td>F</td>
</tr>
<tr>
<td>South Africa</td>
<td>1997-2000</td>
<td>6.3</td>
<td>264</td>
<td>B</td>
</tr>
<tr>
<td>Swaziland</td>
<td>2000-2007</td>
<td>15.5</td>
<td>15</td>
<td>F</td>
</tr>
<tr>
<td>Uganda</td>
<td>2007-2011</td>
<td>0.9</td>
<td>30</td>
<td>F</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>Unknown</td>
<td>14 to 21</td>
<td>100-150</td>
<td>F</td>
</tr>
<tr>
<td>Asia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>1997-2009</td>
<td>0.3</td>
<td>360</td>
<td>E</td>
</tr>
<tr>
<td>India</td>
<td>1967-2012</td>
<td>2.0</td>
<td>1755</td>
<td>E</td>
</tr>
<tr>
<td>Japan</td>
<td>1990-1997</td>
<td>&gt;0</td>
<td>2</td>
<td>C</td>
</tr>
<tr>
<td>Malaysia</td>
<td>2008-2011</td>
<td>0.8</td>
<td>22</td>
<td>F</td>
</tr>
<tr>
<td>Mongolia</td>
<td>2004-2013</td>
<td>1.5</td>
<td>5</td>
<td>A</td>
</tr>
<tr>
<td>Singapore</td>
<td>1970-1979</td>
<td>1.5</td>
<td>3</td>
<td>F</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>2003</td>
<td>2.6</td>
<td>49</td>
<td>C</td>
</tr>
<tr>
<td>Australia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>1980-1989</td>
<td>0.1</td>
<td>2</td>
<td>D</td>
</tr>
<tr>
<td>Europe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Austria</td>
<td>2001-2010</td>
<td>&gt;0</td>
<td>1</td>
<td>D</td>
</tr>
<tr>
<td>France</td>
<td>1990-1995</td>
<td>0.2</td>
<td>11</td>
<td>B</td>
</tr>
<tr>
<td>Greece</td>
<td>2000-2010</td>
<td>0.1</td>
<td>5</td>
<td>F</td>
</tr>
<tr>
<td>Lithuania</td>
<td>1994-2003</td>
<td>0.1</td>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>Poland</td>
<td>2001-2006</td>
<td>0.3</td>
<td>8</td>
<td>F</td>
</tr>
<tr>
<td>Turkey</td>
<td>2012-2014</td>
<td>0.4</td>
<td>28</td>
<td>F</td>
</tr>
<tr>
<td>U.K.</td>
<td>1988-2012</td>
<td>&gt;0</td>
<td>2</td>
<td>F</td>
</tr>
<tr>
<td>North America</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>1990-2004</td>
<td>0.2</td>
<td>9</td>
<td>A</td>
</tr>
<tr>
<td>Mexico</td>
<td>1979-2011</td>
<td>2.7</td>
<td>230</td>
<td>B</td>
</tr>
<tr>
<td>United States</td>
<td>2006-2015</td>
<td>0.1</td>
<td>31</td>
<td>A</td>
</tr>
<tr>
<td>South America</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>2000-2009</td>
<td>0.8</td>
<td>132</td>
<td>F</td>
</tr>
<tr>
<td>Colombia</td>
<td>2000-2009</td>
<td>1.8</td>
<td>76</td>
<td>B</td>
</tr>
</tbody>
</table>

Adapted from Holle (2016a)
Table 2.2. ICD-10 Codes for lightning deaths

<table>
<thead>
<tr>
<th>COD_3</th>
<th>DESCRIPTION CATEGORIES OF THREE CHARACTERS</th>
<th>COD_4</th>
<th>DESCRIPTION CODES OF FOUR CHARACTERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T75</td>
<td>Effects of other external causes</td>
<td>T750</td>
<td>Effects of lightning</td>
</tr>
<tr>
<td>X33</td>
<td>Victim of lightning</td>
<td>X330</td>
<td>Victim of lightning: Living place</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X331</td>
<td>Victim of lightning: Residential institution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X332</td>
<td>Victim of lightning: Schools, other institutions and public administrative areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X333</td>
<td>Victim of lightning: Sports and athletics areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X334</td>
<td>Victim of lightning: Streets and roads</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X335</td>
<td>Victim of lightning: Trade and service areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X336</td>
<td>Victim of lightning: Industrial and construction areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X337</td>
<td>Victim of lightning: Farm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X338</td>
<td>Victim of lightning: Other specified places</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X339</td>
<td>Victim of lightning: Unspecified places</td>
</tr>
</tbody>
</table>

Adapted from National Administrative Department of Statistics – DANE (2015)

Some studies are beginning to take place with the aim of exploring, reconstructing and evaluating the scenarios of the events in which members of the Army troops have been affected by lightning (Cristancho et al., 2015; Latorre et al., 2016; Martinez et al, 2016). These studies seek to obtain a deeper understanding of the aspects involved in such events and devise new and better lightning protection schemes for this vulnerable population (Rojas et al., 2017).
Table 2.3. Deaths, average population, annual lightning fatality rate per million, and percentage of rural population by Department for the period 2000-2009

<table>
<thead>
<tr>
<th>Department</th>
<th>Died</th>
<th>Average population</th>
<th>Annual deaths/million</th>
<th>% Rural Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaupés</td>
<td>3</td>
<td>39,033</td>
<td>7.69</td>
<td>64.7</td>
</tr>
<tr>
<td>Cauca</td>
<td>71</td>
<td>1,263,858</td>
<td>5.62</td>
<td>62.0</td>
</tr>
<tr>
<td>Vichada</td>
<td>3</td>
<td>55,188</td>
<td>5.44</td>
<td>62.4</td>
</tr>
<tr>
<td>Guaviare</td>
<td>5</td>
<td>94,866</td>
<td>5.27</td>
<td>47.9</td>
</tr>
<tr>
<td>Caquetá</td>
<td>14</td>
<td>418,052</td>
<td>3.35</td>
<td>45.0</td>
</tr>
<tr>
<td>Boyacá</td>
<td>41</td>
<td>1,253,671</td>
<td>3.27</td>
<td>48.5</td>
</tr>
<tr>
<td>Magdalena</td>
<td>37</td>
<td>1,145,230</td>
<td>3.23</td>
<td>31.3</td>
</tr>
<tr>
<td>Guainía</td>
<td>1</td>
<td>34,922</td>
<td>2.86</td>
<td>69.4</td>
</tr>
<tr>
<td>La Guajira</td>
<td>19</td>
<td>667,684</td>
<td>2.85</td>
<td>46.1</td>
</tr>
<tr>
<td>Santander</td>
<td>55</td>
<td>1,952,806</td>
<td>2.82</td>
<td>27.2</td>
</tr>
<tr>
<td>Córdoba</td>
<td>41</td>
<td>1,457,229</td>
<td>2.81</td>
<td>49.7</td>
</tr>
<tr>
<td>Casanare</td>
<td>8</td>
<td>292,197</td>
<td>2.74</td>
<td>32.0</td>
</tr>
<tr>
<td>Cesar</td>
<td>24</td>
<td>897,334</td>
<td>2.67</td>
<td>29.4</td>
</tr>
<tr>
<td>Arauca</td>
<td>6</td>
<td>231,074</td>
<td>2.60</td>
<td>39.5</td>
</tr>
<tr>
<td>Antioquia</td>
<td>142</td>
<td>5,643,511</td>
<td>2.52</td>
<td>23.9</td>
</tr>
<tr>
<td>Bolívar</td>
<td>45</td>
<td>1,870,660</td>
<td>2.41</td>
<td>25.5</td>
</tr>
<tr>
<td>Caldas</td>
<td>22</td>
<td>967,591</td>
<td>2.27</td>
<td>30.7</td>
</tr>
<tr>
<td>Norte de Santander</td>
<td>25</td>
<td>1,238,465</td>
<td>2.02</td>
<td>23.8</td>
</tr>
<tr>
<td>Meta</td>
<td>15</td>
<td>774,750</td>
<td>1.94</td>
<td>27.1</td>
</tr>
<tr>
<td>Putumayo</td>
<td>6</td>
<td>308,638</td>
<td>1.94</td>
<td>56.3</td>
</tr>
<tr>
<td>Chocó</td>
<td>8</td>
<td>451,965</td>
<td>1.77</td>
<td>52.1</td>
</tr>
<tr>
<td>Sucre</td>
<td>13</td>
<td>768,273</td>
<td>1.69</td>
<td>36.0</td>
</tr>
<tr>
<td>Cundinamarca</td>
<td>37</td>
<td>2,260,293</td>
<td>1.64</td>
<td>36.0</td>
</tr>
<tr>
<td>Amazonas</td>
<td>1</td>
<td>67,277</td>
<td>1.49</td>
<td>62.1</td>
</tr>
<tr>
<td>Nariño</td>
<td>19</td>
<td>1,531,949</td>
<td>1.24</td>
<td>53.9</td>
</tr>
<tr>
<td>Risaralda</td>
<td>11</td>
<td>894,525</td>
<td>1.23</td>
<td>23.1</td>
</tr>
<tr>
<td>Atlántico</td>
<td>25</td>
<td>2,151,045</td>
<td>1.16</td>
<td>5.0</td>
</tr>
<tr>
<td>Valle del Cauca</td>
<td>38</td>
<td>4,139,615</td>
<td>0.92</td>
<td>13.7</td>
</tr>
<tr>
<td>Tolima</td>
<td>12</td>
<td>1,362,424</td>
<td>0.88</td>
<td>34.4</td>
</tr>
<tr>
<td>Quindío</td>
<td>2</td>
<td>532,965</td>
<td>0.38</td>
<td>13.5</td>
</tr>
<tr>
<td>Huila</td>
<td>2</td>
<td>1,004,140</td>
<td>0.20</td>
<td>40.6</td>
</tr>
<tr>
<td>Bogotá D.C.</td>
<td>6</td>
<td>6,787,079</td>
<td>0.09</td>
<td>0.2</td>
</tr>
<tr>
<td>Arch. San Andrés</td>
<td>0</td>
<td>70,237</td>
<td>0.00</td>
<td>28.5</td>
</tr>
<tr>
<td><strong>National total</strong></td>
<td><strong>757</strong></td>
<td><strong>42,628,541</strong></td>
<td><strong>1.78</strong></td>
<td><strong>25.6</strong></td>
</tr>
</tbody>
</table>

Adapted from Navarrete et al. (2014)
Table 2.4. Number of reports, fatalities, injured persons, and total lightning casualties within the National Army by Department for eight years between 2003 and 2012

<table>
<thead>
<tr>
<th>Department</th>
<th>Number of reports</th>
<th>Number of fatalities</th>
<th>Number of injured persons</th>
<th>Total casualties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazonas</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Antioquia</td>
<td>26</td>
<td>20</td>
<td>23</td>
<td>43</td>
</tr>
<tr>
<td>Arauca</td>
<td>2</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Atlántico</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Bogotá D.C.</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Bolivar</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Boyacá</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Caldas</td>
<td>6</td>
<td>4</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>Caquetá</td>
<td>11</td>
<td>8</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Casanare</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Cauca</td>
<td>10</td>
<td>2</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Cesar</td>
<td>8</td>
<td>5</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Chocó</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Córdoba</td>
<td>4</td>
<td>1</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Cundinamarca</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Guainía</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Guaviare</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Huila</td>
<td>3</td>
<td>0</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>La Guajira</td>
<td>8</td>
<td>3</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Magdalena</td>
<td>7</td>
<td>4</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Meta</td>
<td>10</td>
<td>5</td>
<td>11</td>
<td>161</td>
</tr>
<tr>
<td>Nariño</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Norte de Santander</td>
<td>11</td>
<td>6</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>Putumayo</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Quindío</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Risaralda</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>San Andrés y Providencia</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Santander</td>
<td>6</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Sucre</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tolima</td>
<td>8</td>
<td>2</td>
<td>25</td>
<td>27</td>
</tr>
<tr>
<td>Valle del Cauca</td>
<td>7</td>
<td>2</td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td>Vaupes</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Vichada</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>149</strong></td>
<td><strong>72</strong></td>
<td><strong>210</strong></td>
<td><strong>282</strong></td>
</tr>
</tbody>
</table>

Adapted from Cruz et al. (2013)
2.3 Description and Analysis of Risk Scenarios

Lightning risk scenarios have been traditionally analyzed through High Voltage and Electromagnetic Compatibility techniques, in which laboratory tests and computing simulations are the typical tools to perform such analyses. However, recent studies have aimed at also exploring the social characteristics and psychological aspects of people involved in lightning injuries, as well as making comparisons among different social groups from these elements (Gomes and Gomes, 2014; Mary and Gomes, 2014; Holle, 2016b; Holle and Cooper, 2016c; Hajikhani et al., 2016a; Hajikhani et al., 2016b).

Following the path traced from the abovementioned studies, an analysis of the lightning injuries news reports, presented in Appendix 3, considering leadership, education, and self-care of people within eight groups – school population, sports and recreation, camps and park agencies, rescue teams, rural population and agricultural workers, urban and semi-urban population, army forces, and livestock – is presented below.

School Population

News: 10, 87, 95, and 98

No reports of lightning strikes at Colombian schools were found. Nevertheless, recently local media reported the case of one young man injured by lightning that struck on the campus of his University while he was walking and the cases of some school students involved in lightning injuries when they were going back home after their classes.

University campuses often have large open fields where buildings are separated by long distances, making this a risk factor for pedestrians when a thunderstorm approaches. The student injured by lightning while walking through the campus could have ensured his safety by remaining inside one of the substantial buildings during the
rain and at least until 30 minutes after the thunderstorm ceased, even though doing this could involve arriving late to class.

Regarding the cases of school students, it is typical in rural zones to have long distances between school and the places where the houses of the children are located. These journeys are commonly done by bike, motorcycle or walking. This is a complex situation, for have no safe transport alternatives against the lightning hazard. However, the authorities of the schools might help greatly by giving in a permanent way LS instructions to children, such as not staying at any point along the road during the thunderstorm, not seeking shelter under trees or kiosks, and going home in a group and as quickly as possible.

**Sports and Recreation**

**News:** 21, 24, 32, 37, 74, and 84

Except for number 32, everyone involved in this block of news was injured by lightning during soccer matches. The effective way to prevent this kind of incidents is to stop all the sports activities at the first sound of thunder, seek shelter in a substantial building and resume activities after the last thunder is heard. While this may seem to be primarily the responsibility of the referee, in reality every individual is responsible for their own safety and may also demand immediate suspension of the game for the sake of their own security if the referee is unaware of the danger or does not exercise leadership.

With respect to the 19-year-old young man who died by lightning while crossing the soccer field after the game was postponed because of the heavy rain, the fault was neither of the referee nor of the other people, for he himself decided to do that without paying attention to his own safety. It is possible that he would not have made that decision if he had received appropriate LS instruction.
Camps and Park Agencies

News: 91

In October 2014, eleven indigenous people died and fifteen were wounded by lightning during one of their traditional celebrations. The lightning strike impacted the hut where they were. This event was reported by the media and became widely known throughout the country, causing great consternation due to its magnitude and the rarity of lightning multiple-casualty incidents in Colombia. The incident occurred within the jurisdiction of a park named Tayrona National Natural Park, administrated by the System of National Natural Parks, one of the most popular parks in Colombia for ecotourism and camping.

The national natural parks are home to many native indigenous, who continue to practice their customs and traditions. Therefore, it is necessary that authorities from both the parks and the indigenous communities begin collaborative efforts to raise awareness of the dangers of lightning in these areas.

Rescue Teams

News: 2

A lifeguard died due to a lightning strike in the moment when bathers needed to be evacuated from a dangerous scenario. A thunderstorm was over the beach and the lifeguard started asking people to leave the place. Unfortunately, he died and three people were injured.

This report is a good example of the conflict that may exist between leadership and self-care when facing a lightning risk situation. Even though helping people was his responsibility, the lifeguard should not have neglected his own safety, not only for the sake of his but also because the best way to help others is to ensure the own security first. This behavior is common among rescue teams, largely because in their training they do not receive any instruction concerning lightning safety.
Additionally, if people who were on the beach at that moment had previously been educated in relation to LS information, perhaps they would have left the beach on their own because of the weather conditions.

**Rural Population and Agricultural Workers**

**News:** 7, 12, 13, 15, 16, 18, 22, 23, 26, 30, 31, 40-44, 46, 47, 49-51, 54-56, 59, 61-63, 69, 73, 76, 79, 82, 83, 86, 90, 97, and 100

Most of these news reports are of injuries by lightning to peasants living and/or working in rural zones. The incidents involved people doing their typical work such as fishing, coffee collection, woodcutting, farming, and harvest. Unfortunately, when someone has to choose between working to feed their family and seeking safe shelter against lightning, they may see little choice but to continue work. In addition, as in the case of the students of rural schools, rural inhabitants and workers of rural zones may need to travel long distances between their work and homes, with travel by horses, bicycles, motorcycles or walking. Furthermore, sometimes people were injured by lightning when they sought shelter under trees or inside non-safe structures.

News 31 shows an example of the common belief that an electrical charge remains in a person who has been struck by lightning and must be discharged by burying the victim. The incident involved a 17-year-old young girl who was buried and not taken to the local hospital until an hour later, wasting valuable time. This case reveals how dangerous it could be to act following the customs when they are wrong.

Another important aspect is that immediate medical care is often delayed because the injuries take place in distant or difficult to reach locations, far away from health care facilities. In these cases, first aid assistance is more critical, so more people in rural zones should receive first aid training to help as soon as possible those who are injured by lightning strikes. However, access to such training outside urban centers is limited and only few people want to get involved.
Chapter 2: Lightning Risk Scenarios

Urban and Semi-Urban Population

**News:** 1, 3-6, 8, 9, 14, 19, 29, 34-36, 38, 45, 48, 52, 53, 57, 64-68, 71, 75, 77, 78, 80, 81, 88, 92, and 99

A smaller number of urban dwellers in Colombia are injured by lightning in metropolises and intermediate cities in comparison to the numerous cases reported from semi-urban zones. However, several dangerous practices were identified in both zones from the news reports, including staying on roofs or in open spaces inside the houses, like backyards and small lots, during a thunderstorm. Others were injured when they were outdoors in municipal parks and cemeteries.

