Estimation of Damages and Losses for Disasters in Bogotá D.C. (Colombia)

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Abstract

Bogotá, capital of Colombia, with 8.2 million inhabitants by 2018, have a system to report different types of emergencies (Information System for Risk Management and Climate Change - SIRE), collecting information since 2002. This work presents the results of a project in which more than 200 thousand emergencies records were transformed into a DesInventar database, as a first step for further estimate the damages economically. Considering the particularities and strengths of the SIRE data, the economic assessment of the damages of small and medium-scale disasters was estimated using an adapted DaLA methodology. A set of developed software tools plus DesInventar system, lets District's Institute for Risk Management and Climate Change (IDIGER) analyze this data and generate monthly bulletins showing data, graphs and maps with predetermined analysis.

Introduction

Sendai Framework for Disaster Risk Reduction focuses on the development of indicators to assess the progress of countries in relation to its seven goals. These indicators suggest a standard measurement of the gradual fulfillment of the goals, so United Nations International Strategy for Disaster Reduction (UNISDR) offers methodological guidelines and computer tools to every country that signs the Agreement (UNISDR, 2017). However, taking in account that each country has previous progress and specific needs to strengthen risk management processes, UNISDR is open to other methods to present results.

This possibility could be understood as an open door to dialogue with other approaches. Bogotá city is an example for these initiatives, due is moving forward with methodologies that reflect Sendai's purpose. Since 1998 the city has had a system to report different types of emergencies (SIRE) that has been very useful for the coordination of different actors in the response to emergencies. However, the heterogeneity of the collected information makes difficult and complex to analyze and use data for decision making in Disaster Risk Reduction.

This paper presents the results of a project developed in 2015 and 2016, by Mayor's Office of Bogotá city and the NGO Seismological Observatory of the Southwest (Corporación OSSO, in Spanish). This project aims to process and quantify damages and losses of more than 3.5 million records of emergencies and small-scale disasters, reported in the SIRE for the period 2002-2015 (with an update to 2017). As part of the results, more than 200 thousand emergencies records were transformed into the DesInventar Disaster Inventory System, where quantitative values of damages and losses are now available. A methodological framework for an economic evaluation of damages adjusted to the city was developed based on the experience of The Economic Commission for Latin America and the Caribbean (ECLAC) with The Damage and Loss Assessment (DaLA) methodology. As a result, an interconnection between databases of emergencies and values of annual cost of each item was made.

1. Basic design of the study

The project was developed for Bogotá city, and specifically for the administrative divisions (localities and neighborhoods) affected daily by small and medium scale emergencies (or disasters). This study is focused on the interconnection of methodologies and information systems to classify and quantify a dataset of emergencies and disasters over different scales. Therefore, it could be available for analysis and decision making for urban risk management.

