Designing a Spatial Planning Support System for rapid building damage survey after an earthquake: The case of Bogotá D.C., Colombia

By

DIANA MARIA CONTRERAS MOJICA

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Thesis Assessment Board

Chair: Prof. Dr. V. G. Jetten
External examiner: Ing. K.M. van Zuilekom (University of Twente, UT)
First supervisor: Dr. J. Flacke.
Second supervisor: Dr. C.J. Van Westen.

ITC

INTERNATIONAL INSTITUTE FOR GEO-INFORMATION SCIENCE AND EARTH OBSERVATION
ENSCHEDE, THE NETHERLANDS

Abstract

Ten years ago, in January 1999, an earthquake with a magnitude of 6.2 on the Richter scale and with a depth of 10 km had shaken an estimated area of 1.360 square km in the *Eje Cafetero, Tolima* and *Valle del Cauca* departments in Colombia. Another, strong aftershock of magnitude 5.8 on Richter scale was registered, followed by others with reducing intensity sometimes producing more damage than the first tremor. Eventually, there were 985 casualties in addition to the 4.517 injuries in a period of 3 days.

It was the first time that a building damage survey was carried out in Colombia, in spite that it was an important step and seen as a major improvement from previous disasters in Colombia, some logistic problems were witnessed. These included houses being visited twice or more because of errors in the allocation of the inspectors; delays to have the information collected, due to the lack of trained people and people to type the information, besides absence of standard procedure criteria to assess the damage in the buildings, etc.

Bogotá D.C. (Colombia), is located on a medium hazard seismic zone, and it has not experienced any strong earthquake since 1928. Taking this into account, the Major has allocated funds in seismic hazard research, loss estimation scenarios and preparedness. Taking into account the risk condition, the data available and the preparedness level, the importance to design a *Spatial Planning Support System-SPSS* to support the building damage survey after an earthquake became visible and evident.

The model in the present research is built on by three sub-models aiming to estimate the number of trained people required, their allocation, the ways to manage and map the information before, during and after an earthquake. The model assumes that the inspection area is the residential area in a pre-defined range of damage, and according to this output the model allows to estimate the number of parcels to inspect for every seismic scenario. The combination of the number of parcels to inspect, the inspections times per parcel, the operational times and the control ranges will be addressed by the first model. To allocate the trained people, five methods with different levels of accuracy in their results were applied: *Average number of parcels or blocks, Euclidean allocation, multiple-ring-buffer, network analysis (service area), and route allocation*. All the information about trained people and zone allocation, besides all the information required to respond in an emergency must be collected, updated and shared in order to have indicators in the right time to all the activities that imply the disaster management.

The results show wide ranges of values that can be utilized in the preparedness or in the response phase according to the budget and the availability of trained people. The allocation methods can be used according to the data that every city has, but the highest level of accuracy come from the *route allocation* method. The data must be available, updated and accessible to all the entities involved in the emergency response task, before, during and after the earthquake, due to these reasons the research recommends the use and implementation of a *Spatial Data Infrastructure - SDI* to manage the information.

Key words: Earthquake, building damage survey, GIS, spatial planning support systems , service area allocation, inspection route and Spatial Data Infrastructure - SDI.

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TO MY DADDY
LUIS EDUARDO CONTRERAS ENCISO
(R.I.P)
Because sometimes the sadness is deeper than the tears…

Table of contents

1. INTRODUCTION 15

1.1. BACKGROUND 15
1.2. JUSTIFICATION 17
1.3. RESEARCH PROBLEM 18
1.4. RESEARCH OBJECTIVES 20
1.4.1. Main objective 20
1.4.2. Sub-objectives 20
1.5. RESEARCH QUESTIONS 21
1.5.1. Sub-objective 1: Estimation of the number of trained people required 21
1.5.2. Sub-objective 2: Allocation of trained people to service areas 21
1.5.3. Sub-objective 3: Development of Information management model 21
1.6. CONCEPTUAL FRAMEWORK 21
1.7. RESEARCH METHODOLOGY 24