Dangerous behaviors can only be changed through consistent and persistent LS education. While one might propose that another way of protecting people would be to install lightning protection systems (LPS) in small buildings that are commonly utilized for daily activities, such as guard booths, none of the proposed systems have been tested yet. While there are internationally accepted LPS codes, these are for the protection of buildings, with none for the protection of people (Gomes et al., 2012; Gomes and Gomes, 2014; Gomes et al., 2016a).

Army Forces

**News:** 11, 17, 20, 25, 28, 33, 39, 58, 60, 70, 72, 85, 89, 93, 94, and 96

From this set of news, it is observed that lightning-related casualties within the National Army sometimes involves more than one death per event. The Colombian Military Forces have expressed concern about the high number of deaths and injuries suffered by their personnel due to lightning strikes. The incidents occur frequently while soldiers are patrolling in open fields or standing watch over from non-safe shelters. Therefore, apart from the need for adequate lightning protection systems within military bases and camps, the military personnel should consider lightning safety when they are planning activities, or giving and receiving orders, particularly for activities such as patrolling, standing watch and offensive operations.
Unfortunately, most of the military personnel have not received any instruction regarding the lightning hazard nor their structures at high risk of lightning strike are all protected. Soldiers and commanders can be torn between taking self-care actions, such as avoiding work or standing watch in unprotected spaces during a thunderstorm, the orders of their superiors, and the needs of the military mission at time. Sometimes, they face a difficult decision between ensuring their own safety in a risky situation and being punished for disobeying commands. For this reason, it is always better to educate all military personnel about the dangers of lightning, so that LS instructions can be agreed upon before anyone is put in avoidable danger in a thunderstorm situation.

**Livestock**

**News: 27**

Among all of the groups analyzed, the most difficult situation is probably preventing lightning-related casualties in livestock because the safety of the animals depends entirely on the measures that their owners decide to take. Lightning protection schemes for holding pens are not always viable because of both high costs and great technical challenges, so that the implementation of such LPS schemes is rarely seen at Colombian farms.

Unfortunately, shelters for livestock are probably even less safe against lightning than those for people. Nevertheless, farmers may take into consideration LS recommendations like avoiding to locate herds in open areas during thunderstorms.

**Conclusions of the Chapter**

The above discussion of some of the main lightning risk scenarios shows the evident need of LS education in Colombia. LS education must be done when people are safe, not at the time of a thunderstorm. Sometimes, providing education a few weeks
Chapter 2: Lightning Risk Scenarios

after an incident has occurred may be the best opportunity to influence the audience and thus help change its behavior. If emotions are still running high, an important part of this is listening to those who have been traumatized by the incident and respectfully incorporating folk beliefs and fears into the LS education process. Additionally, numerous variables are usually present when any lightning injury occurs, no matter which type of population is affected, and taking them into account is essential to go further in developing more and better LS methods that are practical and easily implemented whenever possible.

In order to explore the current status of the LS education, next chapter introduces the main LS comprehensive education programs and isolated initiatives that have been implemented around the world in recent years, taking into account both their components and indicators.
Chapter 3: Characterization of Worldwide Lightning Safety Education Programs

“Disaster risk reduction (DRR) aims to build society’s resilience and ability to cope. Education has a central role to play in equipping people with lifesaving and environmentally sustainable knowledge and skills.” (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2011, p. 18). This statement asserts that education is the way to empower people concerning safety and sustainability. Based on this fact, lightning safety education programs are essentially programs designed for providing education regarding the safety of living beings against the injury from lightning hazard.

This chapter depicts the components and the impact indicators of the lightning safety education programs that have been launched since the beginning of this century. Because of the length of these programs, they are often the major references in seeking to have national and continental impacts in promoting lightning safety awareness. Furthermore, the impact indicators are an evidence of the effectiveness they have had since their beginning until now.

3.1 Contextualization of the LS Education Programs

PUBLIC EDUCATION CAN MAKE A DIFFERENCE is the main premise that has been encouraging researchers and professionals from different fields to work together
like never before to prevent injuries from lightning. In this sense, the formation of interdisciplinary teams where multiples areas of expertise are represented has been highly recommended by some LS researchers, in order to create and implement diverse methods to educate as many people as possible about lightning safety (Cooper and Holle, 2004).

At least three Lightning Safety Education Programs, at national and continental levels, have been implemented since the beginning of the last decade. From the oldest to the most recent:

1. **US Lightning Safety Week (LSW)**, conducted in the United States since 2001 (Cooper and Holle, 2012b),
2. **South Asian Lightning Awareness Program (SALAP)**, conducted in Sri Lanka, Bangladesh and Bhutan between October 2004 and March 2005 (Gomes et al., 2005; Jayaratne and Gomes, 2012),
3. **African Centres for Lightning and Electromagnetics Network (ACLENet)**, which has been focused on encompassing the whole African Continent since February 2014 (Cooper et al., 2016).

Likewise, different public and private organizations, including some research centers, have been proposing and attempting to implement lightning safety initiatives that can educate people about the dangers of lightning.

**Message Presented in the LS Programs**

All LS initiatives and programs focus on providing instruction to people about the general lightning safety rules (LSR). LSR seek to cover all the basic information that people need to know to prevent lightning injuries, including an elementary knowledge about the nature of lightning, a set of instructions about what to do before, during and after a thunderstorm, and tips concerning how to reduce risk both indoors and outdoors. The following is an example of LSR presented to the general public through a governmental website (US National Weather Service [NWS], 2017a):
Lightning: What You Need to Know

- **NO PLACE** outside is safe when thunderstorms are in the area!!
- If you hear thunder, lightning is close enough to strike you.
- When you hear thunder, *immediately* move to safe shelter: a substantial building with electricity or plumbing or an enclosed, metal-topped vehicle with windows up.
- Stay in safe shelter at least 30 minutes after you hear the last sound of thunder.

**Indoor Lightning Safety**

- Stay off corded phones, computers and other electrical equipment that put you in direct contact with electricity.
- Avoid plumbing, including sinks, baths and faucets.
- Stay away from windows and doors, and stay off porches.
- Do not lie on concrete floors, and do not lean against concrete walls.

**Last Resort Outdoor Risk Reduction Tips**

If you are caught outside with no safe shelter anywhere nearby the following actions *may* reduce your risk:

- Immediately get off elevated areas such as hills, mountain ridges or peaks
- Never lie flat on the ground
- Never shelter under an isolated tree
- Never use a cliff or rocky overhang for shelter
- Immediately get out and away from ponds, lakes and other bodies of water
- Stay away from objects that conduct electricity (barbed wire fences, power lines, windmills, etc.)

Although the LS message is essentially the same for everyone, not everyone can take advantage of lightning safe structures and vehicles. For instance, 90% of sub-Saharan housing is no ‘lightning safe’ (Holle and Cooper, 2016d); most are small mud brick structures with thatched or sheet metal roofs and with few or none of the features of a ‘substantial building’, which is defined as a habitable building with wiring and plumbing going through the walls to simulate a ‘Faraday cage’ and lead lightning, regardless of where it may have struck, harmlessly around any inhabitants.
Additionally, some people in some countries of Asia and Africa dwell in small structures that, in accordance with the standard risk assessment, do not need any structural lightning protection, but the reported injuries show that they actually do not offer substantial protection against lightning, being inadequate shelters when thunderstorm approaches (Gomes et al., 2016a).

3.2 Components of LS Programs and Initiatives

Several lessons can be learned by exploring the components of the LS comprehensive programs and of the LS isolated initiatives. These components were searched and then classified in Table A.2.1 and Table A.2.2, in which their country(ies) involved, time frame, target population(s), justification, goals, projects, educational methodologies, and indicators are shown. Details of the educational methodologies of both comprehensive programs and isolated initiatives, along with those used within some population groups, are presented below.

*Educational Methodologies of LS Comprehensive Programs*

Table 3.1 presents the principal LS educational methodologies utilized in the LS comprehensive programs listed above. The elements pertaining to these methodologies vary according to the countries in which the programs take place. For example, developed countries have more likely to implement mass educational resources, like websites and TV programs, whereas in developing countries people are educated mostly by receiving the LS message personally where they live. Likewise, the teaching and learning cultures influence greatly in the contents of the educational methodologies, particularly in countries where there are gaps in accessing formal education and employment, resulting commonly in a great number of people living unaware of the possible risk from lightning in their houses or in their works.
Table 3.1. Educational Methodologies implemented in the LS Comprehensive Programs  
(Adapted from Appendix 2)

<table>
<thead>
<tr>
<th>Comprehensive LS Program</th>
<th>Educational Methodologies</th>
</tr>
</thead>
</table>
| South Asian Lightning Awareness Program (SALAP)²              | > Seminars at five school venues with high lightning density  
> Workshops for school teachers and social workers  
> Workshop for engineers, teachers and governmental officers                                                                                       |
| Lightning Safety Week (LSW)³                                   | > LSW website has become the premier lightning safety site with general information, up-to-date injury statistics, games, puzzles, public service announcements as well as special sections for the media, teachers, boaters, and many other interests and concerns  
> LSW materials, reminders and updates have been distributed to the 120 National Weather Service Offices in the United States and to broadcast meteorologists nearly every year since LSW began  
> The LSW core team and others have made themselves available for thousands of interviews with newspapers, radio and television, worked on dozens of documentaries, as well as continuing their own research and publication  
> “Leon, the lightning safety lion”, has become a friendly character useful to teach children what to do when thunder roars                                                                 |

³ Website: [www.lightningsafety.noaa.gov](http://www.lightningsafety.noaa.gov)
Table 3.1. (Continuation)

<table>
<thead>
<tr>
<th>African Centers for Lightning and Electromagnetics Network (ACLENet)⁴</th>
<th>&gt;Training (formal technical training, workshops, seminars)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt;Site surveys of the schools</td>
</tr>
<tr>
<td></td>
<td>&gt;Booklets</td>
</tr>
<tr>
<td></td>
<td>&gt;Graduate education in lightning physics and other technical areas to train Africa’s own experts has begun</td>
</tr>
</tbody>
</table>

**Educational Methodologies of LS Isolated Initiatives**

The following communication means were identified as part of the LS educational methodologies implemented by private and public institutes and by governmental organizations (see Table A.2.2):

- ✓ Websites
- ✓ Guidelines
- ✓ Articles
- ✓ Consultancy
- ✓ Apps for weather alerts
- ✓ Videos
- ✓ Reminiscent gifts
- ✓ Seminars
- ✓ Workshops
- ✓ Books
- ✓ Pamphlets
- ✓ Documentaries

Although many times it is not possible to observe the long-term effectiveness of the LS isolated initiatives, their implementation is a key factor in raising LS awareness among those people who live in countries where there are no LS comprehensive programs yet.

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⁴ Website: [www.aclenet.org](http://www.aclenet.org)
Educational Methodologies by Population

One of the greatest challenges the LS awareness programs face is to find the effective means to spread the LS message effectively among people who may have diverse characteristics, speak multiple languages, and live or work in varying conditions. As Gomes and Gomes say, “there is no uniform safety promotion module that may be applicable to all communities with success” (Gomes and Gomes, 2014, p.1).

Considering this, Villamil et al. state:

Even though information related to fatalities and injuries due to lightning is limited and only available in a small number of countries, mainly in the developed ones, a variety of public education methodologies on lightning safety have been implemented in order to address the urgent need for lightning education in various locations, performed according to the characteristics of each group of people, identified by researchers as the key to make a difference.

(Villamil et al., 2015 p. 146)

Villamil et al. performed a review of the existing educational methodologies on lightning safety, in order to identify the resources and strategies that have been included in them to spread the LS message. These were grouped among the different population contexts considered in section 2.3 (excluding army forces, for which no educational methodologies were found). Results are summarized in Table 3.2.

3.3 LS Programs Impact Indicators

In order to analyze the effect that the LS education programs have had since their beginning, three elements are considered as impact indicators for each one of them, namely, the lightning-related fatality rates, the number of LS centers, and the number of LS publications. Each of these impact indicators are described and analyzed in this section.
Table 3.2. Resources and Strategies of the LS Educational Methodologies by population

<table>
<thead>
<tr>
<th>Population</th>
<th>Resources and Strategies of LS Educational Methodologies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School population</strong></td>
<td>School staff and students have become one of the main targets of the LS awareness programs because of their great potential to replicate learned information to the surrounding contexts. Safety guidelines, survey questionnaires, training at science hubs, workshops, seminars, science exhibitions, videos, webpages, games, quiz competitions, posters, bulletin boards, coloring books, calendars, T-shirts, banners, promotion icons, among others, are part of the resources of LS school programs for students and teachers</td>
</tr>
<tr>
<td><strong>Sports and recreation</strong></td>
<td>Experts recommend following existing LS guidelines and policies with the proposed emergency action plans specifically designed for lightning safety. The guidelines are presented to participants, for example, by employing public address systems and placing directions in event programs, bulletin boards and crowded venues</td>
</tr>
<tr>
<td><strong>Camps and park agencies</strong></td>
<td>One of the mechanisms required to spread effectively the safety message is to raise awareness about lightning danger among camps and parks administrators and staff, because they are capable of providing information, training and support, applying standard procedures previously established according to the content of the existing LS guidelines and research publications</td>
</tr>
<tr>
<td><strong>Rescue teams</strong></td>
<td>Rescue teams could be are often at risk because they are responding to a dangerous situation when weather conditions may not have stabilized. They may also lack knowledge about how to protect themselves before, during or after a lightning storm. Paramount to any rescue is to not make more victims that need to be rescued by taking the team into dangerous situations. The safety of both rescuers and rescued should be always the priority.</td>
</tr>
</tbody>
</table>
### Table 3.2. (Continuation)

<table>
<thead>
<tr>
<th>Population</th>
<th>Resources and Strategies of LS Educational Methodologies</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Rural population and agricultural workers</em></td>
<td>Reaching inhabitants of rural zones with the LS message is an ambitious goal and a high priority. LS programs have taken into account factors as the beliefs, myths and possible misconceptions about lightning phenomenon, as well as the literacy rate of people, multiple languages, and access to technology and medicine. Although low-cost sheltering structures are being developed, none to date have been tested for their efficacy and safety.</td>
</tr>
<tr>
<td><em>Urban and semi-urban population</em></td>
<td>Lightning hazards in urban areas follow certain patterns of downward flashes, which differ from rural ones. Nevertheless, both rural and small urban areas may face the same difficulties when trying to spread the LS message, particularly because of the preconceived ideas of people and the common use of small unsubstantial shelters during thunderstorms. In response, educational efforts among urban and semi-urban communities have been made, for example employing surveys and reading materials such as leaflets and booklets.</td>
</tr>
<tr>
<td><em>Livestock</em></td>
<td>It has been stated by researchers that lightning protection measures should be implemented to decrease the number of livestock casualties. Recommendations include advices for the convenient location of herds (away from open areas) and technical instructions about how to make holding pens and enclosures safer against lightning. This topic is already starting to be an important part of some LS education programs.</td>
</tr>
</tbody>
</table>

*Adapted from Villamil et al. (2015)*
Chapter 3: Characterization of Worldwide Lightning Safety Education Programs

Reduction in Lightning Fatality Rates

The most desired outcome of every LS program is to save lives and injuries. Therefore, the main indicator of the effectiveness of the programs is the lightning-related fatality and injury rates before and after launching them. Nevertheless, collecting the necessary information to calculate these rates accurately is not an easy issue, because it is a long-term process, the sources are not always uniform, as data presented in Table 2.1 shows, not all cases are reported and there are may be many confounders and other interventions that cannot be easily accounted for.

However, in the case of the United States, the implementation of the LS program has been accompanied by updated statistics of the lightning fatality rate per million, having recorded data even since the beginning of the last century. The chart displayed in Figure 3.1 depicts the trend of lightning-related deaths along with the percent rural population until 2013. Cooper and Holle remark that "there has been a steady decrease in the lightning fatality rate over the past twenty years of work with a rate of less than 0.1/million US population in each of the last three years, in part due to the educational efforts of this group (LSW team) and the media’s support in disseminating lightning safety information" (Cooper and Holle, 2012b, p.1).

![Figure 3.1](image)

**Figure 3.1.** U.S. Lightning-related deaths per million people and percent rural population from 1900 to 2013

*Taken from Holle and Cooper (2016d)*
Unfortunately, this kind of historical annual data is not available for the countries involved in SALAP and ACLENet programs, in the former because no fatality rates have been published after its end and in the latter because its implementation is still in construction and the time frame since it started is still too short. Undoubtedly, lightning-related fatality and injured rates are expected to be collected for the African countries benefited by ACLENet during the coming years.

**Increase in the Number of LS Centers**

*There are relatively few centers where lightning studied and small numbers of people study lightning at these centers* is the second premise for mobilizing lightning information to decrease personal injuries presented by Cooper and Holle (2005a), and this fact remains true today. With nearly every launch of an LS program, there has been a firm intention to establish national LS centers dedicated to providing updated knowledge about lightning to everyone who may need it, as well as to supporting every effort oriented to reducing the negative impact of lightning on living beings and property.

After finishing SALAP program, there was an agreement to create Bangladesh and Bhutan Lightning Research and Awareness Centers (Gomes et al., 2005). Likewise, the approval from the Sri-Lankan authorities was obtained for the establishment of a national center for lightning safety (Jayaratne and Gomes, 2012). In the case of ACLENet, its umbrella organization ACLENet and its first national center, ACLE Zambia, are a reality today, and three other national centers are currently being developed (Cooper et al., 2016).

With respect to the United States, until 2105 LSW had been a part of the Weather Safety services offered by the National Weather Service (NWS), which is one of the line offices of the National Oceanic and Atmospheric Administration (NOAA), agency within the US Department of Commerce. This means that the LSW program was linked directly to the US government, so it had been not necessary to have a different institution for national-scale lightning research. Unfortunately, since the lightning death rate was so
low, priorities within the NOAA shifted and LSW did not take place in 2016. An unfortunate result of that was that deaths from lightning jumped from an annual average of 26 for the past five years (2011-15) to 38 in 2016, a 46% jump in one year (National Weather Service [NWS], 2017b).