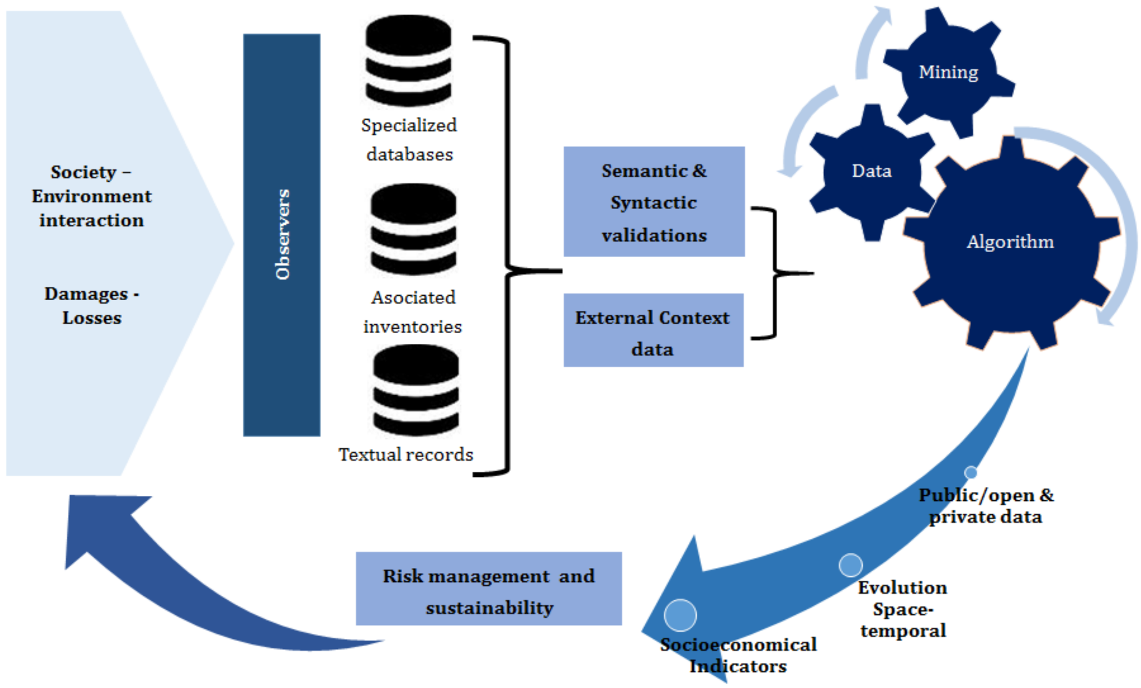
To move along on risks reduction and the disasters prevention, it is imperative to have accurate assessments about risk condition and systematized information of damages and losses caused by daily emergencies. Recent efforts in this matter and International Agreements like Hyogo and Sendai have contributed to identify usefully information from local or national governments.

The complexity of urban dynamics entails even more care for resources and supplies needed for keeping the urban systems functioning. It means the city is prone to increase of risks and face with a higher frequency of emergencies and disasters (Mansilla, 2000). Therefore, the management of information about emergencies is an important key action, especially in large or intermediate cities. Moreover, the coordination of actors involved in the emergencies must be done with post assessments in order to improve risk management measures.

Since the 1990s initiatives such as Disaster Inventory System DesInventar were pioneer in this topic, while in the 2000s others national initiatives (such as National Information Systems for Disaster Prevention and Attention) emerged and managed by agencies related to risk management. These developments have generated a set of experiences and a set of databases or inventories with valuable information for the knowledge of the risk in the territories. The existing information systems in the countries and/or cities fulfill diverse functions related to emergency response, as well as to the collection of damages and losses data and other objectives established in the national framework for risk management.

Given the very wide diversity of information collected in these information systems, the current challenge is to design methods and computer tools for the identification of confident data and find new ways to set interactions in-between different information systems. As illustrated in Figure 1, the general methodology used for of the project was the identification of damages and losses recollected in these databases with the purpose of getting homogeneous datasets available for analysis. Regarding the interrelation with another source of information, two actions were proposed: firstly, to adapt a methodology for the quantification of the effects. Secondly, to develop an application for consulting and communication with options to make, for example, heat maps and newsletters. The following sections will detail the procedures of this general methodology for the case of Bogotá.

Figure 1. Methodology for the processing and quantification of damage and loss data from existing bases



Source: compilation based on documents of project (Corporación OSSO to IDIGER, 2016).

1.1. Processing and classification of emergencies information

The District's Institute for Risk Management and Climate Change (IDIGER) built the Information System of Risk Management and Climate Change (SIRE)[1] for Bogotá in 1998. The system includes diagnoses and technical concepts about risk, emergencies data and legislation. Emergencies data are provided by communities and different entities through a telephone number and includes emergencies of many types for example, traffic accidents, rescue of trapped people in vehicles or buildings, falling trees, failures in public services (water supply, sewerage, electricity, domestic gas, telecommunications) and natural phenomenal such as floods, landslides or earthquakes.