2. LITERATURE REVIEW 26

2.1. ASSESSMENT OF THE HAZARD, VULNERABILITY AND RISK 26
2.2. ASSESSMENT OF THE DAMAGE AFTER AN EARTHQUAKE 27
2.2.1. American methodology 28
2.2.2. Mexican methodology 28
2.2.3. Japanese methodology 29
2.2.4. Colombian methodologies 29
2.3. PLANNING AND SCENARIO DEVELOPMENT 31
2.4. RESOURCE ALLOCATION FOR EMERGENCY RESPONSE 34
2.4.1. General models 34
2.4.2. Approximate solutions 37
2.4.3. Stochastic/fuzzy models 39
2.4.4. Statistical model 41
2.5. INFORMATION MANAGEMENT 42
2.5.1. Data capture 45
2.5.2. Data transmission and analysis 46

3. METHODOLOGY 51

3.1. SUB-OBJECTIVE 1: ESTIMATION OF THE NUMBER OF TRAINED PEOPLE REQUIRED 51
3.2. SUB-OBJECTIVE 2: ALLOCATION OF TRAINED PEOPLE TO SERVICE AREAS 57
3.3. SUB-OBJECTIVE 3: DEVELOPMENT OF INFORMATION MANAGEMENT MODEL 61

4. RESULTS 65

4.1. CASE STUDY AREA 65
4.2. FIELDWORK RESULTS 67
4.2.1. Surveys 67
4.2.2. Interviews 69
4.2.3. Secondary data 69
4.3. SUB-OBJECTIVE 1: ESTIMATION OF THE NUMBER OF TRAINED PEOPLE REQUIRED 70
4.4. SUB-OBJECTIVE 2: ALLOCATION OF TRAINED PEOPLE TO SERVICE AREAS 73
4.5. SUB-OBJECTIVE 3: INFORMATION MANAGEMENT MODEL 92

5. DISCUSSION, CONCLUSIONS & RECOMMENDATIONS.. 96

5.1. FIELDWORK:.. 96
5.2. SUB-OBJECTIVE 1: ESTIMATION OF THE NUMBER OF TRAINED PEOPLE REQUIRED 96
5.3. SUB-OBJECTIVE 2: ALLOCATION OF TRAINED PEOPLE TO SERVICE AREAS 98
5.4. SUB-OBJECTIVE 3: DEVELOPMENT OF INFORMATION MANAGEMENT MODEL 102

GLOSSARY 105

REFERENCES 107

APPENDICES 109

APPENDIX A. ATC-20 RAPID EVALUATION SAFETY ASSESSMENT FORM (AMERICAN METHODOLOGY)... 110

APPENDIX B. RAPID BUILDING DAMAGE SURVEY FORM IN MEXICAN METHODOLOGY .. 111

APPENDIX C. RAPID BUILDING DAMAGE SURVEY FORM IN JAPANESE METHODOLOGY .. 112

APPENDIX D. ALTERNATIVES CONSIDERED BY DANE TO TRANSMIT THE DATA CAPTURED IN THE SURVEYS FOR THE CENSUS 2005 113

APPENDIX E. QUESTIONNAIRE TO TEST AVAILABILITY TO CARRY OUT THE BUILDING DAMAGE SURVEY IN PEOPLE TRAINED IN THE PERIODS 2002 - 2003 AND 2007-2008 114

APPENDIX F. SURVEY RESULTS 116

APPENDIX G. REMARKS ON THE INTERVIEW WITH THE MANAGER OF THE PREPAREDNESS GROUP IN THE EMERGENCY DEPARTMENT OF DPAE 117

APPENDIX H. REMARKS ON THE INTERVIEW WITH THE MANAGER OF THE EMERGENCY RESPONSE GROUP IN THE EMERGENCY DEPARTMENT OF DPAE 118

APPENDIX I. REMARKS ON THE INTERVIEW WITH THE TECHNICAL MANAGER OF THE PROJECT ABOUT DIGITALIZATION OF CADASTRAL CARTOGRAPHY IN IGAC 122

APPENDIX J. REMARKS ON THE INTERVIEW WITH A PUBLIC SERVANT WHO WORKED IN THE CENSUS AND DEMOGRAPHY DEPARTMENT IN DANE 123

APPENDIX K. FIELDWORK REQUIREMENTS AND INFORMATION COLLECTED 124

APPENDIX L. NUMBER OF PEOPLE TO BE TRAINED ACCORDING TO SUB-OBJECTIVE 1 ... 125

APPENDIX M. NUMBER OF TRAINED PEOPLE ACCORDING TO THE INSPECTION TIME BASED ON THE DEGREE OF DAMAGE FOR EVERY SEISMIC SCENARIO (RP)........................... 126