Increase in the Number of LS Publications

The number of publications related to lightning safety education has also increased since the LS programs started, thus contributing greatly to the diffusion and appropriation of the work performed over more than 15 years through them. Some of the most outstanding of these publications are:

LSW


• Cooper, M. A., 2012: *A brief history of lightning safety efforts in the United States*. In Preprints, 4th International Lightning Meteorology Conference, Broomfield, Colorado, USA.


SALAP


ACLENet


Conclusions of the Chapter

An exploration of the strategies of the LS education programs and isolated initiatives from the point of view of their components and impact indicators leads to considering the importance of analyzing and evaluating their qualitative characteristics within a constantly changing global context.

At the same time, it is required to have updated lightning-related casualty rates that may allow evaluating quantitatively the impact of such LS educational strategies. Furthermore, more LS research centers and academic publications as a fruit of the LS programs are expected.

Next chapter takes the current situation of the LS education as a starting point to devise a methodology that may be followed by those who wish to be lightning safety promoters within rural contexts.
Chapter 4: Methodological Approach to the Mitigation of Lightning Risk in Rural Areas

In spite of the recent progress in lightning safety education presented in the previous chapter, there are still groups of people in many countries that have not been reached with the lightning safety message yet. Among them, communities in remote rural areas are especially vulnerable, not only due to the lack of lightning protections systems, but also because most of the lightning safety policies and recommendations have been formed in developed countries for populations with substantial buildings and fully enclosed metal vehicles readily available.

For instance, as seen in the study performed by Navarrete et al., greater lightning related-death rates per million are concentrated in rural and less-populated areas of Colombia, a country in which less than a quarter of the total populace was classified as rural population in 2015 (The World Bank, 2017c).

For that reason, after having a better understanding of the existing lightning safety educational methodologies and exploring their diffusion means, this chapter focuses on providing a methodology for determining the most effective means for spreading the lightning safety message among the rural population, as well as on analyzing the results of its application, in order contribute to the mitigation of the risk from lightning in rural areas.
Chapter 4: Methodological Approach to the Mitigation of Lightning Risk in Rural Areas

4.1 Lightning Safety in the Rural Context

In general, technological and socio-demographical conditions of rural dwellers put them at higher risk of being injured by a lightning strike in comparison with those who live in urban centers where 'lightning safe' locations are more likely to be found. For example, the great number of news reported in Colombia involving lightning incidents within the rural population, some of them analyzed in section 2.3, are evidence of such disproportion. Therefore, consideration of how lightning safety facts apply in rural areas where no 'lightning safe' locations are available is a major challenge.

The Nature of the Problem

On the number of lightning injury cases within the rural context of developing countries, Cooper and Ab Kadir state:

In less developed countries, many people continue to participate in labor-intensive agriculture and live in ungrounded buildings. Lightning frequency is high in many of these areas and outdoor workers and villagers are vulnerable. Many cases involve outdoor activities such as fishing, agriculture, recreation and sheltering in unsafe or unsuitable places. Lack of recognition of lightning danger and education about the warning signs may also contribute to the number of injuries.

(Cooper and Ab Kadir, 2010, p. 3)

From the above statement, it is evident that the lightning safety application in the rural environment is primarily a social problematic. This fact leads to thinking on how to conduct the process of collecting reliable primary and secondary data for determining which methods of diffusion identified in section 3.2 might be the most suitable for rural populations. Some general aspects related to primary and secondary data collection are presented below.
Primary Data Collection

Regarding the strategies for primary data\(^5\) collection in social research, Hox and Boeije state:

To collect data, social scientists make use of a number of different data collection strategies. First, experiments and quasi-experiments are important because they typically involve a research design that allows strong casual inferences. Second, surveys using structured questionnaires are another important data collection strategy because they typically involve collecting data on a large number of variables from a large and representative sample of respondents. Third, within a qualitative research the data collection strategy typically involves collecting a large amount of data on a rather small, purposive sample, using techniques such as in-depth interviews, participant observation, or focus groups.

(Hox and Boeije, 2005, p. 593)

Hox and Boeije introduce experiments, surveys, interviews, participant observation, and focus groups as primary data collection strategies. In essence, the experiments allow researchers to have a full controlled environment over the participants. In the case of surveys, a representative sample of a target population is consulted with standardized questions. On the other hand, interviews, participant observations, and focus groups are based on a close interaction with the public.

Secondary Data Collection

In relation to the secondary data\(^6\) collection, sources can be either published or unpublished. Examples of published sources are government publications, international publications, semi-official publications, reports of committees and commissions, websites, news from the public media, and private publications like journals, books, newspapers, and research articles. On the contrary, “in some cases

\(^5\) Original data collected for a specific research goal

\(^6\) Data already collected and available from other sources
data are collected but these are not put in published form. For example research scholars in the institutes and universities, trade associations and labor bureaus do collect data but they never put it in published form.” (Sharma et al., 2009, p. 24).

Taking into account both primary and secondary data collection strategies, next section introduces a research methodology for determining which are the most appropriate LS diffusion means to be implemented in the rural context.

4.2 Research Methodology

Figure 4.1 presents the flow chart of the research methodology suggested by the Author for determining the most pertinent LS diffusion means for the mitigation of lightning risk in rural areas, whose final result is the presentation of an educational methodology proposal to reach the rural population with the LS message in a given country.

![Figure 4.1. Research methodology flow chart.](image-url)
The methodology begins by reviewing the secondary sources where information about LS applied to rural locations can be found. Then, data obtained are evaluated to know if they are sufficient to attain the final result; if not, the next step is to perform data collection from some primary source, and since this moment the research becomes a primary research\textsuperscript{7}. After completing this process of collecting information, it is expected to make the presentation of an LS educational methodology proposal.

This research methodology was applied by the Author for the development of the current work. The review of research articles, books, websites, news, and government publications resulted in the contents presented in chapters 2 and 3. Nevertheless, from the exploration of these secondary sources, it was clear that it was necessary to conduct a primary data collection in order to make a more complete and accurate presentation.

The selected primary data collection instrument was the survey, since it offers the possibility to obtain information in a short time from a large number of individuals by asking questions defined by the Author. The target population was lightning experts because they are able to provide reliable and updated information about the subject, and thus the subsequent analysis of the survey could be done based on the Expert Judgment Technique\textsuperscript{8}. The design and application of the survey are detailed below.

### 4.3 Design of the Evaluation Instrument

In relation to the survey, it consists of two identifying questions (name and country of birth) and two questions evaluating the LS diffusion means.

\footnote{\textsuperscript{7} Research that involves primary data collection}

\footnote{\textsuperscript{8} “The concept behind expert judgment is to rely on individuals, or groups of people, who have training, specialized knowledge, or skills in the areas you’re assessing. These folks may be stakeholders, consultants, other experts in the organization, or technical or professional organizations” (PMP Project Management Professional Exam Study Guide, Second Edition, p. 69)}
Chapter 4: Methodological Approach to the Mitigation of Lightning Risk in Rural Areas

First question intends to assess the pertinence of a series of 15 diffusion means selected from the different LS comprehensive programs and isolated initiatives already discussed. The degree of pertinence of each one of them is evaluated through a Semantic Differential Scale\(^9\) composed by the following four options: not pertinent, little pertinent, pertinent, and greatly pertinent.

Second question asks for suggestions on diffusion means that should be considered for inclusion in an LS education program for rural population. It is important to note that participants are asked for rural population in general, without specifying any country. Complete survey is presented in Figure 4.2.

4.4 Application of the Instrument

In order to have the opportunity to contact worldwide lightning experts, the Author decided to attend to the 33rd International Conference on Lightning Protection (ICLP 2016\(^{10}\)), which is the most outstanding event in the world on the subject of lightning, with a trajectory of more than 60 years. The event was attended by over 250 delegates from more than 30 countries.

Having a population size of 250 experts, the amount of respondents needed to get statistically significant results was calculated using equation 4.1\(^{11}\), in which the

\(^9\) “... in a semantic differential scale, participants are asked to make judgments regarding words or phrases describing persons, events, activities, or materials... The scale is usually set up so that positive and negative responses occur at each end of the scale with each frequency... One advantage to using semantic differential scales is that responses can be made quickly because little reading is required.” (Methods in Educational Research: From Theory to Practice, First Edition, p. 108)

\(^{10}\) Held in Estoril, Portugal, from 25 to 30 September 2016. Among the topics of the 33rd ICLP, ‘lightning safety, medicine and education’ had its own technical session, in which the latest research results in this field were presented, including one paper performed by the Author as fruit of this research work, who was awarded with the YSA (Young Scientist Award). Further information about the Conference is available at www.iclp-centre.org and www.iclp2016.org

\(^{11}\) Formula for determining sample size published by the research division of the US National Education Association (NEA) in the article “Small Sample Techniques”, and used by Krejcie and Morgan in the article “Determining Sample Size for Research activities” (1970, Educational and Psychological Measurement, 30, pp. 607-610)
Characterization of the Lightning Safety Education Programs in the World as a First Step for the Creation of a Lightning Safety Policy in Colombia

Population proportion was assumed to be 0.95\(^{12}\). The following typical data were also assumed: confidence level = 95%; margin of error = 5%.

\[
 n = \frac{k^2 \times N \times P \times (1 - P)}{(e^2 \times (N - 1)) + (K^2 \times P \times (1 - P))}
\]  
(4.1)

Where:
- \( n \) = sample size
- \( k \) = constant associated with the confidence level
- \( N \) = population size
- \( P \) = population proportion
- \( e \) = margin of error

From equation 4.1, it was calculated that the required sample size was 57 respondents.

A total of 65 experts on lightning from 27 countries answered the survey (see Appendix 1). Sixty-two of them were authors and/or co-authors of the papers presented at ICLP 2016, and three were participants in previous editions. Thirty accepted to fill the survey personally and the rest via e-mail. All of them expressed great willingness to participate in the study. The results are presented and analyzed in the following section.

**4.5 Analysis of Results**

Figure 4.3 shows the results summary chart for the first question of the survey. Only four of the diffusion means were not recommended by the majority of the experts to spread the LS message among rural population, namely, academic articles (76.92%), books (72.31%), reminiscent gifts (67.69%), and research centers (53.85%). For its part, in Figure 4.4 the diffusion means are ordered from lowest to highest according to their pertinence, which was obtained from the sum of the percentages of options ‘pertinent’ and ‘greatly pertinent’.

\(^{12}\) This value was assumed because all individuals in the population had the characteristic for the study.
1. In order to design and implement a lightning safety education methodology for rural population, how do you classify the following diffusion means to spread effectively the lightning safety information among this population?

<table>
<thead>
<tr>
<th>DIFFUSION MEANS</th>
<th>DEGREE OF PERTINENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No pertinent</td>
</tr>
<tr>
<td>Websites</td>
<td>0</td>
</tr>
<tr>
<td>Mobile Apps</td>
<td>0</td>
</tr>
<tr>
<td>Seminars</td>
<td>0</td>
</tr>
<tr>
<td>Workshops</td>
<td>0</td>
</tr>
<tr>
<td>Leaflets</td>
<td>0</td>
</tr>
<tr>
<td>Comic Strips</td>
<td>0</td>
</tr>
<tr>
<td>Games</td>
<td>0</td>
</tr>
<tr>
<td>Videos</td>
<td>0</td>
</tr>
<tr>
<td>Diffusion by television</td>
<td>0</td>
</tr>
<tr>
<td>Diffusion by radio</td>
<td>0</td>
</tr>
<tr>
<td>Academic Articles</td>
<td>0</td>
</tr>
<tr>
<td>Books</td>
<td>0</td>
</tr>
<tr>
<td>Documentaries</td>
<td>0</td>
</tr>
<tr>
<td>Reminiscent Gifts</td>
<td>0</td>
</tr>
<tr>
<td>Research Centers</td>
<td>0</td>
</tr>
</tbody>
</table>

2. Taking into account your expertise in the field of lightning research, which other diffusion means do you consider pertinent to be included in a lightning safety education program for rural population?

Figure 4.2. Survey for the study.
Characterization of the Lightning Safety Education Programs in the World as a First Step for the Creation of a Lightning Safety Policy in Colombia

Figure 4.3. Results summary chart for Question Number 1.
Of the 15 diffusion means, just four (academic articles, books, reminiscent gifts, and research centers) were considered by more than 50% of the experts as unsuitable for the rural context.

Figure 4.4. Chart of diffusion means ordered according to their pertinence.
Results shows a marked preference for the mass media.
In order to analyze the answers that the experts gave in the first question of the survey, the diffusion means that share similar characteristics were analyzed in groups. This analysis was based on data related to the current global context in which the diffusion means are present, paying special attention to the possible impact that they could have within the rural population of Colombia.

**Websites and Mobile Apps**

Results charts for websites and mobile applications presented in Figure 4.5 show that the majority of the experts considered them as pertinent for spreading the LS message among rural population. This fact is becoming more relevant because the average number of internet users worldwide has a growing tendency every year (see Figure 4.6), where the twenty-first century started with less than 7 users and in 2015 this number was almost 45. As seen in Figure 4.7, Colombia and some of its neighboring countries exceeded the worldwide average with more than 55 internet users per 100 people in 2015. It is important to notice that, according to Katz (2015), Colombia had a difference of more than thirty percentage points in the internet access by fixed connection between urban and rural zones for the year 2013, while respect to the mobile connection it is more difficult to know this difference accurately.

The number of mobile cellular subscriptions is also increasing. For the same year 2015, the worldwide average of subscriptions per 100 people was 98.72, while in Colombia it was 115.745 (The World Bank, 2017b). For the case of Africa, Trengove and Jandrell state that “this emergence of a pervasive mobile phone and texting culture in Africa might provide an opportunity to disseminate lightning awareness information and weather warnings in areas where it could reduce the number of annual lightning fatalities.” (Trengove and Jandrell, 2012, p. 1). Colombia might experience similar situation by taking advantage of its high number of mobile subscriptions.

This global and local scenario in relation to internet access leads to thinking about how many inhabitants of rural areas in Colombia could have access to websites and mobiles apps dedicated to delivering the LS message to them.
Characterization of the Lightning Safety Education Programs in the World as a First Step for the Creation of a Lightning Safety Policy in Colombia

Figure 4.5. Results charts for websites and mobile apps

Figure 4.6. Worldwide average internet users per 100 people, 2000-2015
(Internet can be used via a computer, mobile phone, or other media).
Adapted from The World Bank (2017a)
Figure 4.7. Map of Colombia and its region of internet users per 100 people for 2015.  
Adapted from The World Bank (2017a)

_Seminars and Workshops_

Charts in Figure 4.8 show the similarity of the results for seminars and workshops. Despite no details about the contents to be covered in them were given to the experts, most of them recommend these two ways of sharing the LS knowledge for the rural context, probably because they allow a personal interaction between the speakers and the audience, making a more participatory learning experience for the public.

Seminars have been typically conceived as a form of academic instruction. On the other hand, workshops intend to be meetings at which people may engage in discussion. Both seminars and workshops require well-prepared people with a passion for teaching, even when resources are limited. Some resources may not be available at rural locations, so it is important to be creative and uncomplicated.
Leaflets and Reminiscent Gifts

Leaflets and reminiscent gifts are things that people can take home. This is a great advantage when the intention is to help people to have long-term memories of the LS message. However, there are differences between leaflets and reminiscent gifts that may be the cause of having different opinion about them by the experts, as seen in Figure 4.9.

Most of the experts do not consider reminiscent gifts as pertinent to disseminate the LS message to rural population. Reminiscent gifts like fridge magnets often have high costs. Moreover, the message that is placed on them should be short. Nevertheless, they could be a good tool to complement other diffusion strategies like seminars and workshops.

In the case of leaflets, the associated costs are lower and the amount of information that can be included in them is greater. In addition, they can be delivered easily. However, leaflets should be delivered after people hear the LS instructions, so that they can have a better understanding and make a correct interpretation of the contents that are in them.
**Comic Strips and Games**

Comic strips are not just a way to get fun, but also a powerful teaching method. Sharpe and Izadkhah state:

... the visual element of comic strips allows the reader to progress at their own pace which allows them control over their learning, while allocating time for understanding between frames. This has an advantage over other forms of multimedia often used to engage learners, such as film and animation.

(Sharpe and Izadkhah, 2014, p. 139)

Prior statement is consistent with what Marston (1944) says, cited by Sharpe and Izadkhah, in a moment when comics began to have a boom, regarding the advantage of stories with pictures over written texts:

The potency of the picture story is not a matter of modern theory but of anciently established truth. Before man thought in words, he felt in pictures ... It’s too bad for us “literary” enthusiasts, but it’s the truth nevertheless, pictures tell any story more effectively than words.

(Sharpe and Izadkhah, 2014, p. 144)
These features of comic strips make them suitable for rural population, especially for children who could be motivated to consider them as one of their favorite ways to learn about lightning safety. It is likely that most of the experts had these facts in mind, and for that reason they rated comic strips as pertinent to spread the LS message among rural population (see Figure 4.10).

Games were less preferred by the experts, probably because rural inhabitants have access to a limited range of possibilities in comparison to urban inhabitants. Video games and games on the internet are not available to most rural zones, and table games played in groups are usually the only option.

The design of LS games suitable for the rural context is not an easy task. However, the LS promoters should always consider using them as a challenging way of teaching, since these have been successfully included within LS campaigns (Cooper and Holle, 2012b; Villamil et al., 2015).

**Videos and Documentaries**

Results charts for videos and documentaries are presented in Figure 4.11. It can be clearly seen from the pie charts that videos are highly recommended by the experts to educate rural population regarding lightning safety.

![Figure 4.10. Results charts for comic strips and games](image-url)
Both videos and documentaries have been present in LS programs. For example, videos were one of the tools used to display the concept of lightning protection as part of mobile science exhibitions conducted in Sri Lanka (Jayaratne and Gomes, 2012). People from all the country visited the exhibitions, which were housed in railway carriages. Likewise, documentaries on lightning safety have been produced by LS organizations, like the Lightning Strike and Electric Shock Survivors International (LSESSI\(^\text{13}\)), to rise lightning awareness among the general public (Cooper and Holle, 2005a; Cooper and Marshburn, 2005b).