Between 2002 and 2015, SIRE had collected 3,5 million emergencies records. The inclusion of emergencies of different types and the fact that more than 80% of records were incomplete it has been a problem for analysis and use of data. By use of DesInventar methodology it was possible to identify 185 thousand of these records with damages data, it means, with affected people, goods or services. These set of emergencies records was obtained by compared the methodological criteria used by SIRE and DesInventar, as shown in Table 1.

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[1] http://www.sire.gov.co/

Table 1. Comparison methodological criteria between DesInventar and SIRE

Variable to compare	DesInventar	SIRE
Disaster or emergency definition	It includes the effects of natural and *man-made* hazard events of different size.	It includes different types of emergencies, even those not directly related to risk management, for example, rescue of people, medical emergencies or falling trees.
Types of events	Natural and technological events that causes effects on people, goods and services: hydrometeorological events (floods, landslides, rains), geological (earthquakes, tsunami, volcanoes), technological (explosions, fires, leaks, structural collapse) and biological events (intoxications, epidemics, pollution).	Natural events (floods, flooding, fires, explosions, etc.), damage to public service networks, preventive actions (felling, bees swarm); risk situations (risk of structure collapse).
Variables of effects	Effects on people, goods and services such as dead, injured, affected people or homes destroyed.	Detailed effects data, for example, if affected people are adults or children, size of affected area by flooding. But, the system has not a systematically collected effects data and most of the effects data were described in the form of observations and not quantitatively.
Geographic unit for collection of data	Overall, data is related to a geographic unit, for example, municipality or neighborhood.	Accurate location of the emergency or disaster (in most of cases includes geographic coordinates). But not always was registered this data.

Source: OSSO to IDIGER, 2016a

Three criteria were defined to identify the records of interest: 1) Records with effects data, it means, affected people, goods or services. Approximate 80% of the records did not have loss and damages data, but we designed algorithms for the extraction of the data. 2) Damages to public services networks and traffic accidents by different causes. According with the mission of IDIGER, the SIRE system record and keep information in public services and traffic accidents when they are related with natural phenomenon. However, in the process to guarantee the attention it is not always possible determinate the direct cause of the impacts, so the system operators do not register the causes for most cases. In homologation process, the researcher concludes keep those impacts as events, to track them easily and maintain the same usability that SIRE. The huge number of emergencies due to this type of events can be an indicator of new types of risks related to urban development. 3) Records with geographic location to neighborhood level because for planning and decision making to urban risks reduction, the detailed data is required to know the heterogeneity of risk inside the territories (Maskrey, 2000). Several emergencies records had geographical coordinates, which facilitated the use of this criterion.

For the interconnection of both systems, SIRE and DesInventar, was developed a software that implement these criteria and other set of rules to identify and import data from SIRE to a DesInventar database.

1.2. Economic estimate of the effects

In the existing literature, there are different methodologies for the assessment of hazards, vulnerabilities and risks, generally oriented to specific phenomena such as earthquakes, volcanoes and floods. However, by the time this project was developed no system was available to calculate damages and losses *on the fly*. Only until 2016 was it developed the LISA system for the IDIGER in Bogotá, as part of a specific project of adaptation of the CAPRA platform. LISA is a tool designed to preparedness and emergency response, which constantly monitors the accelerograph network from which receives the acceleration time-history recorded after the occurrence of an earthquake, and automatically calculates the intensities of strong motion at the ground surface and evaluates the expected damage in all buildings in the city (Cardona and Bernal, 2018). This system assesses the potential damages for earthquakes, it means, make the estimate of risks.

The most well-known damages and loss assessment methodology is the one developed since 1972 by the Economic Commission for Latin America and the Caribbean – ECLAC. It estimates of damages and losses for big disasters, which are generally carried out by teams of experts (engineers, economists, architects, sociologists). However, the assess reports done during more than four decades were often criticized because it was not easy to compare the results of one mission with another, mainly because each one of them had its own criteria and emphasized one or the other affected sector according to mission chief. Inter-American Bank for Reconstruction and Development (IBRD) and World Bank (WB), gathered a group of experts, with support of ECLAC, which made the ECLAC unified methodology called Damage, Loss and Needs Assessment Methodology (DaLA).