APPENDIX N. COMPARISON OF SCENARIOS ABOUT DAMAGE DEGREE, COLLAPSED AREAS, INJURED AND CASUALTIES 127

APPENDIX O. COMPARISON OF THE APPLICATION OF ALLOCATION METHODS IN EVERY SCENARIO 129

List of figures

Figure 1-1 Conceptual framework 22
Figure 1-2 Research design 25
Figure 2-1 The building blocks in the damage and loss methodology. 27
Figure 2-2 General building damage form in methodology formulated in Bogotá D.C. 30
Figure 2-3 Habitability (safe condition) announcements according to the degree of damage in buildings in Bogotá D.C. 30
Figure 2-4 Passing a highway segment with a damaged point. 35
Figure 2-5 Passing a highway segment with two damaged points. 35
Figure 2-6 Ambulance bases and atoms along the highway 36
Figure 2-7 Power Voronoi diagram logistics districting with barriers. 36
Figure 2-8 Network transformation for the SMDT-MPG problem 38
Figure 2-9 The graphical illustration of the partial optimal solution 38
Figure 2-10 Demand satisfaction (service level) over time. 39
Figure 2-11 Cost over time 40
Figure 2-12 Undirected network with 15 nodes and 19 links. 41
Figure 2-13 Deliveries over time of daily volumes shipped, by commodity groups. 42
Figure 2-14 Procedures in an information system. 43
Figure 2-15 Schematic presentation of SDI conceptual model for disaster response. 44
Figure 2-16 Information value and average survey cost. 45
Figure 2-17 Field surveys for disaster relief using mobile devices. 46
Figure 2-18 Overall picture of a web-based system to facilitate disaster management using a SDI environment. 47
Figure 2-19 NGN layered architecture. 48
Figure 2-20 Three MOBSAT Access Points (one with dedicated air vehicles) configured to provide larger coverage. 49
Figure 2-21 Information flow 49
Figure 3-1 Basic model. 51
Figure 3-2 Sub-objective 1: Model to estimate the number of trained people required 52
Figure 3-3 Sub-model - *Space-parameters* (Stage I). 53
Figure 3-4 Sub-model - *Time-parameters* (Stage II). 54
Figure 3-5 Building Inspection group organizational chart. 56
Figure 3-6 Sub-objective 2: Model to allocate trained people. 57
Figure 3-7 Schematic allocation route according to the inspection time (operational time: 12 hours). 60
Figure 3-8 Sub-model 3: Information management. 62
Figure 4-1 Study area location. 65
Figure 4-2 Location of the trained people who answer the survey. 68
Figure 4-3 Degree of damage in the inspection area in a seismic scenario with a RP 1000 years. 71
Figure 4-4 Residential area in Bogotá D.C. 72
Figure 4-5 Shows in a discriminated way the location of people who answered and who did not answer the survey. 74
Figure 4-6 Inspectors availability according to collapsed area in the seismic scenario RP 1000 years. 75

Figure 4-7 Inspectors availability according to the number of injuries per block in the seismic scenario RP 1000 years. 76
Figure 4-8 Availability according to the number of injuries per block in the seismic scenario RP 1000 years. 77
Figure 4-9 Location of trained people available to carry out the building damage survey. 78
Figure 4-10 Estimation of service areas based on *euclidean allocation method* in the RP 1000 years. 80
Figure 4-11 Estimation of service areas based on *multiple ring buffer* in the RP 1000 years. 82
Figure 4-12 Estimation of service areas based on *network analysis* in the RP 1000 years. 83
Figure 4-13 Inspection time according to the degree of damage in the RP 1000 years. 84
Figure 4-14 Estimation of one service area per day according to the inspection time. 85
Figure 4-15 Estimation of service areas based on the combination of *route allocation* and *buffer analysis* method in the RP 1000 years. 87
Figure 4-16 Comparison of the results applying different methodologies (Euclidean distance, multiple ring buffer, network analysis, route allocation). 88
Figure 4-17 Weights given to carry out the attention priority analysis. 91
Figure 4-18 Attention priority scenarios for Bogotá D.C. 91
Figure 4-19 Attention priority scenarios for the uncovered area in the South-East of Bogotá D.C. 92
Figure 4-20 Visualization of the spatial distribution of the parks compared with the walking-distance-service areas. 93
Figure 4-21 Example of meeting point allocation. 94
Figure 4-22 Flow information model. 95

