Colombian Emergency Response Platform (PCRE): Design and Testing of a SDI- Based System to Facilitate Disaster Management in Colombia

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SUMMARY

As a result of geographical features including earthquakes, volcanic activity, floods, droughts, landslides and bushfires, Colombia has a high frequency of disasters. They occurrences have increased exponentially in recent years, mostly generating the propagation of the unwanted effects on the population. Sharing multi-crowd spatial information is a useful tool for disaster risk management. However, difficulties for the collection,/ access, dissemination and use of the data exist. Despite the existence of regulations for providing information concerning with risk management in Colombia, they are not carried out generating inefficient allocation of resources.

In order to improve data sharing and decision making during all risk management phases, this paper describes the conceptual design of the Colombian Platform for Emergency Response (hereinafter referred to as "PCRE"), developed based on existing approaches of Spatial Data Information (SDI) and Decision Support Systems (DSS). The initial design was tested by a pilot development for the response phase, tested in a local situation in Bogota with the participation of over 40 key stakeholders, including the national government and private sector. As a general sense it was found that the key design aspect of PCRE is to improve communication effectively and efficiently between institutions, serve as a mechanism for sharing multidisciplinary information, connect systems, and incorporate the society.

Future researches are in the areas of preparedness and mitigation. The initial focus of the PCRE is the response stage; some activities are related to monitoring and emergency management, data in real time during the event, short-term updates information regarding listings and location of equipment entities providing answers care services.

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1. INTRODUCTION

One of the most fundamental challenges facing humanity at the beginning of the twenty-first century is to respond effectively to the global environmental changes that are threatening humanity (Craglia, et al., 2011). National territories in Latin America are extensive and have different risks due to geographical features. As an unwanted effect, the impact caused by failures in development models and forms of informal or wrong occupation of the territory is increasingly. Variables as the population growth, rapid urbanization and localization of human settlements in risk areas, increase the vulnerability of the population to natural and man-made hazards. However, the occurrence of these events is not the biggest problem, the issue lies on the mechanisms established to counter them.

Currently, it has not been able to understand the problematic of risk management as a weak point of the territorial planning, in the sense that disaster situations are result of imbalances between the dynamic relationship of the nature and human (General Secretariat of the Andean Community, 2009). Considering society, economy and environment as the three main components of sustainable development, disasters have a negative impact on them making appropriate disaster management a necessity for the community and governments (Mansourian, Rajabifard, Valadan Zoej, & Williamson, 2005).

Disaster management requires a complicated iterative process that includes disaster monitoring, early detection, forecasting, loss assessment, and efficient analysis of disaster reduction (Ding, et al., 2015; Droegemeier, et al., 2005; Hristidis, Chen, Li, Luis, & Deng, 2010). Updated and high-quality information is the key factor for any appropriate decision, primarily in disaster risk reduction. Many technological contributions have been done such as sophisticated tools to predict the behaviour and effects of the natural hazards on different aspects as infrastructure, economics and land-territories. Less attention has been devoted to effective communications, real-time information management of the situation awareness, and to improve the cognitive abilities of decision makers (The University of Melbourne, 2014).

As an answer to the above, the Colombian Emergency Response Platform (PCRE, acronym of the Spanish name *"Plataforma Colombiana de Respuesta a Emergencias"*) attempts to solve problems related the actions to face emergencies in the country. Sharing information, tools and knowledge between agencies, jointly with the lack and standardization of information represent the main issues

to address the disarticulation during the disaster management in the country. PCRE is a technological development oriented to improve effectively and efficiently communications between institutions, serve as a mechanism for sharing information and connect systems. This platform allows the access and visualisation in real-time of information of emergencies at different levels (national, departmental, municipal and local) and contributed as a useful tool for disaster decision making. This "System of systems" is conceived and based on the concept of a Spatial Data Infrastructure (SDI) and Decision Support System (DSS).

In this paper, first is introduced to an overview of risk management in Colombia and the progress made in this sphere. Then, it is presented a synopsis of the conceptual design described as a technological and innovative development based on the SDI and DSS concepts. After this, it is mentioning the participation of national stakeholders during a pilot test (including public and private sector), and their expectations associated with the PCRE project. Finally, a discussion of the related work, main achievements, and future directions is performed.

2. OVERVIEW OF COLOMBIA'S RISK MANAGEMENT

Colombia located in South America is a unitary and constitutional republic comprising thirty- two departments. Major weather events affecting the country, including natural phenomena such as the El Niño Southern Oscillation (ENOS), characterized by changes in atmospheric pressure over the Pacific Ocean, producing floods (La Niña Phenomenon) and droughts (El Niño Phenomenon) (UNISDR, 2013). Over the past four decades, the occurrence of these events has exponentially increased, leaving significant economic and social losses (OSSO Corporation, 2013).

About twenty-eight thousand (28,000) events relating to disasters were made between 1970 and 2011 in the country. Sixty percent (60%) of the losses are reported from the 1990s. The costs associated with the loss of the last forty years reach US $ 7,100 million, an approximate annual average loss of US $ 177 billion. Between 2010 and 2011, a figure equivalent to a quarter of the records and the dead of the previous decade was reached in just 15 months (World Bank & Global Facility for Disaster Reduction and Recovery (GFDRR), 2012).

The concept of risk management in the country has advanced to be conceived as a pillar for sustainable development and includes the participation of the public and private institutions jointly with the community, a key factor for the mitigation of natural disasters (Iwata, Ito, & Managi, 2013). The procedures for disaster risk management have been improved in the present years. Specially, after the disaster and "Public Calamity"[1] declared on 2010 after the "Rainy Season" (from the Spanish name *Temporada Invernal*"[2]) in which the economy of the country was affected.

[1] Defined by the Act 1523 of 2012, a *Public Calamity* is a results which triggers the manifestation of one or more natural or unintentional anthropogenic events with favourable conditions of vulnerability in people, property, infrastructure, livelihoods, servicing or environmental resources, cause damage or casualties, material, economic or environmental losses, generating an intense, serious and widespread disruption in normal operating conditions of the population in the respective territory, which requires the municipality, district or department execute actions of emergency response , rehabilitation and reconstruction.

[2] During 2010- 2011, due to the extraordinary and sustained increase in rainfall, Colombia faced the worst natural disaster in recent history affected more than 90% of the country (1060 municipalities). It hit all sectors, especially the poorest society (about 3 million people, 6% of the national

Consequently, the National Act "1523 of April, 2012" was implemented and defines the National Policy for Disaster Risk Management and establishes the National System for Disaster Risk Management (SNGRD).

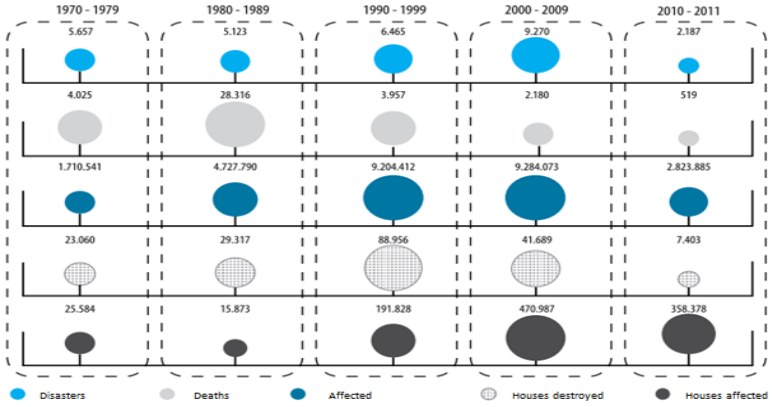


Figure 1. Record of the effects generated by events per decade. World Bank; GFDRR (2012)[3]

The National Policy is describes as "*the commitment of State, from the national to the territory, including structure, direction, control, planning and public investment, financing, legal status disaster or calamity, special regime (...) to face events natural, including climate change, such as unintentional human* ". Other policies associated to the risk management are: Decree 4147 of the creation of the National Unit for Disaster Risk Management; National Development Plan 2014 – 2018 (PND); Departmental and Municipal Development Plans; Act of volunteering; Colombian General Act of fire-fighters. Furthermore, some strategies and guidelines were established: Corporate strategy for the articulation of policies and actions on climate change in Colombia; Guidelines to optimize urban development policy; Regulation of automotive terrestrial handling and transportation of dangerous goods road; among others.