To assess the emergencies data imported to DesInventar database we have adapted DaLA methodology (BM-BIRF, 2012)[2], considering particularities and strengths of the SIRE data, as it was done for Global Assessment Report by UNISDR (2015). SIRE system includes effects data of different sectors, so DaLA methodology it was very useful to get options to economic estimation. This project made the economic assessment for affected goods and services, but not its impact to city's GDP. The steps to the economic estimate were:

A) Definition of baseline of the situation before the disaster. This baseline are the replacement costs of assets and interrupting the services.

[2] DaLA considers two types of disasters effects: the total or partial destruction of physical assets, which it calls "damages” and the changes in the economic flows of the affected sector, which it calls "losses". The damage value is useful to calculate replacement costs of damaged buildings or infrastructure, while the value and type of the losses to calculate disaster socioeconomic impact to achieve economic recovery. DaLA is based on a sector-by-sector estimation, along with the subsequent aggregation of results to estimate the total effects of the disaster and then to measure its impact on society and the economy.

B) Estimation of damages and losses for each sector. It included variables for infrastructure sectors (public services and transport mobility), social sectors (health, education and housing) and productive sectors (agriculture, industry and commerce). Some damages were not estimated economically because there is not information about its replacement cost, it is very complex to do still, for example, health and agricultural sectors.

The information sources for replacement costs data were mainly from public institutions: Cadastral Special Administrative Unit (2014), Public Services Information System (SUI) and Secretary of Education of Bogotá. In some cases, it was not possible to obtain information from public institutions, so were used private sources.

The economic estimation of damages and losses is the result of a basic arithmetic operation that combines damages data and replacement costs, as shown in Table 2, which has examples for economic estimation of destroyed houses and sewerage service affected. The software developed runs the calculation and includes the data in DesInventar database. This process represents a first pilot exercise that requires revisions and strengthening, but it offers an approximation to the economic estimate of the damages and losses that occur in Bogotá.

Table 2. Examples of algorithms for economic estimation

Type of damage	Damage and Losses variables	Replacement costs	Economical Estimation
EE1……. n *[Where DEv1 is Economic estimation for type of damage 1]*	*VDLv1, VDLv2... VDLvn* *[Where VDPv1is Variable of damages and losses for variable 1]*	*RCv1… RCvn* *[where RCv1 is Replacement cost for variable 1]*	**VDLv1 *x* RCv1**
V1 = houses Destroyed	Case 1: there are number of M2 land destroyed (M2L) and M2 construction (M2C) destroyed.	Average price of land (M2) ($M2L) Average price of construction (M2) ($M2C) Average size in land (M2) (SizL) Average size in construction(M2) (SizC) * same neighborhood and year	**Total $ V1 = M2L *x* $M2L + M2C *x* $M2C**
	Case 2: there are only number of houses destroyed		**Total $ V1 = V1 x (SizL *x* $M2L + SizC *x* $M2C)**
V2 = sewerage service affected	Number of hours of service interrupted (#HS) Number of affected families (#FAf)	Price of one hour of sewerage service ($HS): calculated by neighborhood and year	**Total $V2 = #HS *x* #FAf x $HS**