List of tables

Table 2-1 Number and percentage of retailers covered. 41
Table 3-1 Walking distance in a service area. 59
Table 3-2 Required inspection time per parcel according to the degree of damage. 60
Table 4-1 Seismic scenarios 66
Table 4-2 Characteristic of the survey and sampling. 68
Table 4-3 Estimation of trained people required according to a control range of 9 units per person. ...73
Table 4-4 Inspectors availability according to the seismic and loss scenarios. 75
Table 4-5 Estimation of average number of parcels or blocks to be inspected for a team in one day. ..79
Table 4-6 Percentage of coverage using *euclidean allocation* method in every scenario. 79
Table 4-7 Percentage of coverage using *multiple-ring-buffer* method in every scenario 81
Table 4-8 Percentage of coverage using *network analysis* (service area) method in every scenario. 83
Table 4-9 Percentage of coverage using *route allocation* and *buffer analysis* method. 86
Table 4-10 Factors displayed as layers to carry out the attention priority analysis in Bogotá D.C. 90
Table 4-11 Factors displayed as layers to carry out the priority analysis in the not covered area located at the South-East. 90

Acronyms

AIS	Asociación Colombiana de Ingeniería Sísmica. (Colombian association of seismic engineering).
CTM	Cell transmission model.
DACD	Departamento Administrativo de Catastro Distrital (District department of cadastral administration).
DPAE	Dirección de Prevención y Atención de Emergencias. (District office of emergency prevention and management).
DANE	Departamento Administrativo Nacional de Estadísticas. (National administrative department of statistics).
EMS	Emergency services.
FONADE	Fondo Nacional de Desarrollo. (National fund for the development).
ICS	Incident Command System.
IGAC	Instituto Geográfico Agustín Codazzi. (Agustín Codazzi geographic institute).
INGEOMINAS	Instituto Colombiano de Geología y Minería. (Colombian institute of geology and mining).
LP	Linear-program.
NP	Nondeterministic polynomial.
PDPAE	Plan Distrital de Prevención y Atención de Emergencias. Emergency prevention and attention plan in Bogotá D.C.
PEB	Plan de Emergencias de Bogotá D.C. (Emergency plan of Bogotá D.C.).
POT	Plan de Ordenamiento Territorial. Land Use Plan.
PSS	Planning Support Systems.
RP	Return period o seismic scenario.
SAR	Search And Rescue.
SD	System Dynamics
SDI	Spatial Data Infrastructure.
SMDTS-MPG	Simultaneous mobilization destination, traffic assignment, and departure schedule for multi-priority groups.
ULA	Universidad de Los Andes. (University of the Andes).
UNAM	Universidad Nacional Autónoma de México.
UPES	Unidad de Prevención y Atención de Emergencias. (District office of emergency prevention and management).
UPZ	Unidad de Planeación Zonal. Planning unit zone.

1. Introduction

This chapter introduces the research in seven sections. The first section is the background of the topic. The second presents the justification to the research. The third elaborates on the research problem. The fourth provides the research objectives and the fifth, the respective research questions. The sixth describe the conceptual framework and the seventh displayed the research methodology.

1.1. Background

After a major disaster or emergency, houses, buildings, bridges, transportation systems and lifelines utilities might be destroyed or severely damaged. Some of these elements must be reinforced or demolished in order to guarantee the safety of people, already affected.

Damage assessment is a methodological procedure to determine quantitative and qualitative the effects of the disaster. The main purpose is to advise the state about the activities which make up the reconstruction process.

The initial assessment must be done in five aspects: people, lifelines and utilities, houses and public buildings, economic aspects and the environment. The scope of the damage assessment and needs analysis imply the suitable allocation of search and rescue (SAR) and building inspector groups, locating and removing debris, definition of the optimum access routes for emergency vehicles, transport of injured, dead and unharmed people; allocation of priorities for repairing lifelines utilities and support decisions about demolition or stabilization of elements in damaged areas through the technical assistance coming from the building inspectors.