At the national, departmental and municipal levels, different mechanisms have been implemented to optimize the processes associated with the stages of risk management defined by the Act 1523. They are 1) Risk awareness (identification of risk scenarios, risk assessment and analysis, risk monitoring and tracking), 2) Risk reduction (mitigation and prevention) and 3) Disaster management (Emergency response and recovery). Risk management should be understood as two essential ideas: refers as the process and not an

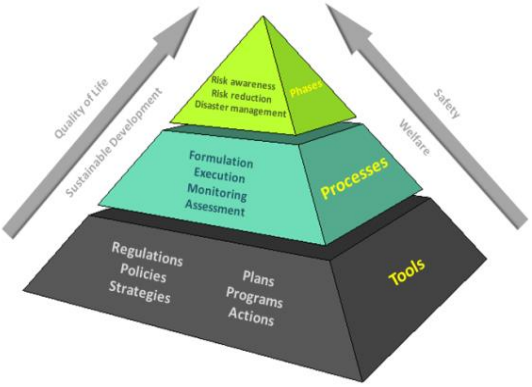


Figure 2. Risk Management components

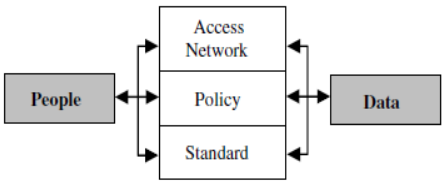
population) and severely deteriorated productive, road and institutional infrastructure. According to ECLAC (2012), losses amounted to about USD 7,200 million. The magnitude of the tragedy overflowed traditional public disaster response mechanisms of the time (Republic of Colombia, 2013).

[3] In the period 1970-2011, major disasters have caused losses in housing of approximately US $ 2 billion, while intermediate and small disasters have caused losses for this same area of approximately US $ 5 billion, which so totalized are 2.5 times more than before events (World Bank & Global Facility for Disaster Reduction and Recovery (GFDRR), 2012).

end, and refers as the reduction and decrease in the generation of new risks. It is divided into corrective and prospective management; while corrective seeking to reduce risk through mitigation works, prospective seeks perform actions that prevent the creation of new risk through the intervention of territorial and sectorial processes risk generators (Rao, R. R., J. Eisenberg, and T. Schmitt., 2007). The first focuses on finding stocks that influence more short-term while the second seeks to change policies and long-term plans (General Secretariat of the Andean Community, 2009).

However, from the experience gained over the last emergencies the country needs projects in the short and long term to become more resilient[4]. The SNGRD has made interventions on major issues such as the developed of strategies for controlling and monitoring projects related to the three stages, but national entities should also address responsibilities and comply measures to support new investments in all the areas (UNGRD, 2013).The responsibilities should include sharing information for any emergency.

As recognized worldwide, sharing spatial data can significantly facilitate the task of disaster management, since most information about disasters has a spatial nature (Amdahl, 2002; Bruzewicz, 2003; Donohue, 2002). Disaster response is dynamic and decision-makers need to be updated on the latest emergency situation; it is also time-sensitive with little allowance on delay in decision-making and response operation (Mansourian, Rajabifard, Valadan Zoej, & Williamson, 2005). In this sense, many contributions for the information management can be improve, including the development of frameworks that allows the creation of environments through a collaborative effort in spatial data production, data collection and data sharing.



2.1 Spatial Data Infrastructure (SDI)

The Spatial Data Infrastructure (SDI) is an initiative to create an environment that encompasses the policies, access networks and data handling facilities, standards, and human resources necessary for the effective collection, management, access, delivery and utilization of spatial data for specific jurisdiction or community (Rajabifard, Mansourian, Valadan Zoej, & Williamson, 2007). The dynamics between the information is required and can be providing by SDI; the users according to the emergencies scenarios need a framework to facilitate the disaster management (Craglia, and others, 2011).

Figure 3. SDI components. Rajabifard (2001)

SDI describes the framework among people and data, with essentials and technological components: access networks, policy and standards (Mansorian, Rajabifard, Valadan Zoej, & Williamson, 2004). In the environment concerning to the risk management is required the retrieve, disseminate and easily access to data for decision making and production of scenarios for decision-making using by the first responders during an emergency. This allows the contribution to

[4] Resilience is ability to anticipate, absorb or recover from the effects of a hazardous event in a short time and efficiently (World Bank & Global Facility for Disaster Reduction and Recovery (GFDRR), 2012).

previously identified gap related to the acquisition of updated and high-quality data for decision-making. However, for disaster management is necessary a tool to provided services such as effective and efficiency communications that allows to enhanced the cognitive abilities of decision makers.

2.2 Decision Support System (DSS's)

A Decision Support System (DSS) according to *Turban* (2011) is an interactive, flexible, and adaptable computer-based in information systems, which utilizes data, provides an easy-to-use interface, and allows for the decision maker's own insights. DSS's based on Geographical Information System (GIS) represents a choice to use in the cycle of risk management with it's used for disaster decision making. The main objectives of a DSS's for disaster management are the improvement of the three aspects slight analysed and vital for emergency care: developing effective communication channels, data flow (situation awareness), and increased cognitive skills of leadership and decision makers and first responders.

2.3 Related work

The Spatial Data Infrastructures have a significant role in the legal and operational framework of geo-services connection (with information of local resources and public services) at different levels of organizations (Molina & Bayarri, 2011). Diverse territories and regions around the world have frameworks focus on the share and management of data. Great examples of this is INSPIRE, the Infrastructure for Spatial Information in the European Community (Birch, 2010 & Craglia, et al., 2011) and the Global Earth Observation System of System (GEOSS) an initiative developed through the voluntary efforts of 84 countries and 58 organizations participating in the Group on Earth Observations- 10-year implementation plan (2005-2015) (GEO, 2005). In the country, the Colombian Spatial Data Infrastructure (ICDE) is the operational tool through which integrate policies, standards, organizations and technological resources that facilitate the production, access and use of geographic information on the Colombian territory, to support decision-making in all areas of public policy (IGAC, 2010).

Many technological developments are proposed to improve the analysis and procedures during emergencies. Some of them focus on the prevention and mitigation; others emphasize on the recovery and cost evaluation for disasters. In this section are listed relevant experiences to the design of the PCRE.

2.3.1 Intelligent Disaster Decision Support System (IDDSS)

A number of major disasters in urbanised regions have occurred in the recent years[5] leaving an urgent plan for protect the population and economy of the regions. In this sphere, the *Intelligence Disaster Decision Support System* (IDDSS) for Australia is one of the newest developments for risk management. It aims to serve as a tool to facilitate scenario planning for urban disaster event and

[5] The most significant events in the Ocean region are: New Zealand earthquake 2011, 181 people killed; Queensland floods, 38 fatalities and damage bill of A$32 billion; 5th largest earthquake in the las 50 years in Japan (2011) creating a tsunami that killed almost 16,000 people and damages bill of US$235 billion (Centre for Disaster Management and Public Safety, 2014).

provides a dashboard for the strategic, tactical, and operational decisions arising during urban disasters. Initially, it was designed for the State of Victoria facilitating decision-making process in natural catastrophes (flood and bushfire) by providing integrated information to enable analysis and ability to optimize and simulate scenarios (The University of Melbourne, 2014).