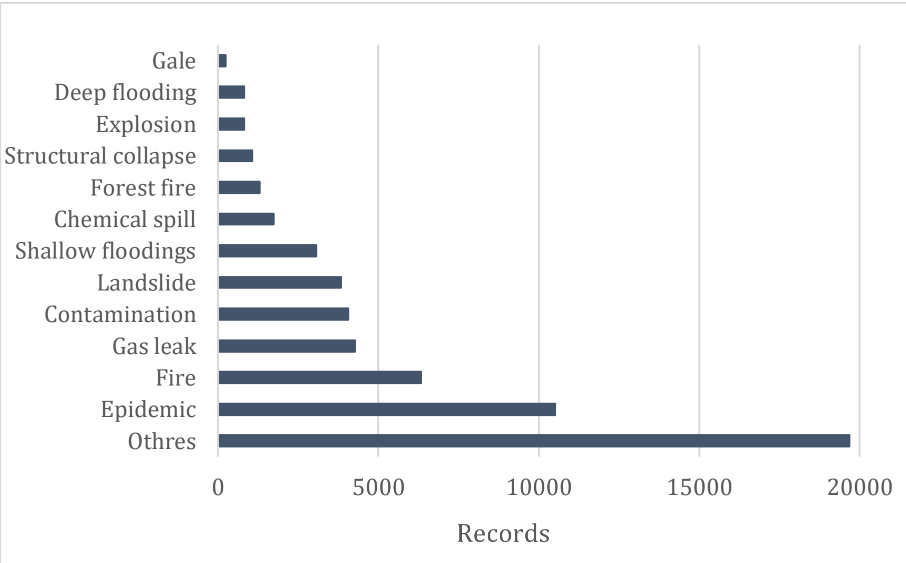
Source: based on documents of the project (Corporación OSSO to IDIGER, 2016b)

2. Major results: database and quantitative values of damages and losses available

2.1. Database of damages and losses due to emergencies and disasters in DesInventar

More than 3,5 million emergencies records from SIRE (related to 145 types of events) were verified to identify and obtain those with effects data. More than 200 thousand records of period 2002-2017 were import into a DesInventar database. This database is available both on DesInventar website and on a server of District's Bogota[3]. By the consulting module of DesInventar, it is possible to obtain some preliminary analyses relation to patterns and trends of damages and losses. Figure 2 illustrates records of emergencies for each type of event, where it can see biological and technological events have more records related to them.

Figure 2. Records by type of events, 2002-2017



Source: based on SIRE in DesInventar (IDIGER, 2017)

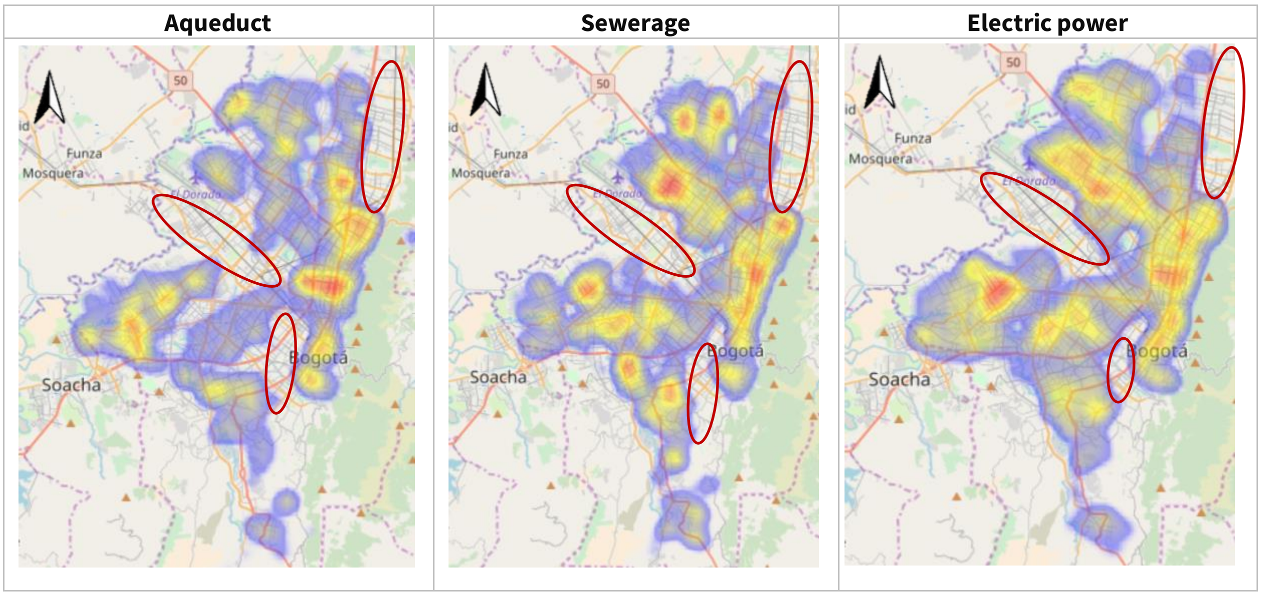
The effects records related to natural events such as floods and landslides are not few. In fact, the main effects on lives and houses was caused by hydrometeorological events between 2002 and 2017. Landslides, "shallow flooding"[4] and "deep flooding"[5] generated the greatest amount of people affected and houses affected. Landslides are notables for the number of destroyed houses associated with them. Un interesting fact is the amount of "shallow floodings" records, since they are small floods that directly affect mobility in the city, which deeper the daily problems of urban transport.