These audiovisual media are widely used to impart scientific knowledge of any subject to the public, since they can present a lot of information at once, and are available to be reused as many times as instructors want.

**Diffusion by Television and Diffusion by Radio**

As seen in Figure 4.12, television and radio were considered by the experts as the most pertinent diffusion means among the list of 15. This fact should not be ignored.

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**Figure 4.11. Results charts for videos and documentaries**

---

\(^{13}\) Lightning Strike & Electric Shock Survivors International, Inc. is a non-profit support group by and for survivors, their families, and other interested parties. Further information at [www.lightning-strike.org](http://www.lightning-strike.org)
The experts believe that television and radio are the most effective ways to reach the rural population with the LS message among all the diffusion means listed in the survey, mainly because nowadays they are the most popular mass media in the world. Only a few locations have no signals of radio and TV available thanks to the advances in communication technology.

Radio broadcasting has the possibility of reaching remote places, even those inaccessible by other means. People dwelling in mountaintops or thick forests can know the LS message by listening to the radio. In addition, radio receivers are usually not expensive.

The first broadcaster in Colombia was inaugurated in 1929, and since then radio has had a remarkable development until the present time (Gómez, 2009). Radio stations are listened in every part of the country, including rural villages. In relation to the situation of the radio in Colombia, Albarran states:

Radio in Colombia has experienced a decrease in the size of its audience. In 1999, 82.7 percent of the population listened to the radio; by 2007, this percentage fell to 68.9 percent ... Nevertheless, radio remains the second most consumed media after television, and it has begun to broadcast its contents through internet platforms.

(Albarran, 2009, p. 70)

Through the television, millions of people could be reached at the same time with the LS message, including a great portion of the rural population, by displaying a short commercial within the prime time. The whole family, or at least a great part of its members, could receive LS instructions in an instant. However, the high cost of having a space on TV exclusively dedicated to promote lightning safety hinders the creation of such spots. On the other hand, usually rural inhabitants have an easier access to public channels than to private channels, so delivering the LS message to them through TV depends largely on governmental initiatives.
Figure 4.12. Results charts for diffusion by television and diffusion by radio

**Academic Articles, Books and Research Centers**

The pie charts presented in Figure 4.13 are clear evidence that the experts consider academic articles, books and research centers as inadequate for disseminating the LS message within the rural population.

Although academic articles and books have been crucial resources for the development and diffusion of knowledge about lightning among researchers, people living in rural zones are unaware of most of the information in them. This is because rural dwellers are not familiar with the theories and terms presented there, mostly due to these lightning concepts are presented using scientific language. Additionally, access to libraries and academic databases is often difficult for those who dwell outside urban areas.

Research centers are a source of knowledge and new ideas. Nevertheless, the benefit of having research centers on lightning safety within rural areas is conditioned on the way in which researchers engage the community and its needs in their work. Therefore, although the opinion of the most of the experts disqualifies them, the presence of LS research centers within the rural context could cause the creation and execution of innovative projects that greatly assist the population.
Figure 4.13. Results charts for academic articles, books and research centers

Question Number 2, answered by 58 of the 65 experts, collected several helpful ideas that may be considered in addition to the diffusion means covered in Question Number 1. Examples of these ideas are:

- “Creation of benchmarks to illustrate the need for lightning safety procedures”
- “Lectures for kids”
“Local divulgation to small communities by official entities”

“Group working”

“Teach it in mandatory science classes for students or already at the elementary school level”

“A roadshow on Principles of Lightning”

“Incorporate information on thunderstorms and lightning as well as on lightning safety in (specific) lessons in school early”

“Interaction with social networks”

“Field training”

“Identify a common interest of the community and do advertisement there e.g. church, football games, music festivals, etc.”

“Social Networks - High School Education”

“Direct in-person visits”

“Discussion with church leaders about the problem”

“Personal visit to their homes”

“Voice to voice - Visit the people periodically”

“Teach in primary schools - Educate teachers of middle / primary schools”

“Advertisements”

“Including the subject in education as a complementary topic related to safety in general, I mean in schools”
Characterization of the Lightning Safety Education Programs in the World as a First Step for the Creation of a Lightning Safety Policy in Colombia

“Send weather reports to phones using a phone carrier as text messages”

“Street acting/dramas in markets for non-literate people, used in India/Nepal – Safety talks to young children (6-10) with games and stories - Public rules”

“Teaching at elementary schools”

“Maybe lightning messages could be put on mobile telephones that open up, for example, when you load airtime.”

“Direct contact with the population through scientific delegations”

“Something like demonstrating experiment”

“Clearly approved material about the lightning danger and the lightning safety”

“Local press and social networks”

“Tips through energy receipts, through municipal government (UMATAS, etc.)”

“Wrap-around bus advertising - Street theatre - Bill boards - Lightning Awareness Campaigns - Awareness Days at the onset of each lightning season - Involvement of the local weather service”

“School subjects that allow the students analyze and understand effects based on videos, books and plays”

“Consistent engagement with community leadership”

Several deductions can be drawn from the ideas given by the experts. Among them, education to children in the schools is highly recommended, whether by lectures, lessons, science classes or by similar activities. In addition, working groups and personal visits are ways proposed to interact with people in their home and work contexts. Similarly, reaching people on the streets with the LS message is also a key
target, and ideas like roadshows, demonstrating experiments, and street acting could be very useful in achieving it.

With regards to LS ads, local press is preferred by some experts for spreading the LS within the rural population. On the other hand, some experts believe that LS advertisements in the social networks are an appropriate resource. Additionally, an idea like providing LS information in the energy receipts is innovative and could become a prominent LS tool in the future.

Likewise, some of the experts gave valuable opinions and commentaries when answering Question Number 2:

- “Work must be done with children at schools”
- “Outreach to schools - Educate the children - Provide material they can bring home - Engage weather people on radio and TV to spread the message”
- “I think most of the means were covered in Q1”
- “Depending on the age group, diffusion means may change”
- “It always works better to teach the CHILDREN!”
- “I think the best way is seminars in the regions”
- “I suggest a process of participation of the people involved to teach by doing and to try to arise from them possible solutions or measures of action to make in action”
- “I think that educating school children in rural schools about lightning would be good, because they will take the message home to their elders.”
- “TV will be the best”
“Develop your methodology and then undertake a pilot study or two in very different rural areas to evaluate its success and understand what changes may be needed. It would be a good project to involve degree students. Good luck!”

“Please provide me further details by e-mail”

**Conclusions of the Chapter**

Due to the complex nature of the lightning risk problem that rural dwellers face, the possible proposals for the mitigation of this risk in rural areas require following a research methodology in which both primary and secondary data are present.

Taking into account both primary and secondary data collection, from the components of the existing LS programs and initiatives presented in chapter 3, along with the opinions and ideas given by the worldwide lightning experts, it is possible to devise LS educational strategies for Colombia that can reach the inhabitants of rural zones as a starting point for then reaching the rest of populations.

The presentation of an LS educational methodology for the formulation of an LS policy for Colombia is the subject of the last chapter of this research work.
Chapter 5: Recommendation for a Lightning Safety Policy in Colombia

Lightning injury continues to be a substantial health risk in many countries (Cooper and Ab Kadir, 2010). For this reason, the efforts made recently in the world regarding the reduction of the risk associated with lightning attempt to establish the foundation of a new culture wherein the lightning safety principles are present everywhere, at any time, and one of the key actions to attain this goal is the creation of lightning safety public policies. By enacting lightning safety public policies both national and local authorities may have the necessary tools to design, organize and execute lightning safety programs that may act today and stand in the future, future that is currently being globally oriented to achieve sustainable development.

Taking this into account this fact, designers of lightning safety promotional programs are starting to link them with the principles and guidelines of disaster risk management (DRM), which is an issue that is now considered as one of the critical factors in pursuing sustainable development.

5.1 Global Disaster Risk Management Context

Risk management is defined as “the systematic approach and practice of managing uncertainty to minimize potential harm and loss” (United Nations International Strategy for Disaster Reduction [UNISDR], 2009, p. 26). This concept is
important due to "risk management is an essential tool for development because people in developing countries are exposed to many risks, and an inability to manage those risks can jeopardize development goals, including economic growth and poverty reduction." (The World Bank, 2013, p. 55).

Regarding the risk caused by natural phenomena, commonly known as ‘disaster risk’, two terms are frequently used: disaster risk reduction (DRR) and disaster risk management (DRM). Disaster risk reduction is "the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events" (UNISDR, 2009, pp. 10-11). On the other hand, disaster risk management is "the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster (UNISDR, 2009, p. 10).

Since 2015, the world has a new plan of action for sustainable development in which DRM plays a prominent role. Transforming our world: the 2030 Agenda for Sustainable Development is the resolution adopted by the General Assembly of the United Nations to stimulate, through its 17 Goals and 169 targets, global action for the period 2015-2030 in the following five key areas: people, planet, prosperity, peace, and partnership (United Nations, 2015). Goal number 11 – ‘Make cities and human settlements inclusive, safe, resilient and sustainable’ – deals with DRM in its section b as follows:

11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels

(United Nations, 2015, p. 22)
Characterization of the Lightning Safety Education Programs in the World as a First Step for the Creation of a Lightning Safety Policy in Colombia

As Goal number 11 states, holistic DRM must be developed and implemented according to the *Sendai Framework for Disaster Risk Reduction 2015-2030*. The Sendai Framework, adopted six months before the endorsement of the 2030 Agenda, is a major agreement whose purpose is “to guide the multi-hazard management of disaster risk in development at all levels as well as within and across all sectors” (UNISDR, 2015, p. 35). In order to accomplish this ambitious purpose, the Sendai Framework has seven targets and four priorities for action (see Table 5.1).

Priority 1, understanding disaster risk, intends to be the foundation of the risk management process. Section 23 of the Sendai Framework asserts:

Policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge can be leveraged for the purpose of pre-disaster risk assessment, for prevention and mitigation and for the development and implementation of appropriate preparedness and effective response to disasters. (UNISDR, 2015, p. 13)

Education plays a prominent role in achieving priority 1. As is stated in the Sendai Framework, it is important at national and local levels “to promote national strategies to strengthen public education and awareness in disaster risk reduction, including disaster risk information and knowledge, through campaigns, social media and community mobilization, taking into account specific audiences and their needs” (UNISDR, 2015, p. 14). Likewise, it is important at global and regional levels:

To develop effective global and regional campaigns as instruments for public awareness and education, building on the existing ones..., to promote a culture of disaster prevention, resilience and responsible citizenship, generate understanding of disaster risk, support mutual learning and share experiences; and encourage public and private stakeholders to actively engage in such initiatives and to develop new ones at the local, national, regional and global levels. (UNISDR, 2015, p. 15)
5.2 Colombian Disaster Risk Management Context

Colombia received the new phase in disaster risk management for sustainable development that the world is now going through as one of the pioneer countries of its region in “developing a comprehensive vision for risk and disaster management” (The World Bank, 2013, p. 77). Three years before the Sendai Framework appeared, the current government created the Colombian national DRM policy through the enactment of the Law 1523 of 2012, initiating the first DRM system. This system integrates all previous efforts in Colombia on DRM.

The National System of Disaster Risk Management (SNGRD in Spanish) is defined as “the set of public, private and community entities, policies, norms, processes, resources, strategies, instruments, mechanisms, as well as information related to the subject, which is applied in an organized way to ensure disaster risk management in the country” (Colombian Congress, 2012, p. 4). Additionally, in 2015 the National Plan for Disaster Risk Management went live under the slogan “A strategy of development”, with the stated purpose of establishing the specific goals in relation to DRM according to the course of the National Development Plan (UNGRD, 2015). These goals are presented in Table 5.2.

Disaster risk management in Colombia is directed, oriented and coordinated by the National Unity for Disaster Risk Management (UNGRD14 in Spanish), which is the entity responsible for the coordination of the entire SNGRD. Headquartered in Bogotá, the UNGRD leads the DRM course through three National Committees – Knowledge Committee, Risk Reduction Committee, and Disaster Management Committee –, which are “advisory, planning and monitoring bodies designed to ensure the effectiveness and articulation of knowledge, risk reduction and disaster management processes” (Colombian Congress, 2012, p. 5).

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14 All information related to the members, regulations, objectives, functions, and projects of the UNGRD is available in its official website: www.portal.gestiondelriesgo.gov.co
### Table 5.1. Global targets and priorities for action of the Sendai Framework

<table>
<thead>
<tr>
<th>Global Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target 1:</strong> Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality rate in the decade 2020-2030 compared to the period 2005-2015</td>
</tr>
<tr>
<td><strong>Target 2:</strong> Substantially reduce the number of affected people globally by 2030, aiming to lower average global figure per 100,000 in the decade 2020-2030 compared to the period 2005-2015</td>
</tr>
<tr>
<td><strong>Target 3:</strong> Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030</td>
</tr>
<tr>
<td><strong>Target 4:</strong> Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030</td>
</tr>
<tr>
<td><strong>Target 5:</strong> Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020</td>
</tr>
<tr>
<td><strong>Target 6:</strong> Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this Framework by 2030</td>
</tr>
<tr>
<td><strong>Target 7:</strong> Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Priorities for Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Priority 1:</strong> Understanding disaster risk</td>
</tr>
<tr>
<td><strong>Priority 2:</strong> Strengthening disaster risk governance to manage disaster risk</td>
</tr>
<tr>
<td><strong>Priority 3:</strong> Investing in disaster risk reduction for resilience</td>
</tr>
<tr>
<td><strong>Priority 4:</strong> Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction</td>
</tr>
</tbody>
</table>

Adapted from UNISDR (2015)
Chapter 5: Recommendation for a Lightning Safety Policy in Colombia

Table 5.2. Goals of the Colombian National Plan for DRM

<table>
<thead>
<tr>
<th>National Plan for Disaster Risk Management 2015 - 2025</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Goal</strong></td>
</tr>
<tr>
<td>To guide the actions of the State and civil society concerning the knowledge of risk, risk reduction and disaster management in compliance with the National Policy Risk Management, that contribute to the safety, welfare, quality of life of people and sustainable development in the country.</td>
</tr>
<tr>
<td><strong>Strategic Goals</strong></td>
</tr>
<tr>
<td><strong>Strategic Goal 1:</strong> To improve the knowledge of disaster risk in the national territory</td>
</tr>
<tr>
<td><strong>Strategic Goal 2:</strong> To reduce the construction of new risk conditions in territorial, sectorial and environmental development.</td>
</tr>
<tr>
<td><strong>Strategic Goal 3:</strong> To reduce the existing disaster risk conditions</td>
</tr>
<tr>
<td><strong>Strategic Goal 4:</strong> To guarantee an opportune, effective and appropriate disaster management</td>
</tr>
<tr>
<td><strong>Strategic Goal 5:</strong> To strengthen governance, education and social communication in risk management with differential approach, gender approach and cultural diversity</td>
</tr>
</tbody>
</table>

Adapted from UNGRD (2015)

5.3 Lightning Risk and Disaster Risk Management

As seen in the aforementioned context, great advances have been achieved in Colombia regarding DRM, resulting in having an increasing awareness about the opportunities it provides for contributing to the Colombian development. However, currently there is no policies to manage specifically lightning risk in the country.

Since the final goal of this research project is to be the foundation for the creation of an LS public policy in Colombia, this final section provides an insight into the basics of public policies, as well as elements to formulate such a policy.
Public Policy Basics

According to Howlett and Ramesh, “public policy is, at its most simple, a choice made by a government to undertake some course of action” (Howlett and Ramesh, 2003, p. 3). A more detailed definition of public policy is given by the Office of the Inspector General of Colombia (PGN in Spanish), stating that “public policy can be understood as a social construction where the Government plays a fundamental role, guiding the behavior of the actors through a set of successive intentional actions that are intended to deal with situations considered socially as relevant.” (PGN, 2011, p. 26).

Conventional theory on public administration sets the development of public policies within a four-stage process known as ‘the public policy cycle’, which begins with the government agenda setting, then continues with the formulation, the implementation, and finally the evaluation (see Figure 5.1). Additionally, in order to have an execution structure, the components of a public policy are associated to four levels of action, namely: strategy, plan, program, and actions (see Figure 5.2).

![Figure 5.1. Public policy cycle. The four stages are: 1) Agenda setting, 2) Policy Formulation, 3) Policy Implementation, and 4) Policy Evaluation. Adapted from PGN (2011)]
Obstacles on the Road to Lightning Risk Management

The introduction of the lightning risk management (LRM) concept into the current Colombian DRM context is something completely new. As previously mentioned, the Colombian DRM System does not have any LS policy yet. Considering this, Villamil et al. indicate two aspects that are hindering the creation of such a policy: a non-unified interpretation of the word *storm* and a wrong classification of the lightning risk within the terminology of DRM.

With respect to the first aspect, Villamil et al. state:

Within Colombian and Latin American literature and media there exist commonly diverse interpretations of the concept *storm* (tormenta in Spanish), which sometimes may confuse or inform erroneously the general public because there is not enough clarity about what does this word really refers to. Frequently, events and statistics associated with rainstorms, tropical storms, windstorms, gales, hailstorms and electric storms are all referenced just using the same word
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torrenta ... Therefore, in order to disseminate adequate information related to natural disasters, including lightning hazard, it is necessary to make the distinction properly and explain the consequences of each one, referencing their features separately, due to all of them have particular characteristics and may produce different shocks.

(Villamil et al., 2016, p. 4)

About the second aspect, the same authors say:

... taking into account the random nature of the lightning hazard, it is also necessary to consider the lightning risk as an extensive risk, not as an intensive risk. That means that, although it is listed among natural disasters, a lightning produces neither a great number of injuries at the same place nor at the same time. The events involving electrical storms in Colombia ... are proof of that, where it is evident their high-frequency and low-severity losses (no high quantity of people affected per event), which ... are the typical characteristics of extensive risks. Not dealing with this fact appropriately has made more difficult the process to integrate lightning risk officially into the programs of the SNGRD, resulting in not having yet a program exclusively dedicated to manage this important natural disaster in the country.