IDDSS was developed by the interest of the national entities for counter the unwanted effects of the last emergencies. The community had a substantial participation with the description of the parameters to improve from the agencies in charge of the risk management[6]. The developers are the University of Melbourne including the School of Engineering, the Centre for Disaster Management and Public Safety (CDMPS) in collaboration with the Government of Australia, Victoria Justice Department, the Association of Public Safety Communications Officials, Victoria Police, VicRoads, Fire Services Commissioner Victoria, Fire, and Emergency (University of Melbourne, 2014).

2.3.2 Integrated Disaster Information Service System (IDISS)

The Chinese Government has faced various disasters in the last decades, leaving social and economic damages jointly a widespread devastation. To address the identified issues as data-centric, centralized, isolated solutions of the National Disaster Reduction Application System (DRAS) of China, the IDISS proposed a novel Focusing Service Mechanism (FSM) capable of scheduling and allocating for optimum utilization of multiple resources, to dynamically generate collaborative and on-demand disaster information services (Ding, et al., 2015).

IDISS performed service strategies of Visualizing, Wrapping, and Integrating allowing disaster's data management network and focus on the conversion of the existing heterogeneous and distributed disaster-related resources into services (Ding, et al., 2015). The system's main characteristics are the perception or acquisition of disaster data, interconnection and collaboration between the disasters resources, and the intelligence developed in the subsystems of the DRAS.

2.3.3 Andean Information System for Disaster Prevention and Relief (SIAPAD)

For the Andean Region (Bolivia, Colombia, Ecuador, Peru), it is a sophisticated tool for analysed the emergencies known as Andean Information System for Disaster Prevention and Relief (SIAPAD). The implementation of this system requires the cooperation of 37 technical organizations; it also has direct relation with the Hyogo Framework for Action 2005 – 2015 (ISDR, 2007). The system consists in the provision of tools for information discovery and visualisation, allow access to data, and decrease the risk disasters in developing countries, with consequent important social and economic positive impacts (Molina & Bayarri, 2011).

[6] The improving the conditions starts from a system established similar to PCRE, managed by Melbourne police and that has real-time connection with the location of equipment, display field, connection with others, people first responders trained for this system, display drones, among others.

SIAPAD follows the architecture of the concept of SDI (Coleman and McLaughlin, 1998), and applies the requirements identifies by the developers: decentralization (autonomy and independence to information producers), accessibility (access to risk management data for different types of users), and sustainability (sustainable solutions, acceptable cost for the countries) (Molina & Bayarri, 2011). This innovative system allows researching of emergencies and disaster per area in different categories: type of user, task and question related to be solve, phenomenon, and specific topic of the risk management.

In the Colombian case, the entities providers data are the civil defence and risk management department (DPAD before the SNGRD), Geology and geophysics, hydro-meteorology, statistics and planning, and geographic institutes. Despite the participation of those entities, the information collected for the systems shows less information products (see Table 4) in four of the six categories of risk management. Those four elements have been improved by the government but this is not enough for correct implementation of the risk management in the country.

Table 1. Number of information products (published with metadata by information providers) for each risk management category and country. (Molina & Bayarri, 2011)

Risk management categories	Bolivia	Colombia	Ecuador	Peru
Policy instruments	285	260	311	357
Risk identification, evaluation, and monitoring	239	551	484	840
Education and socialization for risk management	75	135	124	256
Reduction of risk factors	80	68	124	213
Preparation for emergency response and relief	63	28	98	271
Recovery, rehabilitation, and reconstruction	82	27	71	89

PCRE identifies SIAPAD as one of the main contributors of information and experience of handle hazards and disaster data for the region. It also allows the identification of the emergency, its characteristics and the scenario planning for the current situation. SIAPAD does not perform these services, but incorporates easily the information of the key stakeholders of the risk management in Colombia with the SNGRD.

2.3.4 GeoSUR

Since 2007, GeoSUR mission was gathering valuable spatial information (locate, view and analyze) of Latin America and the Caribbean for sustainable planning of those regions. The program is led by the Development Bank of Latin America (CAF) and the Pan American Institute of Geography and History and it allows the public access to maps information, aerial photos, and geographic data on issues related to topography, environment and infrastructure. (Development Bank of Latin America (CAF) & Pan American Institute of Geography and History (IPGH), 2007).

There are four tools: geoportal, map service, topographic processing services and regional network services; and six geoservices: map viewers, WMS, WFS, topographic services, assessment of hydropower potential and flood mapping.

2.3.5 SNGRD initiatives

The most notorious actions are the improving of the planning instruments and coordination mechanism for risk management, creation of information systems, and risk management financial mechanism (established in Act 1523, 2012). The SNGRD concentrates in the creation of new alternatives for the correct development of the procedures of the three phases: Risk awareness, Risk reduction and Disaster Management.

The prime initiatives encompass the community participation, mitigation and preparedness, recovery and creation of new technologies for controlling, monitoring, tracing and analysis of hazards alerts. Projects like the "System alerts" with Google and IDEAM is the easily way to access to official information of alterations of the last year, and has a connection through the mobile application *"Yo reporto"* which lets report events by the community (type of emergency, risk level, location, and upload pictures). On the other hand, the national documents as strategies and plans have more monitoring in all the division in comparison with three years before, but it is not completely well done (UNGRD, 2013).

Lastly, the National Risk Management Information System or NRMIS (Chapter 4th of the Act 1543, 2012) is established and available to the community. The access is done by web service that contains an interactive map with the visualisation of the alerts; below, are listed the links and documents for each phase:

- Risk awareness: virtual library, Geoportal (public and private access), dashboard alerts, service administrator, Bivapad (Andean virtual library of prevention and risk management), SIAPAD, and geographic viewer.
- Risk reduction: GRD projects and geographic viewer.
- Disaster management: Emergency response consolidated, emergency formats, emergencies, Single victim registry, and geographic viewer.

The NRMIS provides information of the emergencies and is the key provider and user of the PCRE. The data available can be downloading in Excel format and in other cases the access is just the visualisation. The main difference lies in the possible activities permissible by the first responders and the accessibility to real time information and the open data of the emergencies in different formats. PCRE also allows easily the connection with different scales and the identification of the procedure responsible. The community participation in the SNGRD is by the report on the app "Yo reporto", and in the PCRE involves web applications and reports made by the community by other services known as VGI.

In this direction, a research project is being conducted with the aim of developing a system based on SDI to optimize the risk management within a DDS. In the first step of project implementation the design was tested in the local level in a scenario in Bogota for the Disaster management process.

3. COLOMBIAN EMERGENCY RESPONSE PLATFORM – PCRE

PCRE was built on the conceptual framework (see Figure 4) based on the architecture proposed by the Intelligence Disaster Decision Support System (IDDSS)[7] and the SDI Cookbook (GSDI, 2009). The system aims to optimize existing procedures for risk management under current regulations and requirements of national systems and institutions. The information providing by the platforms for disasters shall integrate more the society and the environmental management plans, evaluate costs associated with emergencies, developing mechanisms for long-term sustainability, and establish responsibilities and use of the system for national agencies.

PCRE can be directing to share knowledge and data of risk management by the integration of multi-crowd information and enables connections between simulation and optimization models used for emergencies as a System of systems. The data is also reported with appropriate details depending on the quality and quantity of the data collected using international standards for sharing information. As a result, the decision-making process in emergencies will become more efficient in comparison with current procedures.

The principal PCRE characteristics are[8]:

- Provides mechanisms of spatial information management standards of the Open Geospatial Consortium (OGC)[9]
- Allows easy access to disaster simulation models
- Integrate information systems, databases and websites and mobile services
- Use of open source frameworks for geospatial, modelling and visualization analysis
- Decision makers are able to perform their own analysis, simulations and scenarios that support emergency management.