[3] https://online.desinventar.org/desinventar/#COL-20180227192609
[4] Defined by SIRE as less than 30 centimeters of water
[5] Defined by SIRE as more than 30 centimeters of water

Damage in public services and traffic accidents were identified as recurrent. As we mentioned earlier, the SIRE system in most of cases it has not included the causes of these types of damages. It is the reason because of that there is a mixture of damages in public services and traffic accidents related to natural events and human causes (mainly human mistakes and damages to operational malfunctions). The lack of clarity about damages causes makes it difficult to analyze the trends of disasters and emergencies due to natural phenomena. However, we found it very interesting to identify that these are damages type most frequently in the database.

Damages in public services imply suspension of water, electricity or communications services that have negative impacts on residential areas and different economic sectors. The Figure 3 shows records which had damages on public services between January and December of 2017. The maps show there is a homogeneous distribution of damages in public services throughout almost the whole city, except for three sectors highlighted by red ovals. it would be very interesting to search others information sources to identify if these spatial trends are related to peculiar socioeconomic conditions, quality soil, ground uses or if the gaps are related to under-recording of data.

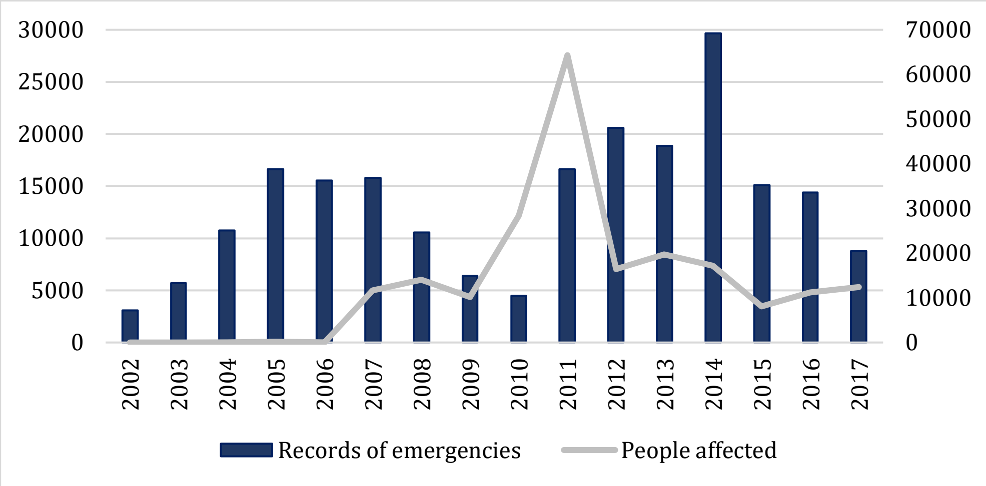
Figure 3. Emergencies records with effects on public services