(Villamil et al., 2016, p. 4)

Additionally, Gomes and Gomes state that "lightning is not treated seriously as a concern of safety by the research community working on safety sciences. Even government policy documents and guidelines on occupational safety, in countries with very high ground flash density, do not address or at least mention the term 'lightning' (Gomes and Gomes, 2016b, p. 7). This last fact leads to thinking that the enactment of a LS public policy requires that lightning be taken into account as a hazardous event by the UNGRD. Otherwise, all proposals regarding the construction of an LS policy for Colombia will be unfruitful.
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*A Step towards the Construction of an LS Policy in Colombia*

The Author presents in this final subsection a recommendation for the creation of an LS educational methodology, mainly oriented to the rural population, which is based on the opinions and suggestions collected from the consulted worldwide lightning experts. The LS educational methodology proposal is composed of the following items:

> **Inclusion of lightning risk in the UNGRD Knowledge Committee:**

The Knowledge Committee of the UNRGD advises and plans the permanent implementation of the risk knowledge process. It has several functions, among them, to guide the identification of risk scenarios, to advise the design of the risk knowledge process as a component of the SNGRD, and to foster the opening of research and training lines on risk management in high education institutions ( Colombian Congress, 2012). Therefore, lightning must be included within the work of the Knowledge Committee so that it begins to be part of the disaster risk management system. Moreover, high education institutions like the Universidad Distrital Francisco José de Caldas can support that inclusion by providing a research platform on lightning and lightning risk management.

> **Addition of lightning to the UNGRD Climate Change Mobile App and Risk Awareness Website:**

Since 2015, the UNGRD has an App named ‘Climate Change in Action’\(^\text{15}\), which provides an interactive game as a learning environment, enjoyable for kids and adults, in relation to the knowledge and actions to face the following hazards: droughts, floods, frosts, landslides, forest fires, gales, and earthquakes. Each of them has its own level, in which the user is provided with the necessary tools and instructions to change a hazardous situation into a safe scenario. Lightning could also have a place in this useful app. Additionally, the UNGRD risk

\(^{15}\) Available in Google Play Store with the name of ‘UNGRD Cambio Climático en Acción’
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awareness website\textsuperscript{16} presents interactive explanations of tropical cyclones, forest fires, floods, landslides, earthquakes, tsunamis, and volcanos in three stages: know and reduce the risk, act, and evaluate. Currently, this website lacks an explanation of lightning hazard.

> \textit{Creation of a lightning safety comic strip:}
As mentioned in section 4.5, comic strips are not only for getting fun, but also an effective way of teaching. The recent successful experience of starting to use comic strips in teaching about earthquakes to kindergarten children in Iran (Sharpe and Izadkhah, 2014) is an evidence of the potential that comics have to disseminate the lightning safety knowledge. For that reason, the design of an LS comic strip, available in newspapers, magazines, and/or on Internet, could also help greatly in spreading the LS message among the rural population of Colombia.

> \textit{Implementation of Lightning Safety radio advertisements:}
Since radio is the second most used mass media in Colombia, and many times the first one where electricity is not available, the inclusion of short LS ads within the radio programming could reach a lot of peasants and their families with the lightning safety message. Undoubtedly, this requires more than the good will of the radio broadcast programmers. This initiative must have economic and human resources to be successfully implemented.

> \textit{Development of a lightning safety documentary for Colombian rural population}
Although most of the rural dwellers maybe could not get familiarized with the scientific concepts of lightning, a lightning safety documentary divided into small segments could provide them a contextualization on lightning safety. This documentary could be presented in schools and other crowded venues.

\textsuperscript{16} With the name of ‘Conciencia ante el riesgo’, this website is aimed at kids, teachers, and the general public. Website address: \url{conciencia.gestiondelriesgo.gov.co}
Chapter 5: Recommendation for a Lightning Safety Policy in Colombia

The presentation of the previous recommendation is the final product of the research methodology presented in section 4.2. However, since this LS educational methodology is intended to be a step towards the development of an LS policy, the research methodology depicted in Figure 4.1 is extended to be articulated with the formulation, implementation, and evaluation of a public policy. The extended methodology is shown in Figure 5.3.

Figure 5.3. Methodology for the development of a Lightning Safety Policy.
As seen in Figure 5.3, the presentation of the LS educational methodology proposal is a prominent part of the methodology for the development of an LS policy because this is the first action towards its formulation, thus fulfilling the last objective of this research-innovation project. The inclusion of this educational methodology in a public policy is expected in the short term.

**Conclusions of the Chapter**

The role that lightning risk management can play in achieving sustainable development could become noticeable if lightning begins to be included within the current national and international context on disaster risk management. However, there are some obstacles that must be overcome to make this happen.

A part of the formulation of an LS public policy for Colombia can be made from the research process conducted for the creation of an LS educational methodology proposal, but the inclusion of such a methodology into a public policy requires the support of the SNGRD. Otherwise, there is no possibility to implement a national-scale strategy to increase the awareness of lightning risk and lightning safety among the Colombian population.
Conclusions

- From observation of multiple lightning incidents reported in Colombia, patterns of individual and group behavior have been identified, which could be included in the count and analysis of lightning casualties, particularly in populations with similar characteristics, in order to achieve a better understanding of the socio-demographic aspects related to lightning hazard.

- The design of a lightning safety educational methodology is possible from the existing LS comprehensive programs and isolated initiatives, by considering both their components and indicators as a referent of the path already traveled on the subject.

- Rural dwellers are the first target population when designing a lightning safety educational methodology because, in general, they are more vulnerable to be injured by lightning. For the case of Colombia, the inclusion of lightning in the Knowledge Committee and the Climate Change App of the UNGRD, the creation of a lightning safety comic strip, the implementation of lightning safety radio advertisements, and the development of a lightning safety documentary are the items to be included in such educational methodology.

- It is necessary to incorporate the proposed lightning safety educational methodology in the formulation of a public policy that may deal directly with lightning hazard in Colombia, within the framework of the existing DRM System. This lightning safety policy would be a powerful tool in contributing to save lives, as well as to the achievement of the goals of the National Development Plan and of the Agenda 2030 for Sustainable Development through Lightning Risk Management.
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# Appendix 1: List of Lightning Experts

Name, country of birth, and current affiliation of the 65 lightning experts who contributed to this research by answering the designed survey are listed below.

<table>
<thead>
<tr>
<th>Country of Birth</th>
<th>Name</th>
<th>Current Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Algeria</em></td>
<td>Kaddour Arzag</td>
<td>University of Saida – Department of Electrotechnics</td>
</tr>
<tr>
<td><em>Argentina</em></td>
<td>M. Gabriela Nicora</td>
<td>Instituto de Investigaciones Científicas y Técnicas para la Defensa, CITEDEF</td>
</tr>
<tr>
<td><em>Austria</em></td>
<td>Gerhard Diendorfer</td>
<td>Austrian Electrotechnical Association, OVE – Department of ALDIS (Austrian Lightning Detection &amp; Information System)</td>
</tr>
<tr>
<td><em>Brazil</em></td>
<td>Antonio Lima</td>
<td>COPPE/Universidade Federal do Rio de Janeiro</td>
</tr>
<tr>
<td><em>Brazil</em></td>
<td>Alexandre Piantini</td>
<td>Institute of Energy and Environment of the University of São Paulo</td>
</tr>
<tr>
<td><em>Brazil</em></td>
<td>Marcelo Saba</td>
<td>National Institute for Space Research, INPE</td>
</tr>
<tr>
<td><em>Brazil</em></td>
<td>Miltom Shigihara</td>
<td>Institute of Energy and Environment of the University of São Paulo</td>
</tr>
<tr>
<td><em>Brazil</em></td>
<td>Sandro Assis</td>
<td>Companhia Energética de Minas Gerais, CEMIG</td>
</tr>
<tr>
<td>Country</td>
<td>Name</td>
<td>Institution</td>
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<tr>
<td>Brazil</td>
<td>Silveiro Visacro</td>
<td>Federal University of Minas Gerais</td>
</tr>
<tr>
<td>Cameroon</td>
<td>Ngamini Jean Blaise</td>
<td>African Centers for Lightning and Electromagnetics Network, ACLENet</td>
</tr>
<tr>
<td>Canada</td>
<td>Abdul Mousa</td>
<td>British Columbia Hydro</td>
</tr>
<tr>
<td>China</td>
<td>Zixin Guo</td>
<td>North China Electric Power University</td>
</tr>
<tr>
<td>Colombia</td>
<td>Alejandro Latorre</td>
<td>Universidad Nacional de Colombia – Department of Electrical and Electronics Engineering</td>
</tr>
<tr>
<td>Colombia</td>
<td>Francisco Román</td>
<td>Universidad Nacional de Colombia – Department of Electrical and Electronics Engineering</td>
</tr>
<tr>
<td>Colombia</td>
<td>Fernando Diaz-Ortiz</td>
<td>Universidad Nacional de Colombia – Department of Electrical and Electronics Engineering</td>
</tr>
<tr>
<td>Colombia</td>
<td>Jesús Lopez</td>
<td>Universitat Politècnica de Catalunya, UPC – Department of Electrical Engineering</td>
</tr>
<tr>
<td>Colombia</td>
<td>Jorge Alarcón</td>
<td>Universidad Distrital Francisco José de Caldas – Faculty of Engineering</td>
</tr>
<tr>
<td>Colombia</td>
<td>Jorge Cristancho</td>
<td>Universidad Nacional de Colombia – Department of Electrical and Electronics Engineering</td>
</tr>
<tr>
<td>Colombia</td>
<td>Jorge Rodríguez</td>
<td>Universidad Nacional de Colombia – Department of Electrical and Electronics Engineering</td>
</tr>
<tr>
<td>Country</td>
<td>Name</td>
<td>Institution</td>
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<tr>
<td>Colombia</td>
<td>José Cuarán</td>
<td>Universidad Nacional de Colombia – Department of Electrical and Electronics Engineering</td>
</tr>
<tr>
<td>Colombia</td>
<td>Liliana Arévalo</td>
<td>ABB AB – Research and Development Department</td>
</tr>
<tr>
<td>Colombia</td>
<td>Luis Perdomo</td>
<td>Universidad Distrital Francisco José de Caldas – Faculty of Engineering</td>
</tr>
<tr>
<td>Colombia</td>
<td>Marley Becerra</td>
<td>KTH Royal Institute of Technology – School of Electrical Engineering</td>
</tr>
<tr>
<td>Colombia</td>
<td>Oscar Diaz</td>
<td>Uppsala University – Faculty of Engineering Sciences, Division of Electricity</td>
</tr>
<tr>
<td>Denmark</td>
<td>Søren Find Madsen</td>
<td>Global Lightning Protection Services</td>
</tr>
<tr>
<td>France</td>
<td>Alan Rousseau</td>
<td>Société d'Etudes et de Fabrication des Techniques Industrielles Modernes, SEFTIM</td>
</tr>
<tr>
<td>Germany</td>
<td>Alexander Kern</td>
<td>Aachen University of Applied Sciences – Department Juelich</td>
</tr>
<tr>
<td>Germany</td>
<td>Tobias Kopp</td>
<td>Technische Universität Braunschweig</td>
</tr>
<tr>
<td>Germany</td>
<td>Michael Rock</td>
<td>Technische Universität Ilmenau</td>
</tr>
<tr>
<td>Greece</td>
<td>Pantelis Mikropoulos</td>
<td>Aristotle University of Thessaloniki – Faculty of Engineering, School of Electrical &amp; Computer Engineering</td>
</tr>
<tr>
<td>Greece</td>
<td>Zacharias Datsios</td>
<td>Aristotle University of Thessaloniki – Faculty of Engineering, School of Electrical &amp; Computer Engineering</td>
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<tr>
<td>Country</td>
<td>Name</td>
<td>Institution and Department</td>
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<tr>
<td>Hungary</td>
<td>István Kiss</td>
<td>Budapest University of Technology and Economics - Department of Power Engineering</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Andri Haryono</td>
<td>The Petroleum Institute – Electrical Engineering Department</td>
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<td>Italy</td>
<td>Elisabetta Fiori</td>
<td>CIMA Research Foundation</td>
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<tr>
<td>Italy</td>
<td>Fabio Fiamingo</td>
<td>National Institute for Insurance against Accidents at Work, INAIL</td>
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<tr>
<td>Japan</td>
<td>Kazuo Hiruma</td>
<td>Obayashi Corporation – Mechanical &amp; Electrical Design Department</td>
</tr>
<tr>
<td>Japan</td>
<td>Masaru Ishii</td>
<td>The University of Tokyo</td>
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<tr>
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<td>Mikihisa Saito</td>
<td>The University of Tokyo</td>
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<td>Japan</td>
<td>Misao Kobayashi</td>
<td>Meidensha Corporation</td>
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<tr>
<td>Malaysia</td>
<td>Dalina Johari</td>
<td>Uppsala University - Faculty of Engineering Sciences, Division of Electricity</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Wooi Chin-Leong</td>
<td>Universiti Teknologi Malaysia, UTM-Faculty of Electrical Engineering</td>
</tr>
<tr>
<td>Mongolia</td>
<td>Myagmar Doljinsuren</td>
<td>Institute of Meteorology, Hydrology and Environment</td>
</tr>
<tr>
<td>Poland</td>
<td>Miroslaw Zielenkiewicz</td>
<td>Center of Protection against Overvoltages and Electromagnetic Interferences</td>
</tr>
<tr>
<td>Poland</td>
<td>Tomasz Kisielewicz</td>
<td>Warsaw University of Technology</td>
</tr>
<tr>
<td>Country</td>
<td>Name</td>
<td>Affiliation</td>
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</tr>
<tr>
<td>Portugal</td>
<td>Sandra Correia</td>
<td>The Portuguese Meteorological Institute, IPMA</td>
</tr>
<tr>
<td>Portugal</td>
<td>Fernanda Cruz</td>
<td>Société d'Etudes et de Fabrication des Techniques Industrielles Modernes, SEFTIM</td>
</tr>
<tr>
<td>Russia</td>
<td>Alexander Temnikov</td>
<td>National Research University Moscow Power Engineering Institute, MPEI - Department of Electrophysics and High Voltage Technique</td>
</tr>
<tr>
<td>Russia</td>
<td>Stanislav Sokolov</td>
<td>Moscow Technical University of Communications and Informatics</td>
</tr>
<tr>
<td>South Africa</td>
<td>Estelle Trengove</td>
<td>University of The Witwatersrand – School of Electrical and Information Engineering</td>
</tr>
<tr>
<td>South Africa</td>
<td>Ian Jandrell</td>
<td>University of The Witwatersrand – School of Electrical and Information Engineering</td>
</tr>
<tr>
<td>South Africa</td>
<td>Ryan Blumenthal</td>
<td>University of Pretoria – Department of Forensic Medicine</td>
</tr>
<tr>
<td>Spain</td>
<td>Joan Montanya</td>
<td>Universitat Politècnica de Catalunya, UPC – Department of Electrical Engineering</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>Ashen Gomes</td>
<td>Universiti Putra Malaysia, UPM – Center for Electromagnetic and Lightning Protection</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>Chandima Gomes</td>
<td>Universiti Putra Malaysia, UPM – Center for Electromagnetic and Lightning Protection</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>Lasitha Gunasekara</td>
<td>University of Colombo – Department of Physics</td>
</tr>
</tbody>
</table>
Sri Lanka  Mahendra Fernando  University of Colombo – Department of Physics

Sri Lanka  S.P. Amila Vayanganie  University of Colombo – Department of Physics

Sri Lanka  Sidath Jayalal  University of Colombo – Department of Physics

United Kingdom  Derek Elsom  Oxford Brookes University – Faculty of Humanities and Social Sciences

United States  Earle Williams  Massachusetts Institute of Technology, MIT

United States  Jennifer Morgan  Lightning Safety Alliance Corporation

United States  Mary Ann Cooper  African Centers for Lightning and Electromagnetics Network, ACLENet

United States  Ronald Holle  Holle Meteorology & Photography

Venezuela  Marcos Rubinstein  University of Applied Sciences of Western Switzerland

Venezuela  Yarú Mendez  Universidad Simón Bolívar, USB – Energy Conversion and Transport Department
Appendix 2: Components of LS Comprehensive Programs and Isolated Initiatives

The components of the LS comprehensive programs and the isolated initiatives on the subject, investigated for the development of this project, are listed below.

Table A.2.1. Components of the Lighting Safety Comprehensive Programs

<table>
<thead>
<tr>
<th>Continent</th>
<th>Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acronym</td>
<td>SALAP(^\text{17})</td>
</tr>
<tr>
<td>Countries</td>
<td>Sri Lanka, Bangladesh, Bhutan</td>
</tr>
<tr>
<td>Time</td>
<td>October 2004 - March 2005</td>
</tr>
<tr>
<td>Target population</td>
<td>General public</td>
</tr>
</tbody>
</table>

Justification

Every year, in South Asia more than 500 people die and several thousand encounter injuries of various degrees due to lightning. The damage caused by lighting in the power, communication and industrial sectors and even at domestic level, is over several hundred million dollars per year. Many of the lightning threats can be minimized by giving proper education to engineers, scientists, administrators, and general public regarding the lightning safety culture.

Goals

> To educate the general public and engineering community in South Asia regarding the basics of lightning, lightning related hazards and lightning protection
> To have the lowest possible level of lightning damages in industries, service providing institutions, electronic and electrical storages, power plants, oil refineries, in Bangladesh and Bhutan so that the replacement cost of equipment and downtime losses will be kept at minimum level
> To have a power and communication systems with minimum exposure to lightning threats, so that a reliable and uninterrupted service can be provided to the consumers
> To have a general public, knowledgeable in Lightning protection so that the lightning related human and live stock deaths, injuries and property damages at domestic level etc. will be kept at minimum

Table A.2.1. (Continuation)

| Projects | > Conveying the lightning safety message to the society through the school students. Schoolteachers are also a powerful communication media between the experts and the society. Especially, in rural areas the school teacher plays a vital role in the community and most often takes the leadership in communal programs (Sri Lanka)  
> Developing an inter-disciplinary forum for the education and exchange of knowledge in the latest research and developments in the area related to lightning related atmospheric physics, lightning protection and discharge, in order to promote links and collaborations among the practicing engineers and scientists in the region (Bhutan) |
| Educational methodologies | > Seminars at five school venues with high lightning density (Sri Lanka)  
> Workshops for school teachers and social workers (Bangladesh)  
> Workshop for engineers, teachers and governmental officers (Bhutan) |
| Continent | North-America |
| Acronym | LSW\(^{18}\) |
| Countries | United States |
| Time | 2001 until now |
| Target population | General public |

### Justification

Lightning is one the greatest storm-related threats in the United States. Over the past 30 years, National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS) have documented about 1900 lightning fatalities in the United States based on statistics through 2006. These statistics show that lightning ranks second in terms of storm-related fatalities with only flooding causing more storm-related deaths in the United States. To reduce the number of lightning casualties (deaths and injuries) in this country, NOAA and the NWS have worked to find ways to draw attention to this underrated killer.