The accessibility of the system is for all type of users, including the entities related directly or indirectly to risk management, experts in the use of the terminology of emergencies and the community. The information can be provided by the information systems or databases of any entity. Some of them have created mechanisms to share information as web applications for provide an insight into the data produced. Through this project a common point is creating for allowing data access under security and accessibility restrictions. The visualization will be by maps with georeferenced information (Shapefiles, WFS, WMS), including data collected from real-time emergencies. It is known that the deliverable of the relationship between risk management and GIS

[7] The IDDSS for urban disaster is a platform designed to help emergency services agencies Victoria in efforts to improve management disasters. Aims to facilitate decision-making process in natural catastrophes (flood and bushfire) by providing integrated information to enable analysis and ability to optimize and simulate scenarios. Developers: the University of Melbourne includes the School of Engineering, the Centre for Disaster Management and Public Safety (CDMPS) in collaboration with the Government of Australia, Victoria Justice Department, the Association of Public Safety Communications Officials, Victoria Police, VicRoads, Fire Services Commissioner Victoria, Fire, and Emergency (The University of Melbourne, 2014).

[8] The main characteristics are modified and adapted to the Colombian case from the IDDSS Technical report (The University of Melbourne, 2014)

[9] Open Geospatial Consortium (OGC) brings together public and private organizations worldwide, defines open and interoperable standards within the GIS and the World Wide Web (Open Geospatial Consortium, 1994; Weiser & Zipf, 2007).

is maps generation (Aydinoglu & Yomralioglu, N. R.); however the deliverable of PCRE is the display on maps but allowing the manipulation of information to generate new knowledge.

3.1 Scales and accessibility

The legislation established upon any alteration of the normal situation of the territory, the jurisdiction responsible should face the emergency (General Secretary of the Mayor of Bogota, 2012). This means that if the alteration occurs in a specific area of a municipality, the municipal government should deal with the emergency. Once the emergency exceeds the capacity of municipal government should seek help from neighbouring municipal governments or departmental or national government according to the categorization of the emergency. For this reason, PCRE has fourth different modules based on information scales: local, municipal, departmental and national. The coordination during and emergency will depend on the PCRE scale which will be connected the disaster management committee of the same scale of government.

There are three accesses to the PCRE Web service depending on the user's permissions. Decision makers have access to "Operations Centre" which allows visualizing the five components described above (*Control System*, see section 4 Pilot Test: Local Scale). The second access log information belongs to the field, especially to Drone's pilots. Finally, access to results and progress of the activities undertaken with date and time are in the *Logger*, this in order to have records of activities per user is set.

There is a special access for the community, especially for the development of skills similar to the first responders. However, for the initial conceptual it was not taken into account. This design will be in the second phase of design PCRE.

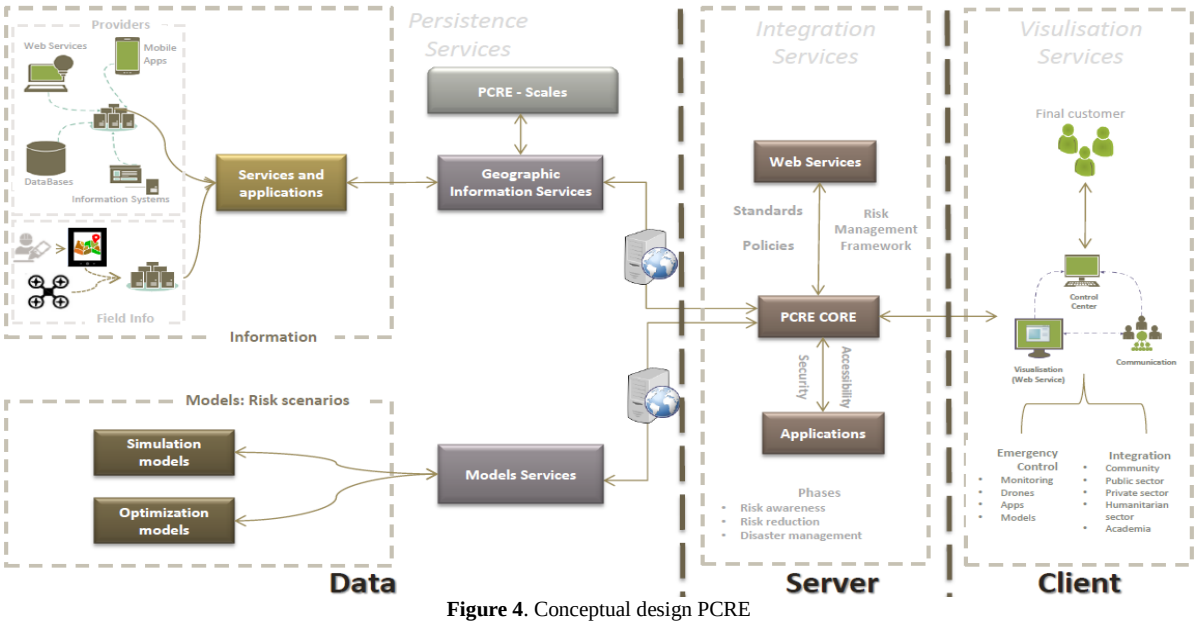


Figure 4. Conceptual design PCRE

3.2 Development of the PCRE

To perform the preliminary design of the PCRE (Figure 5) has raised seven stages: Assessment of the current situation in Colombia; State of art - Analysis of technological developments in best practices; Preliminary conceptual design; Workshops and participation with stakeholders; Development Pilot Testing; Adjust the conceptual design; Connection and system implementation.

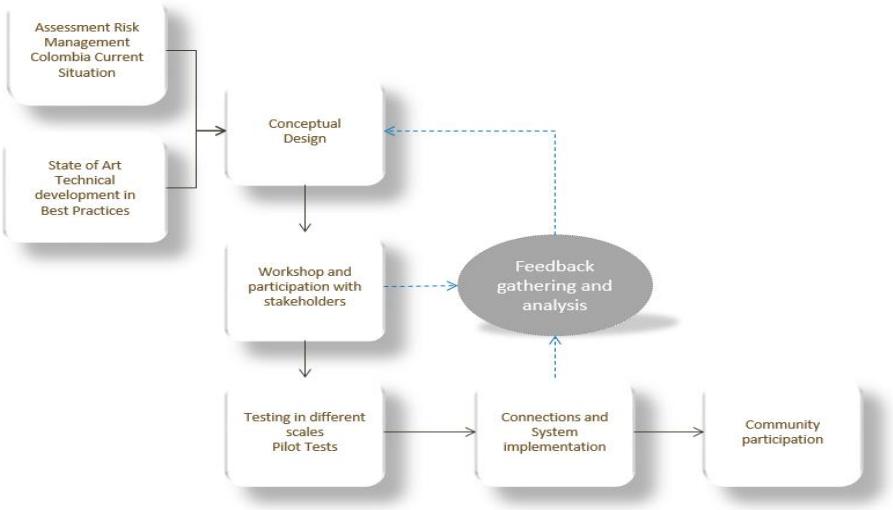


Figure 5. Overall methodology

- *Assessment of the Risk Management current situation in Colombia*: For the successful implementation of the project was necessary the needs analysis of the territory and take into account the parameters identified for the case study. The state of the art for the country contains aspects of existing regulations (laws, procedures, strategies, plans, protocols and / or action plans) and project executed.
- *State of the art (technological developments in best practice):* Analysis of technological tools developed for regions, countries and local territories. Likewise, were analysed the innovations from corporations and international institutions reflected in programs and strategies. This in order to identify the optimal conditions for PCRE. The main territories and corporations analysed are: Americas (including USA, Andean region, Chile, Brazil, and national development), Australia; United Nations, Inter-American Development Bank, World Bank, Global Spatial Data Infrastructure, Rockefeller Foundation, HYOGO Framework for Action 2005 – 2015 and Sendai Framework for Disaster Risk Reduction 2015 -2030.