Source: Interconnection System between SIRE and DesInventar (IDIGER, 2017b)
Note: these maps are only indicative of trends we want to show

The Figure 4 shows the records related to hydrometeorological events, they have a cyclical trend with two periods (2002 - 2010, 2010 - 2017). It could be possible database has data under-recording; however, it allows deduce tendencies and patterns confirmed for the context and other information sources. For example, the tendency of records is not incremental. Affected people have a maximum value in 2011 because the country suffered widespread impacts due those years were characterized by a La Niña phenomenal of strong intensity (ECLAC, 2012).

Figure 4. Emergencies records and people affected by hydrometeorological events, 2002- 2017



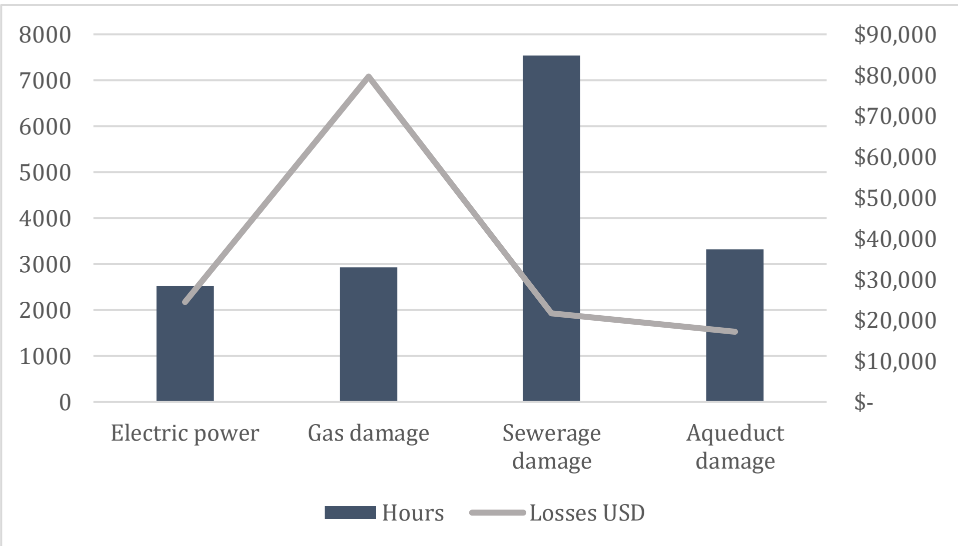
Source: based on SIRE in DesInventar (IDIGER, 2017)

2.2. Methodological framework for quantification of effects

A methodological framework for the city was developed considering the DALA methodology. We used a profuse and diverse database for a big and complex city like Bogota. It was the first exercise for the economical estimation of damages using the records of emergencies and small-scale disasters. To show an example of the estimation, the Figure 5 illustrates losses data in public services sector, which were obtained from the number of hours of service interruption during 2017.

This methodology is a tool for the district government to identify the negative impacts of emergencies and disasters on the district's GDP so it will support the make decisions to reduce risks and increase its resilience.