### Goals

> The main goal of NOAA's Lightning Safety Awareness effort is to reduce the number of lightning deaths and injuries in the United States  
> To educate and raise awareness about the hazards of lightning in order to lower the number of deaths and injuries caused by lightning strikes  
> To offer insight into the science of lightning

\(^{18}\) Website: [www.lightningsafety.noaa.gov](http://www.lightningsafety.noaa.gov)
Table A.2.1. (Continuation)

<table>
<thead>
<tr>
<th>Projects</th>
<th>&gt; Lightning Safety Week (LSW) occurs annually the last full week of June</th>
</tr>
</thead>
</table>
| Educational methodologies | > LSW website has become the premier lightning safety site with general information, up-to-date injury statistics, games, puzzles, public service announcements as well as special sections for the media, teachers, boaters, and many other interests and concerns  
> LSW materials, reminders and updates have been distributed to the 120 National Weather Service Offices in the United States and to broadcast meteorologists nearly every year since LSW began  
> The LSW core team and others have made themselves available for thousands of interviews with newspapers, radio and television, worked on dozens of documentaries, as well as continuing their own research and publication  
> “Leon, the lightning safety lion”, has become a friendly character useful to teach children what to do when thunder roars |

<table>
<thead>
<tr>
<th>Continent</th>
<th>Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acronym</td>
<td>ACLENt¹⁹</td>
</tr>
<tr>
<td>Countries</td>
<td>All Africa</td>
</tr>
<tr>
<td>Time</td>
<td>February 2014 until now</td>
</tr>
<tr>
<td>Target population</td>
<td>General public</td>
</tr>
</tbody>
</table>

Justification

For the last few years, it has been observed at the African Centres for Lightning and Electromagnetics Network (ACLENet) that the number of lightning deaths and injuries across Africa is overwhelmingly high compared to the USA, Europe and other ‘developed’ countries and even when compared to other high lightning density countries like Malaysia and Singapore. While phrases such as “When Thunder Roars, Go Indoors” may be effective in developed countries where there are substantial and generally safe buildings, 90% of sub-Saharan buildings are not lightning safe. In fact, research shows that the majority of multiple death reports in Africa involve people seeking shelter in the “permanent structures” available in their communities.

¹⁹ Website: [www.aclenet.org](http://www.aclenet.org)
Table A.2.1. (Continuation)

<table>
<thead>
<tr>
<th>Goals</th>
<th>Projects</th>
<th>Educational methodologies</th>
</tr>
</thead>
</table>
| > To support national lightning centers in Africa in capacity building by transfer of knowledge, development of skills, training of educators, exchange of students and experts, channeling of possible funding, and providing required technical facilities and other assistance  
> To establish a strong research team to work on meteorological, physics, engineering, health, societal and other aspects of lightning with scientific output of international standing  
> To develop a robust African regional lightning safety awareness promotion network penetrating into remote rural areas  
> To advocate for the installation of national and regional lightning detection and warning systems and to encourage sharing of data between all involved African communities  
> To train engineers and technical personnel in scientifically accepted lightning protection systems with emphasis on low-cost solutions and to form a regional network of experts  
> To develop a lightning database including information on fatalities and statistics in the region  
> To commit itself to fulfill various other objectives included in the Colombo Declaration (24 May 2007), Kathmandu Resolution (14 October 2011), and Kampala Resolution (7 February 2013) on Lightning Protection and Safety that were endorsed by participating international stakeholders | > Lightning Detection  
> Research  
> Education  
> Awareness and prevention - Working with teachers and students to spread lightning safety information, form weather clubs, etc  
> Lightning Protection - Design of Lightning Protection Systems (LPS) for each school  
> Save a Life in Africa – Fundraising  
> Lake Victoria Early Warning Project | > Training (formal technical training, workshops, seminars)  
> Site surveys of the schools  
> Booklets  
> Graduate education in lightning physics and other technical areas to train Africa’s own experts has begun |
Table A.2.2. Components of the Lighting Safety Isolated Initiatives

<table>
<thead>
<tr>
<th>Continent</th>
<th>North-America</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>National Collegiate Athletic Association (NCAA) 20</td>
</tr>
<tr>
<td>Target population</td>
<td>Those involved in athletics and recreation</td>
</tr>
<tr>
<td>Goal</td>
<td>To supply specific information to lightning safety and prevention and treatment of lightning injury and provide lightning-safety recommendations for the certified athletic trainer and those who are involved in athletics and recreation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Educational methodologies</th>
<th>Website</th>
<th>Guidelines</th>
<th>Articles</th>
<th>Book sections</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Lightning Protection Institute (LPI) 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target population</td>
<td>Professionals, consumers and general public</td>
</tr>
<tr>
<td>Goals</td>
<td>&gt; To promote lightning protection education, awareness and safety</td>
</tr>
<tr>
<td></td>
<td>&gt; To expand information to potential consumers/users aggressively and offer member support services to further this effort</td>
</tr>
<tr>
<td></td>
<td>&gt; To become the leading authority on safety through complete lightning protection systems in the construction marketplace</td>
</tr>
<tr>
<td></td>
<td>&gt; To expand the size of the lightning protection market through education, additional specifications, and member revenues</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Educational methodologies</th>
<th>Website</th>
<th>Guidelines</th>
<th>Videos</th>
<th>Leaflets</th>
<th>Scientific papers</th>
<th>Consultancy</th>
</tr>
</thead>
</table>

21 Website: [www.lightning.org](http://www.lightning.org)
Table A.2.2. (Continuation)

<table>
<thead>
<tr>
<th>Name</th>
<th>National Lightning Safety Institute (NLSI)(^{22})</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target population</strong></td>
<td>Professionals, researchers and general public</td>
</tr>
</tbody>
</table>
| **Goals** | > To promote, through education, lightning safety for the public good  
> To provide forums through which the principles and techniques of lightning safety may be reported, discussed, and published  
> To provide a bridge from professional researchers to those who need objective information about lightning safety  
> To establish specific audit and certification protocols, as well as engineering site survey programs, to improve lightning safety where needed  
> To encourage the inclusion of lightning safety information in the technical curricula of schools  
> To cooperate with national and international organizations having common or related objectives |
| **Educational methodologies** | > Website  
> Consultancy  
> Training  
> Technical reports  
> Books |

<table>
<thead>
<tr>
<th>Name</th>
<th>National Fire Protection Association (NFPA)(^{23})</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target population</strong></td>
<td>Firefighters and general public</td>
</tr>
<tr>
<td><strong>Goal</strong></td>
<td>To teach how to keep people and their families safe when storms strike</td>
</tr>
</tbody>
</table>
| **Educational methodologies** | > Website  
> Reports  
> Guidelines |

\(^{22}\) Website: [www.lightningsafety.com](http://www.lightningsafety.com)  
Table A.2.2. (Continuation)

<table>
<thead>
<tr>
<th>Name</th>
<th>Struck by Lightning Organization&lt;sup&gt;24&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target population</strong></td>
<td>General public</td>
</tr>
</tbody>
</table>
| **Goals**                      | > To promote lightning and electrical safety education  
                                  > To make the slogan "When Thunders Roars Go Indoors" as effective for lightning safety as "Stop Drop and Roll" is for fire safety  
                                  > To provide Safety Magnets to every elementary school child in the country |
| **Educational methodologies**  | > Website  
                                  > Consultancy  
                                  > Strike database  
                                  > Strike statistics  
                                  > Interviews  
                                  > Videos  
                                  > Magnets related to lightning safety |

<table>
<thead>
<tr>
<th>Name</th>
<th>Environment and Climate Change&lt;sup&gt;25&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target population</strong></td>
<td>General public</td>
</tr>
<tr>
<td><strong>Goal</strong></td>
<td>To keep people informed about lightning and its dangers, as well as to predict when and where lightning will strike</td>
</tr>
</tbody>
</table>
| **Educational methodologies**  | > Website  
                                  > Guidelines  
                                  > Lightning danger map  
                                  > Official videos  
                                  > Quizzes  
                                  > Technical documents |

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<sup>24</sup> Website: www.struckbylightning.org
<sup>25</sup> Website: www.ec.gc.ca/foudre-lightning
### Table A.2.2. (Continuation)

<table>
<thead>
<tr>
<th>Continent</th>
<th>Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Lightning Awareness Research Centre (LARC)\textsuperscript{26}</td>
</tr>
<tr>
<td>Target population</td>
<td>Researchers and general public</td>
</tr>
</tbody>
</table>
| Goals | > To disseminate information on lightning safety among public so that precious lives and property can be protected  
> To train various stakeholders on latest technologies and protection systems for lightning safety  
> To ensure that lightning protection devices marketed in the country comply with the prescribed standards  
> To offer policy and technical advice in the areas related to lightning  
> To encourage inclusion of lightning safety information in the curricula of schools, IEC activities of all concerned organizations  
> To cooperate and network with national and international organizations having similar objectives |
| Educational methodologies | > Website  
> Classes, seminars, training programmes and workshops  
> Consultation, and inspection services  
> Publishing books, posters, pamphlets and documentaries on lightning related subjects |

<table>
<thead>
<tr>
<th>Continent</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Royal Society for the Prevention of Accidents (ROSPA)\textsuperscript{27}</td>
</tr>
<tr>
<td>Target population</td>
<td>Educational Sector and general public</td>
</tr>
<tr>
<td>Goal</td>
<td>To provide safety risk education to cover the needs of the education sector and general public</td>
</tr>
</tbody>
</table>
| Educational methodologies | > Website  
> Safety education consultancy  
> Guidelines |

\textsuperscript{26} Website: [www.cissa.co.in/activities/projects/lightning-protection](http://www.cissa.co.in/activities/projects/lightning-protection)  
\textsuperscript{27} Website: [www.rospa.com/leisure-safety/advice/lightning](http://www.rospa.com/leisure-safety/advice/lightning)
Table A.2.2. (Continuation)

<table>
<thead>
<tr>
<th>Name</th>
<th>British Mountaineering Council (BMC)(^{28})</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target population</strong></td>
<td>Hill climbers</td>
</tr>
<tr>
<td><strong>Goal</strong></td>
<td>To provide information regarding lightning to climbers, hill walkers and mountaineers</td>
</tr>
<tr>
<td><strong>Educational methodologies</strong></td>
<td>&gt;Website</td>
</tr>
<tr>
<td></td>
<td>&gt;Guidelines</td>
</tr>
</tbody>
</table>

\(^{28}\) Website: [www.thebmc.co.uk/search?q=lightning](http://www.thebmc.co.uk/search?q=lightning)
Appendix 3: News of Lightning Injuries

The news\textsuperscript{29} of lightning-related casualties referenced in chapter 2 are available in this Appendix.

1 \textbf{04/08/2011 – Marialabaja/Bolivar}

At 3:00pm, a woman was in her house while it was raining and received a strong electric shock when lightning struck her house. People said the woman was leaning back on the kitchen wall when she received the discharge. The electric shock burned her left arm and affected her heart. (Primary Source: "Un rayo la mató", ElUniversal.com, August 06, 2011)

2 \textbf{04/09/2011–San Juan de Acosta/Atlántico}

A 30-year-old lifeguard was struck by lightning when he was asking some swimmers to leave the beaches because of a strong electric storm in Turipaná, Juan de Acosta municipality, Atlántico. Unfortunately, three people were injured and he was killed as he was getting people to leave the water. (Primary Source: "Rayo mata a salvavidas en San Juan de Acosta, Atlántico", ElUniversal.com, September 04, 2011)

3 \textbf{21/03/2012 - San Andrés de Sotavento/Córdoba}

A 35-year-old woman, identified as Nélfina del Carmen Suárez Baltasar, and her children of 7 and 12 years old respectively, belonging to the Zenú ethnicity, were injured by lightning in the Arroyo de Piedra’s district in San Andrés de Sotavento. The family said the tragedy occurred as a heavy downpour fell, the first recorded during this year in that area. The woman and the children were attempting to collect water, because of the lack of water in the zone from the prolonged drought. The downpour

\textsuperscript{29} Most of the news were found through the website www.lesionesxrayos.com
came with thunderstorms and lightning struck the family’s home, reaching the three family’s members. Her husband received the discharge too and lost consciousness. To save his life, his neighbors, using the Zenú culture beliefs, buried the man in his home’s backyard, leaving just his head above the surface, at which point he began to revive. The family’s members were crafters who manufactured the Sombrero Fino Vueltiao. (Primary Source: “Rayo mató a mujer y a dos de sus hijos, en San Andrés de Sotavento”, ElTiempo.com, March 22, 2012)

4 21/03/2012 – Málaga/Santander

A 52-year-old man and his 8-year-old son suffered acoustic trauma and nervous breakdown on Wednesday at 7:30 pm when lightning fell near to their house, in the Chingará district, located at kilometer six of the road to Málaga. "At the time of the storm we were in the kitchen when we saw a spark, everything was lit and then everything went dark. In a matter of seconds, I realized my husband and my son were lying on the floor", said Rosa Elena Ramírez. The Anaya Ramírez family were injured by one of many lightning strikes that shook Piedecuesta Wednesday night, and also caused several trees to fall the destruction of dozens of roofs. "I helped them but I did not really know what to do because they cried a lot and said they felt a current circulating all over their bodies and also they had tachycardia and headache. So, I gave them an acetaminophen and called my sisters to send the Piedecuesta’s firefighters", reported by Rosa Elena. As there was no time to lose, father and son were transported in a local vehicle that took them to the main road where they met the ambulance that finally transferred the wounded to the Local Hospital of Piedecuesta. (Primary Source: “Fuera de peligro padre e hijo afectados por un rayo”, Vanguardia.com, March 23, 2012)

5 21/03/2012 – Sincelejo/Sucre

In the Babylonia district, province of Sincelejo, lightning killed Onalvis Velásquez Lidueña, 22 years old, as he fixed a canal so that the rain would not penetrate his house. According to his family, at 4:00pm on Wednesday, before the first downpour of the year fell, the young man was tying the canal with some bejucos when the electric discharge reached him and took his life away. Another person that was near that place was also affected and had severe headaches and pain in its extremities. (Primary Source: “Muere joven campesino alcanzado por un rayo en Sincelejo”, El Heraldo.co, March 22, 2012)
6 30/03/2012 – Manizales/Caldas

A fire that was recorded at 2:16 am today affected three families. The flames consumed two houses and left another partially affected. The people who were affected said no one was wounded because there were no people in the houses at that time, and people in the third house managed to escape in time. The stories told by those affected indicate that lightning caused the fires. (Primary Source: “Tres familias afectadas por incendio en el barrio Bajo Andes, en Manizales”, LaPatria.com, March 30, 2012)

7 03/04/2012 – Candelaria/Atlántico

A 22-year-old man named Marco Aurelio Guzmán González was identified as the man killed Tuesday night by lightning when he was moving cattle. When he did not return home, his family went to look for him, worried for his safety because of the strong thunderstorm. When they arrived to the place, they found Marcus Aurelius had been struck by lightning. (Primary Source: “Rayo mata a joven en Candelaria, Atlántico”, ElColombiano.com, April 05, 2012)

8 05/04/2012 – San Benito Abad/Sucre

A person died and another was injured yesterday afternoon when lightning struck the place where they were near Ciénaga de Machado’s, a few meters to the urban side of this locality. The victim was identified as Julio César Herrera Peñate, 32 years old, who died instantly. His girlfriend was also injured and transported to the Hospital Universitario de Sincelejo. Witnesses said that Herrera Peñate was in the place named as El Puerto, a tourist place of San Benito, taking photos of his girlfriend with a cellphone at the time. (Primary Source: “Muere hombre al que le cayó un rayo”, ElHeraldo.co, April 06, 2012)

9 10/04/2012 Villavicencio/Meta

Rescue teams reported overflow of the Parrado Spout, Maizaro Spout, and Guatiquía River due to a strong downpour from the storm last night, leaving several families affected. The affected sectors are Galán, where 14 persons were evacuated and accommodated in a sports center, and Brisas del Guatiquía, Lambada, all on the right part of the Guatiquía River. The SENA young watchman, Juan Carlos Rodríguez, received the electric discharge and was moved to a Care Centre. (Source: “Un celador result afectado por un rayo”, Lesionesxrayos, April 11, 2012)
10 11/04/2012 - Armenia/Quindío

A 19-year-old student of the Agroindustrial Engineering program at Quindío University, Armenia, suffered burns when she was injured by lightning. The student was walking by the University as it was raining during the thunderstorm, Wednesday afternoon, which occurred in several sectors of the Eje Cafetero. (Primary Source: “Un rayo le ocasionó quemaduras a un joven en Armenia”, ElTiempo.com, April 11, 2012)

11 13/04/2012 - Caldono/Cauca

Five soldiers were struck by a lightning that fell on a military base in Caldono municipality, in the middle east of the Cauca. One of the affected was admitted to a care center of Popayán with injuries in different parts of the body. The natural phenomenon was produced by storms with electric discharges, because of the strong winter. (Source: “Rayo hirió a cinco soldados en Caldono, Cauca”, LesionesxRayos, April 17, 2012)

12 16/04/2012 - Apía/Risaralda

On Monday afternoon, José Octavio Largo Jaramillo passed away while he was working in the rural zone of Apia town. According to his co-workers, his death happened in the middle of a thunderstorm that affected several towns of Risaralda. His co-workers ran looking for refuge, but it seems he did not do the same and was struck by lightning that ended his life at 72 years of age. His body was found hours later at his workplace and, according to the story, he had multiple burns that caused his death. (Primary Source: “Rayo terminó con la vida de campesino en Apía”, ElDiario.com.co, April 17, 2012)