- *Preliminary Conceptual Design*: Development of conceptual design took into consideration the parameters described in the early stages, plus an innovative component focused on emergency response in Colombia after the identified needs. At this stage were contemplated for designing the overall operation (connection parameters, accessibility, security restrictions, information collection), components (services and applications), scope, implementation (pilot and future directions tests), among others.

- *Workshops and participation with stakeholders:* Integration with national institutions is vital to the project because they grant their experience and knowledge about the responsibilities of each one during

the process of risk management. Also, they are the major information providers and users (such as decision makers during emergencies). Thru this phase, related activities are planned: Identifying needs and expectations; Listing information systems, databases and services per entity; Identifying needs for security and privacy per entity and information; Preliminary division of responsibilities during the emergency response using PCRE. With the development of this phase will be possible to identify weaknesses in the conceptual design to provide feedback and later analysis for previous or later phases

- *Development Pilot Testing:* The demonstration of the PCRE is a major source of motivation for the involvement of the entities in the project. For this, various demonstrations, called "Test Pilot" for different scales (local, municipal, departmental and national) will be made. This in order to link participants to the project and test the changes made from the feedbacks of each workshop and demonstration. The activities planned for the collection and knowledge of information (information systems, databases, web services and existing phones) in each test are: Identification of input and output formats of information; Identification of gaps and areas for improvement through the PCRE.

- *Adjust the conceptual design:* From the *Feedback gathering and analysis*, areas for improvement and incorporate into the PCRE will be identified. These issues arise from the entities and the community with access to project through project presentations, workshops and progress reports, which can be accessed on the website of the project.

- *Connection and system implementation:* Entities interested in participating in the project should link their data and systems own information via the connection parameters established for PCRE. If each one develops new services that may be an important point in the process of risk management, these can be linked and if necessary will have experience in the development of connection services provided by PCRE developers (University of Los Andes).
  There have established training sessions for the new users, primarily the decision makers since they have security permissions for develop specific analysis during emergencies. For the population, components or modules with easy access and user assistance applications will be made.

It is noteworthy that as an innovative technology may not be detailed standards for its operation. This is one of the main challenges of the project, whereby it is remarkable the participation of the Ministry of Information Technologies and Communications (MinTIC), especially with the direction of Standards and IT Architecture and direction Security and Privacy TI.

3.3 Visualization

The visualization platform is through a web service that contains access restrictions depending on the type of user. There are two types of views on the web service: the first has the core to decision makers and organizations participating in the response phase; the second one will be for the population, which is based on effective and efficient communication and interaction between them during an emergency (Figure 6).
For the first view, it is established the monitoring and control of the basic information and real data of emergencies. The visualization for decision makers should have split into distinct components:

- Progress Report: Allows know the progress of the emergency and disseminate the activities undertaken. It is the core of decision-making, where emergency information (location, type, image and description) is received and the process developed by the participants were evaluated.
- *Location of equipment and information display:* The georeferenced information of entities and associated data to the emergency is displayed on an interactive map where is possible to make previous analysis to use for optimized decision making analysis.

- *Field emergency Status:* Display the video of the emergency provided by UAV technology. It contains a list of assets drones, location and pilot. Initially, the projects developers conducted the flights during emergencies.

- *Model connections:* entraining component list of models and parameters associated with each. It also enables access and description of simulation and optimization models used for emergencies. The parameters required by the models may be obtained from the PCRE.

- *Risk scenario:* The simulations of events can be made by users for optimize decision-making and analyses the possible consequences of an emergency.

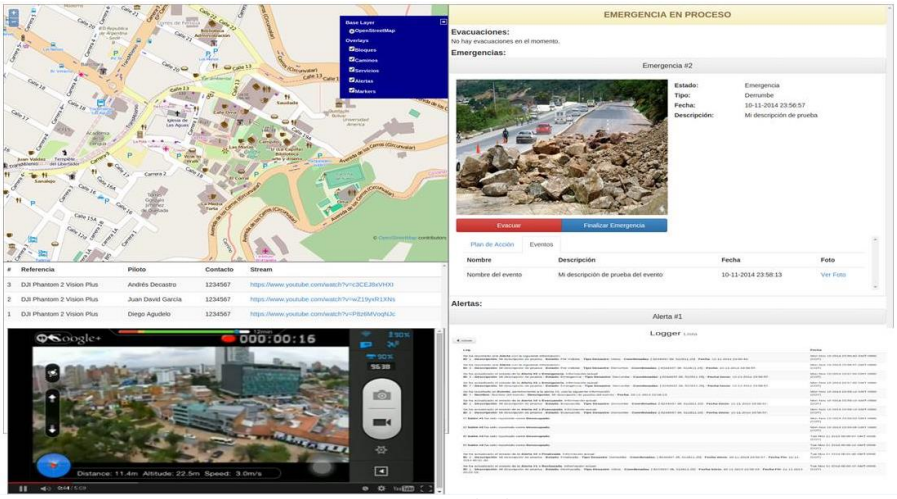


Figure 6. Visualisation for first responders

For the second vision (community), the information provided will be easily accessible considering the possibility of not driving in the same lexicon to risks. This display contains an interactive map that displays the progress of the emergency and the relevant information, risk areas, type of emergency, progress, images, videos, etc. The display of the emergency status depends on the permission granted by decision makers.

3.4 Architectural Design

The most important input of PCRE is information; the development must be capable of receiving and delivering agile and dynamically data through mechanisms that facilitate these tasks. To achieve this goal the system is based, in its central part *"Integration service"*, which is able to

access the different information sources independently, safely and in real time. As a sample of the information required for the PCRE, the following table illustrates the services and interfaces used in the Integrated Disaster Information Service System (IDISS).

Table 2. Services and interfaces used in the IDISS. Source: (Ding, et al., 2015)

Service	Type	Specification	Description
Sensor	Sensor service	OGC Sensor Observation Service (SOS) OGC Catalog Service for Web (CSW) OGC Web Map Service OGC Web Processing Service (WPS)	This offers the functionality to search and provide all observation data cataloged of the study areas and provides a web service interface that allows querying observations, sensor metadata, and representations of observed features.
Map	Portrayal service	OGC Web Map Service SuperMap: Map Representational State Transfer (REST) SuperMap Web Map Tile Service (WMTS)	This provides the user with certain 2D maps of datasets over customized areas.
Data	Data service	OGC Catalog Service for Web (CSW) SuperMap: Data Representational State Transfer (REST) OGC Web Feature Service (WFS) OGC Web Coverage Server	This provides geospatial data management service interface that allows users to modify, delete, add, discover, access, and download process of geospatial data, including raster and vector data.
Data processing	Processing service	OGC Web Processing Service (WPS)	This provides typical GIS and RS operations and functions, including image processing, data conversion, coordinate transformation, and so on.
Analysis	Analysis service	SuperMap: Spatial Analysis REST Service SuperMap: Location REST Service	This provides spatial analysis functions, including raster computations, topological operations, interpolation, and so on.

Current methods of decision making occur rudimentary in certain elements due to the inappropriate usage of data to satisfy the needs identified of the risk management. Through the use of different technologies designed can be facilitating and streamlining current processes to provide effective support for decision-making. Recent developments in the Service-Oriented architectures (SOA), allows the virtualization and the migration of existing resources from dedicated desktop systems to a holistic open-architecture service system (Crawford, Bate, Cherbakov, Holley, & Tsocanos, 2005). To address this scenario the PCRE, it must provide elements or features to improve the current situation. These elements are: *Integration and publication of information*, provide detailed information on the current situation to a specific event, either through information systems or file transfer with georeferenced information, among others; *Public and/or private notification*, allow alerting about the different types of events supporting by the platform regardless of the user. (E.g. use of mobile applications); *Analysis and simulation*, let prevent or respond to disaster events; *Mechanisms developers of new technologies*, new applications and integration with the platform

easily and quickly (APIS); and *Visualization tools in-situ*, allow the transfer of images in real time (Zhishan, Run, Yanjiang, & Xiaoling, 2012).