Figure 5. Hours without service and losses in USD – 2017



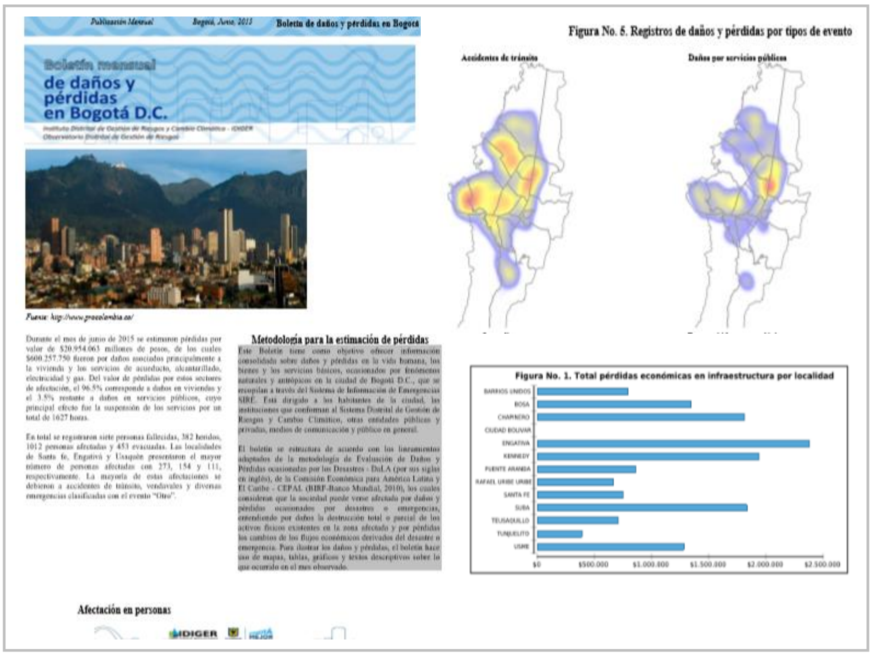
Source: Interconnection System between SIRE and DesInventar (IDIGER, 2017b)

2.3. System of interconnection between databases of emergencies and disasters

As part of the project, a software tool was developed for the interconnection of SIRE and DesInventar databases, the estimation of damages and the dissemination of data and analyses. The informatics application allows the semi-automatic import of records from SIRE into a DesInventar database, using the selection criteria of the records described in numeral 1.1. Database can be consulted through the DesInventar query module, which allows making thematic maps, graphs and summations of data. It also includes the module for estimation of damages, calculating “on the fly” economical values, which results are attached to the DesInventar database system. The software also has a module to generate thematic maps of administrative levels or heat maps.

Finally, a module to generate a periodical bulletin was developed too, and it includes data, graphs and maps for various types and analysis periods (Figure 6) that can be defined by manager of system. It is proposed as a tool for the publication of consolidated data of damages and losses by phenomena associated with the characteristics and dynamics of Bogotá and its environment. It is also is conceived as a means of communication with enormous relevance for all institutional and community actors, as participants in risk management in the city.

Figure 6. Images of the periodic Bulletin of damages and losses for Bogota



Source: Interconnection System between SIRE and DesInventar (IDIGER, 2017b)

Conclusions

The methodology developed to classify records of damages and losses by emergencies and disasters using DaLA is based on two central assumptions. Firstly, the recognition of the strengths and limitations of the existing systems for information management at the local levels. Secondly, risk management implies an articulation with the goals and indicators of the Sendai Framework. Always keeping in mind that the local management strategies of the risk not only respond to national institutional frameworks, it also responds to the dynamics of their environments. This means the application of standard methodologies, such as the indicators proposed to achieve the goals of Sendai (UNISRD, 2017), must be adapted to the needs of the territories and local governance.

The consolidation of a historical inventory of disasters for cities with high concentration of population impact of several possibilities for the research of urban risks. Thus, a preliminary analysis identified that in addition the emergencies related to natural events, damages on infrastructure and interruptions of public services such as water supply, sewage or energy also have a significant impact on the local risk management. The updated database makes possible to study the effects of risks related to complex systems such as the critical infrastructure to functioning of the city (Mansilla, 2000).

The economic evaluation of damages and losses is the first approach to takes advantage the existence and availability of detailed information. The use and improvement of this tool will make possible, a better investment in measures to risk reduction and validate the risk reduction measures implemented by the local government and other stakeholders.

This project represents an important effort to provides a strong and quantified basis to be used as a tool for decision making for the city. Also, its results could open a window of dialogue with the Sendai Framework that is encouraging the building of databases of damages and losses and its economic estimation.

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