13 16/04/2012 - Salento/Quindío

A thunderstorm occurred yesterday afternoon in the rural zone of Salento municipality. Initially two brothers lost their lives when they were struck by lightning in the sector known as Los Pinos at the entrance to the Quindian locality. The victims were identified as Jhon Alexánder Daza Arévalo, 24 years old, and Fabio Andrés, 25 years old. Miraculously, a cousin who accompanied them and another citizen were left unharmed and told of the minutes of anguish that they lived through. In a separate incident, Camilo Giraldo, 81 years old, and Julián Rojas, 51 years old, were walking next to a mare carrying canteens with milk when lightning struck them. Although this, they survived. (Primary Source: “Dos hermanos murieron por el impacto de un rayo en el Quindío”, CronicaDelQuindio.com, April 17, 2012)
14 20/04/2012 – Bogotá/Colombia

Luis Antonio Anaya, 36 year old, and his 58-year-old co-worker Victor Manuel Suarez, were struck by lightning when they were working in the Inmaculada Cemetery, located in the north of the capital. The first died and the second was injured. Because of the downpour, they found a tree to shelter themselves from getting wet, when suddenly they received a lightning strike. The survivor is currently in the hospital recovering from his injuries. (Source: “Caída de rayo deja un muerto y un herido en cementerio del norte de Bogotá”, LesionesxRayos, April 20, 2012)

15 20/04/2012 – Coromoro/Santander

On April 20, around 4:50pm, in Mina district, Mango farm, Comoro municipality, a 14-year-old minor, identified as Danilo Miranda Orozco, died when he was looking for a shelter in the corridor of his house because of the downpour. His father Arselino Miranda, who was with him at the time, said lightning struck his leg where he was carrying a cell phone. (Primary Source: “Falleció un joven al ser alcanzado por un rayo”, Vanguardia.com, April 22, 2012)

16 21/04/2012 – Pueblo Nuevo/Córdoba

Previecto Berrío Gómez, a natural farmer from Tierralta and a resident in the Limón village, Jurisdiction of the Pueblo Nuevo municipality, died as a consequence of lightning that struck him last Saturday. The injury occurred while Berrío Gómez worked in the middle of a light drizzle. His death was instantaneous. (Source: “Un rayo fulminó a un campesino”, LesionesxRayos, April 30, 2012)

17 23/04/2012 – Campamento/Antioquia

Three soldiers were injured when lightning struck the military base located in the Los Chorros, district of Campamento municipality. The soldiers were serving guard duty in the facilities of the battalion when a downpour began to occur and lightning suddenly fell upon them. They suffered second-degree and third-degree burns. (Source: “Tres soldados resultaron heridos por un rayo”, Lesionesxrayos, April 23, 2012)

18 23/04/2012 – Pamplona/Norte de Santander

A strong storm occurred in the late hours, in the Belial district of Laureano Gómez village, a rural zone of Pamplona municipality, as peasants walked to start their daily
work and were struck by lightning. The victims were identified as Humberto Parra Peláez and his children Víctor and Aníbal Parra. All of them suffered injuries and burns on different parts of their bodies. The father died and the children are being taken care of in San Juan de Dios hospital, in Pamplona. (Source: “Un campesino murió y sus dos hijos resultaron heridos por una descarga eléctrica”, LesionesxRayos, April 23, 2012)

19 26/04/2012 – Sincelejo/Sucre

A housewife was struck by lightning when a strong downpour was falling during thunderstorms last Tuesday. Noralba Taboada Montes, 45 years old, was in the kitchen when everything happened. At the same time, the lightning killed two pigs that the woman had in her backyard, located in the Corazón de Jesús neighborhood. At that moment, she was preparing a salad for the dinner with a steel knife, which apparently attracted the energy generated by the lightning. (Primary Source: “Colombia: Rayo mandó a mujer al hospital y mató dos cerdos”, ELUniversal.com.co, April 26, 2012)

20 26/04/2012 – Santa Rosa/Bolívar

During a strong downpour, accompanied by thunderstorms, a 21-year-old soldier named Luis Castaño Legua, belonging to the Second Army Brigade, was injured by a lightning that fell a few meters from where he was. The natural phenomenon was registered yesterday at 10:00 am. (Primary Source: “Herido soldado al que le cayó cerca un rayo”, ElHeraldo.co, April 27, 2012)

21 07/05/2012 – Magangué/Bolivar

Lightning caused burns in the right arm of an 18-year-old young man identified as Carlos Alfredo Salgado Castañeda, and to three team members who were playing soccer. (Source: “Rayo causó muerte a un hombre e hirió 4 jóvenes en eventos diferentes”, LesionesxRayos, May 11, 2012)

22 17/05/2012 – Armenia/Quindío

A 46-year-old man was injured by lightning while he was riding a horse during his work. The animal died. The injury occurred in the rural zone of the Armenia municipality. He was moved to Bogotá. (Primary Source: “Herido por rayo”, Lesionesxrayos, May 17, 2012)
23 18/05/2012 – San Benito Abad/Sucre

A fisherman died when lightning struck during a thunderstorm in El Cauchal district, a rural zone of San Benito Abad municipality. The victim, 31 years old, was identified as Santander Manuel Valerio Rodríguez. Santander Manuel had picked up his fishing net that served to gain sustenance for him and his family as usual. Valerio Rodríguez was killed as he was looking for a co-worker. To shelter for the rain, he took himself to an abandoned hut near the river, when lightning struck him, killing him instantly. (Primary Source: “Rayo mató a un pescador en Sucre”, ElUniversal.com.co, May 19, 2012)

24 19/05/2012 – Florida/Cauca

A 22 years-old sportswoman identified as Marcela Sandoval Bedoya died when lightning struck her while she was playing a friendly soccer match in Corinto, Cauca. The incident occurred last Saturday at 4:40 pm, according to her family. The young woman was the goalkeeper. (Primary Source: “Joven deportista murió al ser alcanzada por un rayo cuando jugaba un partido”, ElPais.com.co, May 23, 2012)

25 21/05/2012 – Samaná/Caldas

A thunderstorm approached an Army company performing military operations in the rural zone of Berlín de Samaná village, Caldas. Lightning struck a soldier identified as Hugo Andrés Toro Hurtado, 18 years old, apparently causing a cardiac arrest that killed him. (Source: “Un rayo ocasionó la muerte de un soldado en Samaná, Caldas”, Lesionesxrayos, May 21, 2012)

26 31/05/2012 – Rioacha/La Guajira

A 40-year-old man identified as Jairo Mendoza Tabarcas was struck by lightning and died while working with livestock in La Finquita, a country estate located in south zone in the Cotoprix village. Witnesses said that there was sun and it was not raining at the time. Jairo Mendoza had decided to take his horse and work with the livestock, when lightning surprised him in the middle of a field and finished with his and the horse’s life, too. (Primary Source: “Rayo seco mató un campesino y el caballo en que se desplazaba en La Guajira”, Caracol Radio, May 31, 2012)
**27 02/06/2012 – Tierralta/Córdoba**

Lightning killed twenty-three calves between 7 and 9 months old at a farm in Tierralta Township. The animals were together under a tree, when they were surprised by the electric shock that killed them. It was 9:30 p.m. when the storm started with lightning in Tierralta. The owner of the farm said that the economic loss was around 7,500 USD. (Primary Source: “Un rayo mató a 23 animales en Córdoba”, ElUniversal.com.co, June 06, 2012)

**28 26/06/2012 – Cajibío/Cauca**

Lightning finished the life of a soldier in El Carmelo village, a rural zone of Cajibío municipality. The natural phenomenon produced a strong hailstorm. Three other soldiers were injured in the same place. (Source: “Soldado murió por un rayo, otros tres uniformados están heridos” Lesionesxrayos, January 17, 2013)

**29 30/06/2012 – Juan de Acosta/Atlántico**

The thunderstorm that hit last Saturday in the Atlántico coastal zone left one dead and two injured at a shack of the Santa Verónica village. Jorge Hasbún Lombana, owner of the property, was killed while a worker and another person who was at that moment visiting the place were injured. (Primary Source: “Un muerto y dos heridos por rayo en cabaña en Santa Verónica”, ElHeraldo.co, July 01, 2012)

**30 22/07/2012 – Tarazá/Antioquia**

On July 22, in the Alto del Loro state, one man and one woman died in the middle of a thunderstorm while they were installing an antenna to listen to the radio. (Primary Source: “Este martes sepultan en Medellín a soldado muerto por un rayo”, ElColombiano.com, October 01, 2012)

**31 18/08/2012 – El Bongo/Sucre**

The 17-year-old young woman Karen Alexandra Polo Avila died yesterday afternoon after being struck by lightning when it was raining in the municipality. Around 2:00 pm, the young woman, who did not go to the Santa Clara school where she was in 9th grade, was with her family washing the clothes on a dam, located in Bongo village. When lightning struck her body, she received help by her family who buried half of her body in the ground. An hour later, she was taken out of the hole and taken to the Local
Hospital where she arrived without any vital signs. The young woman lived in El Porvenir neighborhood with her parents Róger and Piedad. (Source: “La mató un rayo”, LesionesxRayos, September 06, 2012)

32 20/08/2012 – Marialabaja/Bolivar

At 5:30 p.m., a 19-year-old man crossed the soccer field of San Pablo Township, Bolivar, during a heavy rain. At that moment, lightning struck him. He was waiting next to the field to start the match in which he would play that had been postponed due to rain. After he decided to return home by crossing the field and received the discharge. (Primary Source: "Le cae un rayo y lo mata", ElUniversal.com.co, August 22, 2012)

33 23/08/2012 – Sardinata/ Norte de Santander

The peasant soldier named Carlos Andrés Arévalo Sánchez, 24 years old, died when lightning struck him in La Victoria village. This occurred on Wednesday afternoon at 5:00 pm, when the soldier, belonging to the 30th Army Brigade, was watching over the area where it was raining heavily. (Source: “Un rayo mató a un soldado campesino. Sardinata. Santander”, LesionesxRayos, January 18, 2013)

34 26/08/2012 – Magangué/Bolívar

The broadcaster of the community radio station of Las Brisas village, a Magangué jurisdiction, was seriously injured and suffered burns in several parts of his body when a lightning strike destroyed all his work team and a part of his house. The injured was identified as Ivan Benavides Díaz, 31 years old. The event occurred around at 9.30 am when a strong breeze knocked down the antenna of the Internet service of the village. Apparently, the lightning got inside in the home of the victim through the speaker and ended up in the room where Benavides Díaz was in company with his mother, wife, and children. Two of his children suffered burns on their legs. (Source: “Herido por un rayo locutor en Las Brisas”, LesionesxRayos, August 31, 2012)

35 22/08/2012 – Guaranda/Sucre

A one-year-old child, member of the Martínez Escobar family, died when he was struck by lightning during a storm Wednesday night. The little child was sleeping on the same bed with his parents Enrique Martínez and Yajaira Sofía Escobar, and with his siblings too, when the electric discharge fell just in the space where they were occupied. The adults suffered second-degree and third-degree burns. The woman lost consciousness,
and those who helped her dug a hole and buried her in the ground for one hour to de-
energize her. (Primary Source: “Rayo mató a un niño”, ElMeridianoDeCordoba.com.co, August 23, 2012)

36 31/08/2012 - Tuluá/Valle del Cauca

Edir Ledis Jaramillo, 32 years old, died on Friday afternoon last week in La Mina village. Some people said that around 4:00 pm, lightning fell over the house where she was along with her children, and she received the electric discharge. (Source: “Muere por un rayo”, Lesionesxrayos, August 31, 2012)

37 08/09/2012 - Baranoa/Atlántico

A young player died after being struck by lightning while playing a soccer game in Baranoa Township, Atlántico. According to his colleagues, he was carrying the ball when he received the discharge that killed him instantly. Witnesses said that it was raining and thundering, but the referee apparently did not see any danger and decided to start the match. After ten minutes of playing, the young player took the ball and moved it some meters. He was alone at the time of the discharge. (Primary Source: “Muere joven futbolista impactado por un rayo en Atlántico”, ElUniversal.com.co, September 08, 2012)

38 23/09/2012 - Sucre

In yesterday morning, around 1:00 pm, lightning almost kill a 24-year-old young man, Héctor Ballesteros Camargo, when he was with his friends having a good time. A familiar said he was celebrating the Happy Valentine’s Day and, when it started to rain, they stayed outside where they were drinking. Suddenly, lightning struck him and he lost consciousness, but he survived. (Source: “Rayo casi lo mata”, LesionesxRayos, January 18, 2013)

39 29/09/2012 - Anorí/Antioquia

A soldier died and another was injured when lightning struck them in the Montefrío district, Anorí municipality. The soldier was identified as Brayan Stiven Ossa Guerra, 19 years old. The soldier was sleeping last Saturday night in a camp when he was surprised by the natural phenomenon. (Primary Source: “Este martes sepultan en Medellín a soldado muerto por un rayo”, ElColombiano.com, October 01, 2012)
40 02/10/2012 – Pueblo Bello/Cesar

A farmer died after receiving an electric discharge from lightning. He was identified as Remberto Vanegas Alfaro, 21 years old, a resident in Chimichagua, Cesar. According to his co-worker, the victim was washing his hands after working all day harvesting coffee in Pueblo Bello municipality. (Source: “Joven murió por descarga de un rayo”, Lesionesxrayos, January 13, 2013)

41 05/10/2012 – Barrancabermeja/Santander

A 28-years-old fisherman, identified as Leonardo Pineda Cárdenas, died at the Magdalena River after receiving an electric discharge produced by lightning, in the middle of a storm. (Primary Source: "Muere pescador tras ser alcanzado por un rayo" Vanguardia.com, October 06, 2012)

42 05/10/2012 – Canalete/Córdoba

A coffee collector, from Canalete municipality, died because of lightning. He was identified as Lorenzo Pérez. It was midday when a storm began. Lightning killed him instantaneously. (Primary Source: “Una descarga fulminante”, ElMeridianoDeCordoba.com.co, October 06, 2012)

43 09/10/2012 – Suaita/Santander

Lightning fell on Tuesday night in the Vado Real village, Suaita, and struck a young man of 17 years-old and his mother when they were on the kitchen in their farm. (Primary Source: "Rayo alcanzó a madre e hijo en el municipio de Suaita", Vanguardia.com, October 12, 2012)

44 09/10/2012 – Buenaventura/Valle del Cauca

Lightning killed instantly a man who was working as woodcutter during the middle of a storm. A friend who was with him was seriously injured and was moved to the hospital of Buenaventura. The incident was registered on La Guarapera Street, Alberto Lleras Camargo neighborhood. (Source: “Lo ‘partió’ un rayo”, Lesionesxrayos, January 18, 2013)
45 12/10/2012 - Ibagué/Tolima

Three people were injured in the town center of Ibagué, when lightning fell near to a home in the city. One of the injured was a child, 12 years old, who was taken to a hospital. Two relatives were injured as well. (Source: “Tres heridos por caída de un rayo en Ibagué”, Lesionesxrayos, November 29, 2012)

46 12/10/2012 - San Andrés de Sotavento/Córdoba

An indigenous woman died when lightning struck her. She was identified as Doris Isabel Teherán Rosario, 17 years old. (Source: “Un rayo mató a una indigena en San Andres de Sotavento”, Lesionesxrayos, January 17, 2013)

47 12/10/2012 - El Doncello/Caquetá

A 22-year-old woman, identified as Marly Yuneidy Salamanca Molina, died in the rural zone of El Doncello, after lightning struck her. Apparently, the discharge was attracted by a radio antenna. People said she was listening to music when the lightning went down the antenna, reached her and threw her on the floor. (Source: “Tormenta eléctrica mató a joven mujer”, Lesionesxrayos, January 18, 2013)

48 18/10/2012 - Bogotá/Cundinamarca

A couple who were burned after lightning hit the roof of their home in Bosa, Bogotá, are no longer in danger, according to Fernando Fernández, head of the Simón Bolívar Hospital burn unit. (Primary Source: “Fuera de peligro dos personas quemadas por un rayo en Bogotá”, Vanguardia.com, October 18, 2012)

49 18/10/2012 - Puerto Lleras/Meta

Last Thursday, lightning ended a peasant's life from Puerto Lleras municipality. The incident occurred when a man identified as Napoleón Cerquera Rodríguez was working on a farm. Cerquera was with his son when they saw the storm coming and decided to seek refuge under a roof. Unfortunately, the lightning fell over them causing Cerquera’s death and injuries to his son. (Source: “Campesino murió electrocutado por un rayo”, Lesionesxrayos, January 18, 2013)
50 02/11/2012 – Tambo/Cauca

A man around 60 years old lost his life after being struck by lightning. This tragedy occurred around 5:00 pm on Friday, when the victim was at Cascajal, Los Anayes’s, rural zone of Tambo municipality. (Source: “Un rayo mató a un campesino en El Tambo, Cauca”, Lesionesxrayos, November 29, 2012)

51 15/11/2012 – Angelópolis/Antioquia

Because of a strong downpour, Julián Adolfo Rendón, 23 years old, decided to seek shelter under a tree while he was riding a bike going back home; minutes later he received an electric discharge that finished his life. (Primary Source: “Murió un joven al caerle un rayo en Angelópolis, Antioquia”, Caracol Radio, November 15, 2012)

52 04/12/2012 – Pereira/Risaralda

After working all afternoon in a house of Los Molinos neighborhood, Carlos Arturo Zapata, 36 years old, decided to get down of the roof to continue with other works. However before he could touch the floor, he was struck by lightning and fell from three meters high. (Primary Source: “Un rayo acabó con la vida de “Arturito””, ElDiario.com.co, December 05, 2012)

53 06/12/2012 – Bogotá/Cundinamarca

A patient was in a guardhouse when lightning fell over it, damaging the radio and television, but did not suffer severe injuries. (Primary Source: “Herido por rayo vigilante”, Lesionesxrayos, January 18, 2013)