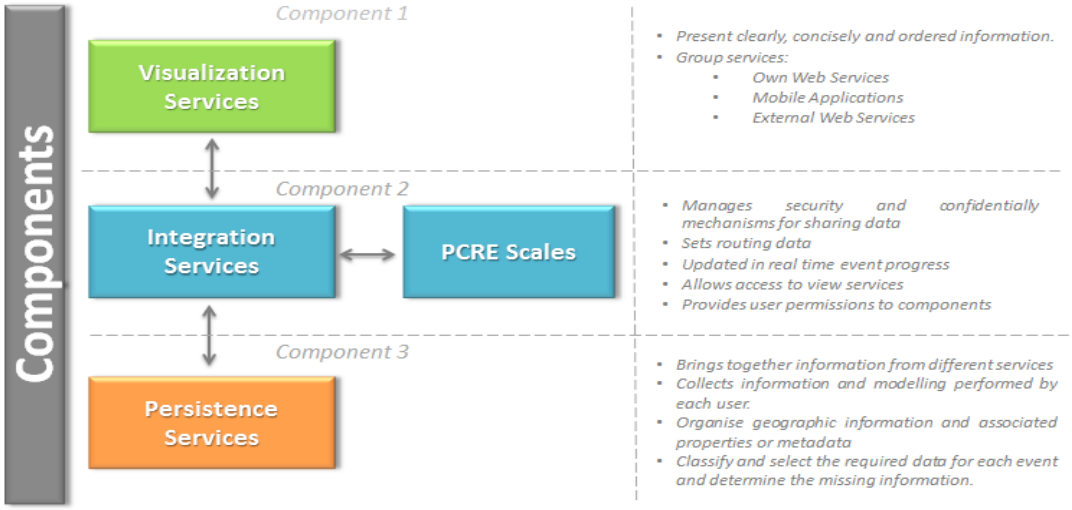


Figure 7. Basic Architecture Design

The PCRE is composed of three oriented components services (see Figure 7) where it should not necessarily be an implementation per component. The development incorporates the processes of risk management (Risk awareness, Risk reduction and Disaster management) and the protocols and/or action plans related to each. These components are: visualization services, integration services and persistence services. Jointly, another fourth component references the integration to others PCRE scales.

- *Integration services:* Main component of the architecture based, through this component travel information from official or unofficial (as it is citizenship) entities. The information is able to obtain periodically or upon request.

- *Persistence services:* Once the platform get the information, the integration component uses the services provided by the component *"Persistence Services"* for storage in databases of the platform to be processed or sold later. It has established the physical existence of these databases in some entities exploring the possibility of access to information were to present a major event that inhibits internet connection networks.

- *Visualisation Services:* play a significant role as having high amount of information, it must be presented clearly, concisely and ordered to decision makers for optimize their work. That is why the view services must be able to provide information that is stored in different formats; among these are the Shape, WFS, WMS, KML, CSV, GML, GeoJSON. Between the services there are three sub-classifications of groups of services (See Table 2).

It is important to have a connection with other platforms because exists a possibility that a territory does not have the capacity to cope an emergency or in the case of the presence of an event that relates several territories (among municipalities or departments). Through these connections can be established national network for disaster management. The connection of the platforms is done through integration services.

3.5 Services

The system has seven main analysis services, some based on the Australian Disaster Management Platform (ADMP)[10], with modifications for the case study (See Table 3).

Table 3. Visualisation services

Own Web Services	Mobile Applications	External Web Services
Developments in terms of risk management from the current participant's projects. One of the main service is the data visualisation, allowing SNGRD stakeholders participation and the identifications of determinants factors for performing activities of disaster management.	Different mechanisms of communication between entities and population before event's reporting, identidication of safe areas, inter alia. VGI from social networks belong to this category.	Entities' systems that have the ability to obtein information or developed models related to risk management. Examples includes the national or territorial mapping services, open-source software models that allows simulation for disasters (floods, bush fires, earthquakes, inter alia); economic models associated to an events.

Table 4. PCRE services

Service	Description
Data Acquisition and Fusion	Management of multi-crowd information sources (aggregation and merge). The standardization of information is a key point for optimizing the analysis and assessment of the data, allowing identify data weaknesses. Sources: different web services that allow information and databases of different institutions. *Many improvements are developed in specifications of geographic information by the Colombian Spatial Data Infrastructure (ICDE).*
Optimisation and Decision Support	Enhances the cognitive abilities of decision makers and responders. Gives a holistic view of disaster integrating strategic, tactical, and operational response and recovery. With the use of scenarios of events and each analysis the abilities can be improved.
Simulation and Forecasting	Provides visibility of potential future scenarios, achieving compromises between speed, accuracy and precision. Also, can be assessing the readiness of systems to a disaster and identify areas for improvement.
Visualisation and Interaction	Provide unprecedented situational awareness to decision makers, responders and the public about the evolution of an emergency, the response and the decision processes. Visualization and interaction is done through web services, taking into account relevant information for each actor.
Detecting and Monitoring	Collects information and monitors situation in the field. Taking information and display it in real time using different technologies (mobile applications, UAV technology, among others).
Behavioural Modelling	Build understanding of how communities, first responders and decision makers react in emergencies situations to inform optimization algorithms. This is one of the key points of the PCRE proper functioning: it is necessary to analyse the emergency response in the different cases or national scales.
Infrastructure and Geospatial Modelling	Merge the facilities of the country in an integrated set of maps. This service will actively participate the Agustin Codazzi Geographic Institute (IGAC), responsible for producing the official map and basic mapping of Colombia, develop the national cadastre of real property, inventory of soil characteristics, advance geographical research to support the territorial development, train and educate professionals in geographic information technologies and coordinate the Colombian Spatial Data Infrastructure (ICDE). (Instituto Geográfico Agustin Codazzi) Data required include basic information - electrical and transportation infrastructure networks, land (forests /rivers), and cities (including buildings and occupancies), population- and risk information: natural hazards, vulnerability.

[10] ADMP is an innovative, integrated, open standards based whole-systems disaster-management platform developed by the University of Melbourne and IBM. Enable the actors involved in the planning for, responses to and the recovery from multi-hazard disasters including communities to make swift, effective decisions, based on comprehensive, accurate, real-time information (Centre for Disaster Management and Public Safety, 2014).

3.6 Expected results

PCRE will allow the easily emergency's information management, thus optimizing the processes of disaster management improving development and social aspects of the country. Besides, allowing improve conditions in the presence of high magnitude disaster. With the accessibility of SNGRD members including the community, achieve better, efficiently and effectively managing resources (economic, financial, social, technological and informational).

In addition, will be established a better communication mechanisms, analysing future projects to improve risk management and allowing the joint participation of different entities. The data integration provided by the entities will be under conditions of strict privacy and use for risk management and standards for become the basis for improving information sharing mechanisms at the national level. The identification of areas for improvement in the stages of risk awareness, risk reduction and disaster management will be one of the great contributions of the project. The information and knowledge will enable timely for make changes in each process including the division of the responsibilities for each entity.

3.6.1 Implementation process

After the elaboration of the *Conceptual Design*, the assessment of it in real cases needs to be done. For this, the realizations of test for the different scale levels called *Pilot Test* are implemented and include feedback for the users, experts and community. The feedbacks allow improving the performance of the PCRE in the needs of the risk management.

The integration of current researchers developed by the entities and developers of the project is a key step for the model connections. This lets determine which standards are for data sharing and information required by the simulation models depending on the scale. As a result, the creation of knowledge and identification of point to be improved for getting resilience are doing.

4. Pilot Test: Local scale

The development of the PCRE was initiated in 2013 and presented to the organizations at 2014 in a local scale scenario. The presentation called "Test Pilot" aims the verification of the PCRE operation in a local scenario and the collection of comments provided by the main users of the system (SNGRD members). This first version was performed by a simulation of an emergency and evacuation at the University of Los Andes and includes the integration of the web services of the local study, models developed by the team and the data collection all in real time.

4.1 Methodology

The process for the simulation was realized in two phases: Emergency Plan Institutional Analysis; and Connection of institutions applications and preliminary designs of applications and models. All national institutions have an Emergency Plan (EP) that includes the analysis of disaster risk in the coverage of their service area. The University of Los Andes has several EP's: one at a general level

(institutional) and others with more detail per building. For the case study, the General Emergency Plan (GEP) and a building EP were analysed. The GEP analyse risks associated with all the buildings of the institution and physical condition of structures; identifies and analyse the resources including human, material and technical; indicates the meeting points; and introduces to the Emergency Care System Emergency (ECS) including their functions, objectives, contacts and resources.

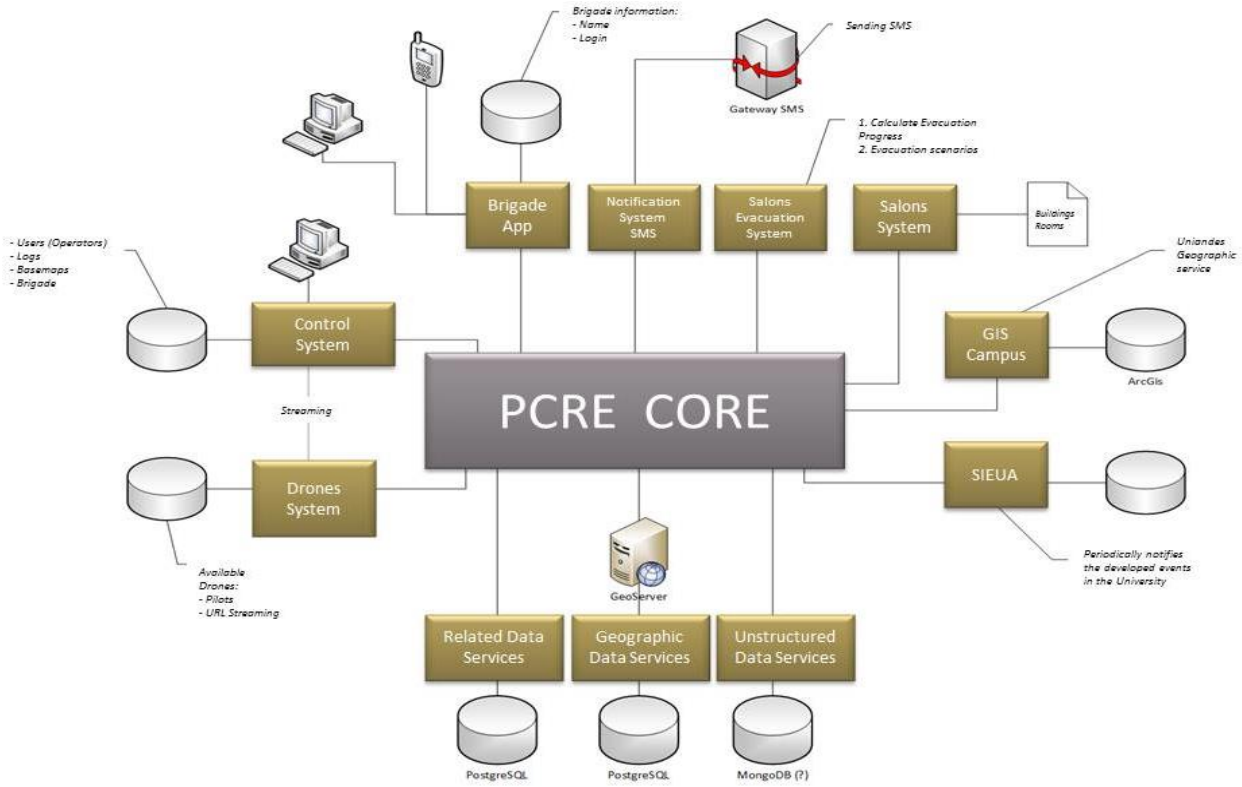


Figure 8. Test Pilot Conceptual Model

In the first phase two activities are performed: Identification of existing web services and technology design for the evacuation of buildings. The University has two geographic information services that allow access to data required for decision-making: *SIG Campus* a geographic data service with the campus infrastructure developed in the ArcGIS software; and *UA Events System (SIEUA)* service that contains the periodic notification of events develop in college. On campus it is not possible the access to living population information in particular areas due to the services division within the institution.

Six applications for emergency data collection took place based on the needs identified by the analysis of the EP's and interviews with first responders:

- *Control System (preliminary version):* System responsible for orchestrating the flow of information to facilitate decision making in emergencies.
- *Brigade App:* Mobile Application that allows notifies alert events and tracks these in evacuation case.
- *Notification System:* System (Mock) that enables decision makers to perform early warning through text messages.
- *Salons Evacuation System:* system responsible for maintaining the state of an evacuation.
- *Salons System:* A system allowing consults information of a building evacuation.
- *Drones System (UAV technology):* System that lets watches the emergency status in real time and through the camera of a drone.

For the second phase, the development of the design of the implementation of technologies proposed for evacuations from buildings and existing systems at the University of Los Andes to the mock evacuation of a building was done. The connection made incorporating the three components mentioned in the architectural design of PCRE. The categorization of the services depends on the sub-classification of the visualisation services: External Web Services incorporated the SIG Campus and SIEUA; Developed Web Services allow the connection to the PCRE by Internet via, includes the *Control System* and *Drones System*. And Mobile Applications including the Streaming of drones and visualization Control System; Mobile applications: applications incorporate the *Brigade App*, *Notification System, Salons Evacuation System*, and *Salons System*.

The demonstration of the pilot had two stages: first tried the context and explanation of PCRE, including the needs explanation of official studies and activities that support it; the second was the real-time demonstration of the use of the control centre and other services during an emergency.

4.2 Participating organizations

The risk management has a holistic component that illustrates the need for participation of actors from different areas and sectors. Organizations of public, private and social character make part of the PCRE are presented in Table 6.