54 16/01/2013 – Cucaita/Boyacá

Germán Enrique Vanegas, 37 years old, decided to seek refuge from a downpour under a tree, minutes later he received an electric discharge that ended his life. The incident occurred in Chipacata district of Cucaita municipality, when the peasant, who was going to his home, was struck by lightning. (Primary Source: “Una descarga eléctrica deja una persona muerta en Boyacá”, Caracol Radio, January 17, 2013)
Lightning killed a couple identified as Aurelio Ballén and Graciela Rodríguez, when they were working on harvest at Faracía district. (Source: “Un rayo mató a una pareja”, Lesionesxrayos, 2013)

One worker died and another was injured when lightning fell on the Palmera Macondo farm, located in the rural zone of Mapiripan. The dead person was identified as Fredy Parra Cuartas, 31 years old, and the injured as Orlano Moreno Ramírez, 27 years old. (Source: “Un obrero muerto y otro herido por caída de un rayo”, Lesionesxrayos, 2013)

One little girl died and three were injured when lightning fell in La Colinita neighborhood, causing the death to Sandra Janeth Román, 11 years old of age, and wounds to the other three kids. This occurred while it was not raining; it was a ‘dry lightning’. (Primary Source: “No es necesaria la lluvia para que caigan los rayos”, ElColombiano.com, 2013)

Although they originally thought an explosive device killed a soldier and injured 10 more, after investigating, they found it was from lightning. The event occurred in the rural zone of Morales Cauca, Danubio district. (Primary Source: “Rayo mató a soldado e hirió a diez más”, Noticias Caracol, March 18, 2013)

Lightning struck Carlos Andrés Rincón Patiño, who was returning to his house. The incident was registered in the Pedregal Bajo district. (Primary Source: “Un hombre murió al ser alcanzado por un rayo”, Excelsio.net, March 20, 2013)

Three soldiers died and six more were injured by lightning in La Vega, Cauca, while performing offensive operations at 3:00am. (Primary Source: “Rayo mata a tres militares en Cauca”, Noticias Caracol, March 21, 2013)
61 21/03/2013 – Inírida/Guainía

A gale accompanied by a thunderstorm killed an indigenous, 23 years old, in Inírida, Guainia. (Source: “Murió indígena, victima de un rayo”, Source: Lesionesxrayos, 2013)

62 22/03/2013 – Fuentedeoro/Meta

A man died in La Luna district, Fuentedeoro municipality, near to San Martín, Meta, when he was carrying a motor to fumigate. He was identified as Avelino Bermúdez Tunjano. (Primary Source: “Un hombre murió electrocutado por un rayo”, ReporteroDeLosHechos.com, March 26, 2013)

63 04/04/2013 – Morales/Cauca

A peasant, David Zambrano, died as a consequence of lightning in the San Isidro de Morales district, Cauca. An engineer of the IDEAM recommends lying on the floor to avoid being injured by lightning. (Primary Source: “Rayos han causado seis muertes en menos de un mes”, Noticias Caracol, April 04, 2013)

64 17/04/2013 – Piendamó/Cauca

Two women were injured by lightning that was registered Wednesday afeternoon in Piendamó, when lightning fell on the home of Marisol and Geraldine, 25 and 60 years old. (Source: “Dos heridos por la caída de un rayo en Piendamó”, Lesionesxrayos, 2013)

65 28/04/2013 – Bogotá/Cundinamarca

A 42-year-old man was hurt in Bogotá by lightning. He needed to be transferred to Simón Bolívar Hospital burn unit. (Primary Source: “Lesionado por rayo en Bogotá”, Lesionesxrayos, 2013)

66 29/04/2013 Vergara/Cundinamarca

A 41-year-old woman was hurt by lightning in Vergara, Cundinamarca. She needed to be transferred to Bogotá to Simón Bolívar Hospital burn unit. (Primary Source: “Mujer de 41 años lesionada por rayo”, Lesionesxrayos, 2013)
67 05/05/2013 - Líbano/Tolima

One man died and one was injured by a lightning strike in Tolima. The incident took place when the couple sought shelter under a tree at a park in El Líbano municipality. (Primary Source: “Un muerto y un herido por caída de rayo en Tolima”, Noticias Caracol, May 05, 2013)

68 20/05/2013 - Barrancas/Guajira

Jesús Baños Gutierrez died when he was struck by lightning. The 33-year-old bricklayer, originally from Sandoval (Bolívar) and residing in the El Pilar neighborhood of Barrancas since five years ago, lost his life instantly as he was picking up clothes he had hung in the backyard of his house. According to the acquaintances of 'Chu', as he was known, the man went out to pick up the clothes shortly after a strong storm raged, ignoring the advice of one of his friends. He threw himself into the yard in the rain, his cell phone lit up in one of his pockets, which made the dangerous element of nature fall upon his humanity. He was immediately taken to the Nuestra Señora del Pilar Hospital, where he arrived without any vital signs. (Primary Source: “Un rayo le quitó la vida a 'Chú', el albañil de Barrancas”, DiarioDelNorte.net, May 23, 2013)

69 22/05/2013 - Quinchía/Risaralda

Lightning finished the life of a Quinchía's farmer. William Alberto Puerta Gómez, 32 years old, was trying to avoid the rain in a small space that had a zinc roof. (Source: “Rayo terminó con la vida de un agricultor de Quinchía”, Lesionesxrayos, 2013)

70 30/05/2013 - Tarazá/Antioquia

Two soldiers lost their lives after being struck by lightning while they were doing their military work in a mountainous area of Tarazá, Antioquia. The soldiers were identified as Nicolás de la Torre Avila and Omar Soler Cogollo. (Source: “Dos soldados perdieron la vida tras ser alcanzados por un rayo”, Lesionesxrayos, 2013)

71 11/06/2013 - Soledad/Atlántico

Marcela Isabel Cervantes Suárez was identified as the woman that was struck by lightning when she was with her husband, Javier Enrique de Moya Garizábal and two of her three children, at her home located in Ferrocarril neighborhood of Soledad municipality, Atlántico. They were in the kitchen that was made with zinc sheets
72 19/06/2013 – Toro/Valle del Cauca

Lightning caused injuries to two soldiers in El Valle. Although the two injured soldiers suffered second-degree and third-degree burns, they are now out of danger. (Primary Source: “Un rayo causó heridas a 2 militares al norte del Valle”, 90minutos.co, June 19, 2013)

73 27/06/2013 – Cartagena del Chairá/Caquetá

Two people were injured in Bocana de Anaya district, Cartagena del Chairá. While they were doing work in the countryside, they were struck by lightning. One of them required to transfer to Simón Bolívar Hospital in Bogotá. (Primary Source: “2 heridos en la vereda Bocana de Anaya en Cartagena del Chairá”, Lesionesxrayos, 2013)

74 29/06/2013 Valledupar/Cesar

Lightning killed a student of the SENA, in Los Angeles country estate, a rural area of Aguas Blancas, Valledupar village. The student was playing with some friends when lightning struck him. (Source: “Un rayo mata a estudiante del SENA”, Lesionesxrayos, 2013)

75 29/06/2013 Cajibío/Cauca

A 52-year-old man was a victim of lightning and another was injured. The first died in the medical center of Cajibío municipality, when he was taken after lightning struck him as he was walking in the central park of this municipality. (Source: “Un hombre de 52 años víctima de un rayo, un herido”, Lesionesxrayos, 2013)

76 07/07/2013 – Piedecuesta/Santander

A man died when was struck by lightning and another was injured. The victim, along with his friend Gabriel Bayona, decided to seek shelter in Tres Esquinas country estate, of Faldriguera de Piedecuesta district. Roberto was killed instantly, while Gabriel lost consciousness, then he woke up and went for help. (Primary Source: “Hombre murió al ser alcanzado por un rayo”, Vanguardia.com, August 09, 2013)
77 07/08/2013 - Ciénaga de Oro/Córdoba
An electric discharge caused the death of a 9-year-old child in Bugre village, Ciénaga de Oro, Córdoba. Luis Mariano Olivares, accompanied by his 12-year-old brother, was going on a bicycle to the store when a strong downpour surprised them. (Source: “Un rayo lo mató”, Lesionesxrayos, 2013)

78 21/08/2013 - Juan de Acosta/Atlántico
Lightning killed a 5-year-old little girl. Her grandmother was also injured. The 5-year-old died in the afternoon at the Bocatocino health resort, Juan de Acosta municipality, after being struck by lightning. The grandmother had the girl between her legs. (Primary Source: “Rayo mató a niña de 5 años en Juan de Acosta”, ElHeraldo.co, August 22, 2013)

79 02/09/2013 - Purísima/Córdoba
Lightning killed a fisherman named Rafael Antonio Pitalúa Meza, 53 years old. The incident occurred at 5:00 am yesterday morning, while it was raining, in Ciénaga Grande, Los Corrales village, rural area of Purísima municipality. (Primary Source: “Un rayo lo mató”, ElMeridianoDeCordoba.com.co, September 03, 2013)

80 06/09/2013 Barranquilla/Atlántico
A man died from due to lightning in Barranquilla. One person was hurt in the middle of a strong downpour that fell in Barranquilla when lightning struck him. The 48 years old victim was identified as Juan de Avila Buelvas. The man received the electric discharge as he was riding his bicycle going back home. (Primary Source: “Un hombre muere al ser alcanzado por un rayo durante aguacero en Barranquilla”, ElHeraldo.co, September 06, 2013)

81 06/09/2013 - Istmina/Chocó
Lightning killed a 16-year-old man, in Istmina, Chocó. The young man had died in Santa Genoveva neighborhood, because of an electric discharge. The victim was identified as Sergio Luis Murillo Torres. (Source: “Rayo mata a joven de 16 años, en Istmina, Chocó”, Lesionesxrayos, 2013)
82 10/09/2013 – San Onofre/Sucre

Lightning killed a fisherman and his cousin was injured. Luis Angel Tovar Julio, 17 years old, was fishing with his cousin Dairo Tovar on a swamp in San Antonio village, San Onofre, Sucre. It was 3 o'clock in the afternoon when the cousins took a trammel-net and threw it into the water. At that moment, while a slight drizzle fell, lightning struck Luis Angel. (Primary Source: “Rayo mata a pescador”, ElUniversal.com.co, September 12, 2013)

83 11/09/2013 – Cartagena/Bolivar

Lightning almost killed three young men were fishing. The incident occurred at 5:30am yesterday morning in the sector known as Isla Panda, San Bernardo archipelago. (Source: “Un rayo casi los mata. 3 heridos”, Lesionesxrayos, 2013)

84 15/09/2013 - Simijaca/Cundinamarca

After suffering burns and wounds caused by a lightning strike while he was playing a soccer match, the sports director of Simijaca municipality, Cundinamarca, Julio Alberto Bustos, is at the Chiquinquirá Hospital. (Primary Source: “Director de deportes herido por la caída de un rayo”, Caracol Radio, 2013)

85 15/09/2013 – Convención/Norte de Santander

Lightning killed a soldier from Montería and two more injured. The deceased was identified as Amaury José Montes Urango, 28 years old, soldier who died when lightning struck his squadron. The incident occurred in El Repollo district, Convención municipality, North of Santander. The lightning also injured two other soldiers. (Primary Source: “Rayo mató a soldado monteriano”, ElMeridianoDeCordoba.com.co, September 17, 2013)

86 17/09/2013 – Zambrano/Bolivar

A farmer was sleeping in a tent on the Tucurinca farm at night with three companions when a severe thunderstorm began. The man, who was 37 years old, got out the tent with his fellows because the water was getting into it. They settled near a radiotelephone antenna installed on the site, when lightning struck. The electric shock killed the man instantly. The other three farmers were also affected (Primary source:
87 26/11/2013 – Guamo/Tolima

Juan Heriberto Melo Cruz, 17 years old, was riding his motorcycle in the middle of a downpour from his school to his home as he usually did, when he decided to seek shelter in Las Palmitas kiosk. The young man turned off his motorcycle and sat on it waiting for the downpour to stop. As he was taking a phone call, lightning struck him, killing him instantly. (Primary Source: “Joven muerto por un rayo en el Guamo”, girardot.extra.com.co, November 26, 2013)

88 11/07/2014 – Sahagún/Córdoba

A professor from Sahagún municipality, Córdoba, died because of the electric discharge when lightning struck where he slept next to his cell phone. This occurred in Tarazá, Antioquia; the professor was identified as Nichar Londoño Sánchez, 19 years old. (Primary Source: “Rayo mató a Nichar Londoño Sánchez, docente cordobés”, ElUniversal.com.co, July 11, 2014)

89 03/08/2014 – San Francisco/Antioquia

Lightning killed three soldiers who were patrolling in the middle of a thunderstorm in Aquitania de San Francisco village. The soldiers were identified as Brayan Mosquera Vallejo, Yovany Giraldo Quintero and John Alzate Arias. According to the witnesses, they were watching the energy tower, one of FARC’s targets. (Primary Source: “Murieron tres soldados que patrullaban en medio de tormenta eléctrica”, ElTiempo.com, August 04, 2014)

90 07/09/2014 – Marialabaja/Bolivar

A 26-year-old farmer, who used to move herds of cows between towns, was struck by lightning. According to his father, at 2:00 p.m., the young man was riding his horse while he was eating on a metal dish, it was raining and suddenly the lightning struck. The farmer died instantly, as did his horse and a dog which was close to him. His relatives believe that the metal dish attracted the lightning. (Primary Source: “Rayo mató a hombre que arreaba vacas en Marialabaja”, ElUniversal.com, September 09, 2014)
During sunrise, eleven members of an indigenous community lost their lives and fifteen were wounded, eight of them seriously, as result of a lightning that impacted a hut named Casa María, a place where the ethnic authorities of the Sierra Nevada Mountains were carrying out a traditional ritual of their culture. The powerful lightning storm happened on Kemakumake, a town of Santa Marta rural zone, in the foothills of the Sierra Nevada. (Primary Source: “Gobierno ofrece apoyo a familias indígenas de la Sierra Nevada”, ElUniversal.com, October 06, 2014)

A fire was produced early morning by a lightning that destroyed the house of a woman in the village of La Palma, la Mojana municipality. The woman indicated that at 2:45 a.m. she heard a powerful thunder and a part of her house started to burn. She tried to save some of her belongings, but it was too late. (Primary Source: “Incendio producido por un rayo destruyó una casa en La Mojana”, ElUniversal.com, October 08, 2014)

The soldier identified as Yílmer Duván Porras Pérez, was struck by lightning. One of his friends said: “When lightning began to fall, we all went out and ran to some little houses to protect ourselves. Another comrade went to look for Porras but he did not answer”. The soldier was found lying on the floor, where lightning had struck him in the middle of the downpour. Cardiac arrest was the cause of his death. (Primary Source: “Una tormenta truncó los sueños de Yílmer Duván”, ElTiempo.com, April 01, 2015)

Lightning left one soldier dead and four others injured. The soldiers were in a mountainous area patrolling aboard a vehicle in the rural area of Cartagena del Chairá. (Primary Source: “Un rayo mató a un soldado y dejó heridos a otros cinco uniformados en Caquetá”, ElUniversal.com.co, August 28, 2015)

An electric discharge fell over two minors and left them lying on the street, Manga district, La Florida village, Pereira. While everybody was aware of the thunder that announced the rain over La Perla del Otún, a shock between the clouds caused an
electric discharge that was received by Laura Gil Suárez, 17 years old, and Nicolás Cardona Gutiérrez, 15 years old. They were waiting for a relative and were lying on a mesh when everything happened. This reporter learned that the minors had just left school. The minors are alive. (Primary Source: “Un rayo alcanzó a los novios”, ElDiario.com.co, September 30, 2015)

96 14/10/2015 - Yacopi/Cundinamarca

A 20-year-old soldier died due to Lightning. Eduardo Pachón Cruz was patrolling in the Pueblo Nuevo sector, Yacopi municipality. It seems that the electric discharge occurred when the young soldier was manipulating his mobile phone. (Primary Source: “Soldado murió al ser alcanzado por un rayo cuando usaba el celular”, Noticias Caracol, October 14, 2015)

97 28/04/2016 - Cartagena/Bolivar

Leonardo Ortega Martínez, 68 years old, who had a farm in Santa Ana district, perished after being struck by lightning. “My father was entering the kitchen to prepare lunch when lightning fell. On the door of the kitchen, it is possible to see a burnt piece where the lightning struck”, told Afonso Ortega, Leonardo’s son. (Primary Source: “Rayo mató a campesino dentro de una finca”, ElUniversal.com.co, April 30, 2016)

98 16/09/2016 - Cereté/Córdoba

Ana Ballesteros, 18 years old, will remain buried up to her neck for several hours during three days to let the earth “take the energy”, local media reported. The girl received a lightning strike in the Colombian municipality of Cereté while she was walking towards the school. After the discharge, the young woman was hospitalized but affirmed that since then she suffers very strong pain in the back that keeps her from walking. “Physicians studied medicine, but not for lightning. I know that getting into the gap ... Maybe I’m going to get better because they’re old things”, she said. (Primary Source: “Mujer se entierra en Colombia para quitarse ‘energía’ tras impacto de rayo”, ElComercio.com, September 21, 2016)

99 28/10/2016 - Itagüí/Antioquia

This afternoon a woman died because of lightning. According to residents of the neighborhood La Aldea, Itagüí municipality, the 48-year-old female was walking with a girl she had just picked up at the Carlos Enrique Herrera School. The incident caused
burns in the minor, who at this time is being taken care of in a care center. (Primary Source: “Mujer falleció víctima de un rayo en el barrio La Aldea de Itagüí”, TeleMedellin.tv, October 28, 2016)

100 05/12/2016 – Santander de Quilichao/Cauca

A 5-year-old child died and his sister was injured by lightning in the rural zone of Santander de Quilichao, Cauca. Daniel Pacue, father of the children, said that they were inside the house when the unfortunate event occurred. "The boy ran out to the laundry to take water and his sister went behind him, and the lightning struck both of them". (Primary Source: “Niño de 5 años murió tras ser alcanzado por un rayo en Santander de Quilichao”, Noticias Caracol, December 05, 2016)
Appendix 4: Publications from the Project

Partial results of the work performed during this research have been presented in the most important international events on the subject of lightning. These published papers are listed and presented below.


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30 Available on IEEE Xplore Digital Library