Table 6. PCRE organizations participants

Organization	Sector	Responsibilities	Provides
Colombian Association of Unmanned Aerial Vehicle (ART)	Private	Framework for the development of technology remotely manned aerial vehicle	Images, point clouds, among others, in high resolution
Colombian Society of Surveyors	Private	Supports and promotes the lawful exercise of surveyors in the country guaranteeing the correct order to monitor compliance professionals	Guideines for new technologies in the adquisition of information on the field
District Institute of Risk Management and Climate Change (IDIGER)	Public	Coordinates the District System Risk Management and Climate Change in Bogota and Information System for Risk Management and Climate Change (SIRE). Manages, coordinates and performs actions in the processes of risk management including risk awareness, risk reduction and emergency management, calamity and/or disaster. (IDIGER, 2014)	Experience in emergencies, mapping services, advice, realtime information
Esri Colombia	Private	Distributors of the ArcGIS platform; Implements business solutions with geographic information. (ESRI Colombia)	Supports with experience in technology development and optimization of simulation models and optimization of events
Geographic Institute Agustin Codazzi (IGAC)	Public	- Produces the official map and basic mapping Colombia; Elaborates national register of real property; Makes an inventory of soil characteristics; and coordinates the Colombian Spatial Data Infrastructure (ICDE)	Maps, cadastral and soil data, and parameters of participarion with the ICDE
Government of Cundinamarca - Special Administrative Unit for Disaster Risk Management of Cundinamarca	Public	- Manager and developer of integrated development (provide services developing plans and programs, coordination, protection, administrative, technical and financial) (Government of Cundinamarca) - The Special Administrative Unit guides and coordinates management of entities from the Departmental System for Disaster Risk Management.	Information on population, geographic, equipment, projects, and other relevant risk management; Threats, risks, vulnerabilities, organizations and developed actions for risk management; realtime information
Ingeniar	Private	Business consulting approach to issues of construction and structural analysis	Risk management experience, data and studies of hazards assessment; access to CAPRA
Institute of Hydrology, Metereorology and Environmental Studies of Colombia (IDEAM)	Public	Responsible for the management of scientific, hydrological, meteorological and everything related to the environment in Colombia.(IDEAM, 2012)	Models (flood, bushfire, climate change); Hydrological and metereological data; environmental studies; realtime information and forecasts
Ministry of Information Technologies and Communications (MinTIC)	Public	Designs, adopts and promotes policies, plans, programs and projects in the sector of Information Technology and Communications; Implements facilitate public access to Information Technology and Communications and its benefits. (MinTic, 2014)	Monitoring and safety advice; management of public information; PCRE legal framework for the proposal and connection with other secure systems
Procalculo	Private	Organization that provides services in geospatial and associated technologies	Satellite imagery, sensors, simulation and topography
National Unity for Disaster Risk Management (UNGRD)	Public	Directs and coordinates Disaster Risk Management in Colombia, strengthening the capacities of public, private, community organizations and society in general, in order to contribute to improving the quality of life and sustainable development; Coordinates the National System for Disaster Prevention and Response - SNPAD (UNRD, 2014)	Policies, strategies, plans, programs, projects and procedures of disaster risk management; Databases and experience in emergencies; realtime information
Red Cross - Colombia	Global Organization	Coordinates Emergency First Response; prevents and relieves the normal situation changes (Red Cross Colombia, 2014)	Data of emergencies, entities location, previous studies, realtime information
United Nations Development Programme- Colombia (PNUD)	Global Organization	PNUD advocating for change and connecting countries to knowledge, experience and resources to help people build a better life. (United Nations Development Programme in Colombia, 2014)	Advice based on experiences in the country about decreased risk in areas such as the Caribbean
United Nations Office for the Coordination of Humanitarian Affairs (OCHA)	Global Organization	Conducts coordination, information, humanitarian financing, advocacy and policy support. (OCHA, 2014)	Map information of natural events and affected, realtime information
Universidad de los Andes	Academia	Developer and principal coordinator of the PCRE	PCRE Conceptual design, Core, and management
Universidad de Melbourne	Academia	Principal International assessor	Experience in the design and implementation of the IDDSS and risk management actions
World Bank	Global Organization	Source of financial and technical assistance to developing countries around the world.	Emergency data, studies, risk management experience

4.3 Surveys – Stakeholders perspective

The outcomes of the presentation were the growth of the network of participants and the change of the project perception (from an idea to a reality). To analyse this perspective shift a survey was performed for the assessment of six parameters: Prior knowledge of the project; Responsibilities in the Risk Management of the entity representing; Opinion regarding the project according to the Test Pilot presentation; Participation of the respondent or respective institution in the project; expected aspects of PCRE; and recommendations and areas for improvement.

During the Test Pilot, a participatory session was held to discuss the needs of risk management in Colombia from the perspective of every individual. As a result, the risk management and the project

knowledge was analysed. For the analysis of the other five parameters, the answers provided by the survey were used and compiled (see Table 5).

Table 5. Survey answers

Parameters	Conclusion
1. Responsibilities in the Risk Management of the entity representing	There are different responsibilities of the participants based on the mission and vision of the organizations. Some of the responsibilities are: control and monitoring, management and promotion, coordination, information and technological infrastructure providers, humanitarian response, among others.
2. Opinion regarding the project according to the *Test Pilot* presentation	- Good initiative to establish technologies needed to risk management - Allows citizen interaction, rarely applied - Innovative strategy in emergency response - Should expand the application area - Requires strengthen the link with other information-generating institutions
3. Participation of the respondent or respective institution in the project	There is an interest of the participants to participate with the resources of entities (data, software training, equipment, current information systems, network, institutionality).
4. Expected aspects of PCRE	- Incorporate more environmental management plans and Regional Corporations - Analyze how to involve more to society - Evaluation costs - Clarify the chain's management and will use every entity - Mechanisms for long-term sustainability - Involving more international experiences
5. Recommendations and areas for improvement	In general terms, an interest to participate in the development of PCRE and there is contribution of ideas to improve communications between institutions and the community is presented. It will incorporate: - Policy Management Technologies - Greater coordination with the Colombian Spatial Data Infrastructure (ICDE) - Implementation of protocols for risk management (SNGRD)

The perceptions of respondents describes that the project appears feasible and necessary. This represents one of the project's goals: to involve all national entities categorized as public, private and community. The entities also concluded that areas for enhancement are related to the integration of entities to improve procedures in the field, generating entities multidisciplinary projects, knowledge of existing information, training of current tools for risk management, development of mechanisms to share information between entities, community involvement, program development in the short and medium term, integration of educational and humanitarian sector in risk management, and development of new technologies that meet the needs arising.

The pilot test is a valuable tool for recognize and evaluate the conceptual design of the PCRE. As one of the main inputs for the identification of the key factor to improve, it also allows the assessment of the adjustment mentioned by the stakeholders. On the other hand, it is a source for generation of connection between the different scales of the disaster management and determines which factors disturbs the implementation process and provides tools for research and analysis. Stakeholders also can identify potential enlargements for sustainable development and improvements on the Land Administration System (LAS).

5. FUTURE DIRECTIONS AND CONCLUSIONS

The current emphasis of the risk management is the reduction of the disasters, it should be the reduction of the risk promoting the sustainable development (Paudyal, McDougall, & Apan, 2013; Sutanta, Rajabifard, & Bishop, 2009). The transition will be made by the analysis of the current situation (needs, risk scenarios, threats, vulnerability, land use, inter alia) and the procedure awareness using the existing protocols. PCRE allows the identification on changing factors with the participation of the entities involve with the sustainable development and risk management. A support for the long-term sustainability will be obtained as maintenance checks and framed projects and programs established continuity by the incorporation of the risk management and LAS into development plans at the different levels in the long-term and short-term.

The conceptual design developed comprehends the issues of the risk management identified by the investigation and creates models that reveal the potential risks, improve prevention by reducing effects, optimizes processes as risk reduction, and ripen the risk management networking in different scales. In Colombia, this technological system of systems provides a challenging answer to the lack of information, systems mismatching, limited collaboration and coordination between political and administrative institutions. By improving these aspects, it is possible to identify faster where resources must be invested without wasting on existing or unnecessary data.

PCRE as an innovative system differs with the best practices, mainly on the process of feedback, collecting data, tests pilots, analysis and implementation. As a goal to optimize national resources the investigation started on the identification of the main issues and made a comparison with the world best practices as IDDSS, IDISS, GeoSUR, SIAPAD, ICDE, among other, and identifies which good factors can be adapted to the Colombian case. Hereafter, the collecting data and test pilots information are collected in real-time and the analysis can be done by scenarios produced by different users or during any emergencies. At last but not least, the implementation incorporates the participation of the private, public and communal sectors to identify mutual interest and solve troubles between agencies.

Future researches are in the areas of preparedness, mitigation and recovery. The initial focus of the PCRE is the response stage; some activities are related to monitoring and emergency management, data in real time during the event, short-term updates information regarding listings and location of equipment entities providing answers care services.

With the development of the PCRE parallel projects should be created among the participants, in order to improve all phases of risk management, not just disaster management. It is clear that work only on emergency response will not completely solve the problems of risk management, but whether it will be one of the points to improve the stages of risk knowledge and risk reduction.

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