The present research focuses on the damage assessment of private houses and buildings, because building damage survey after an earthquake is a collective consumption service provided by the state as a way to ensure that all citizens are living or staying in safe places after an earthquake, in the case of aftershocks.

The most recent documented experience about building damage survey was after the Yogyakarta (Indonesia) earthquake. ”Response activities began immediately, and included extensive ground-base mapping by Indonesian entities, as well as activation of the International Charter “Space and Major Disasters”, which led to the rapid production of image based damage maps and other assistance” (Kerle & Widartono, 2007).

As Kerle and Widartono (2007) pointed out that in Yogyakarta the government carried out a rapid damage assessment for 300 public buildings to inspect their safety, followed by an extensive house-to-house mapping campaign. 100 people carried out several ground mapping projects before *rapid building damage survey* was initiated, followed by the detailed. Data entry and processing was still on going for the time that the article was written.

On January 25 of 1999, an earthquake with a magnitude of 7.3 on Righter scale struck the departments located on the West of Colombia: Caldas, Quindío, Risaralda, Tolima and Valle del Cauca. There has been a damage survey in the city of Pereira organized by the major, but because of lacking of previous planning and training of the surveyors, the information collected could not be considered due to the problems in the procedure. The construction of a database is difficult due to not enough people were available to digitize such large amount of information in the short time and sometimes the information has not been written in non understandable way, thus the information collected was lost. Furthermore, the Ministry of development decided to carry out another survey, doubling and dispersing efforts.

In the case study of Bogotá D.C., the District office of emergency prevention and management (DPAE), as the entity in charge of promoting the actions required to reduce the risk produced by natural hazards and man-made unintentional events, has been working on the project about strengthening the response capacity against a big earthquake, since 2003.

The mentioned project includes the Emergency response plan of Bogotá D.C. (PEB), which covers five subjects. One of them, it is the identification and quantification of the possible damage in the level of urban and rural habitat, which includes the building damage survey after the earthquake.

The Colombian association of seismic engineering (AIS) developed a methodology and also a manual in 2002, for inspecting buildings after an earthquake. DPAE has been applying that methodology to train architects, engineers and students in these areas; since that time until 2003, and from 2007 until now. It is important to say that in spite of presence of trained people on building inspection after an earthquake the methodology has not been tested, yet.

On the one hand, prior to an earthquake, a loss estimation study needs to be done in order to estimate the human and economic losses for different possible earthquake scenarios. On the other hand, it is necessary to carry out a post earthquake damage assessment in order to know the actions that must be taken related to locate temporal shelter in the emergency stage and to formulate the restoration and recovery plan, later.

For preparedness purposes, it is necessary to have loss estimation scenarios in order to calculate the number of people that must be trained on the different levels of SAR, building damage survey, first aid, etc. and also for mitigation purposes because the study should investigate where buildings, houses and lifelines facilities require to be strengthened or in the case of lifelines, set out if it is necessary to create another lifelines facility to support in the case of the failure of the main.

In order to have an overview on how different types of earthquakes can affect the city; DPAE contracted to the Universidad de Los Andes (ULA) to undertake *The risk and loss study scenarios after an earthquake in Bogota D.C.*(CEDERI, 2005), which aimed at estimating the following parameters depending on the scenarios analyzed: Number of affected houses (with some degree of damage) and housing seriously affected (with the possible occurrence of a partial or total collapse), people affected by damage to houses, who needs temporary relocation or housing replacement; number of injuries and casualties and their possible location.

1.2. Justification

Authors as Waugh (2000) states that disasters present to the governments challenges and opportunities and one of the opportunities is to be prepared but "planning, evaluation, preparedness, community integration have played minor roles in disaster response and the consequence are serious" (Debarati Guha-Sapir, 1986).

Nevertheless, as many authors remark, there must be a flexible strategy that encourages public awareness of seismic risk, in order to persuade appropriate responses by individuals, families, communities, and government.

As Waugh (2000) mention in public policy terms, disasters create the responsibility to assist people. It is a kind of *war-time* planning if we look at the classification of the planning activities according to the nature of planning goals.

Patricelli, Beakley, Carnevale, Tarabochia and Lubitz (2009) contends that fundamental issues of disaster management are: definition of critical elements, coordination of search and rescue activities and planning after the critical moment, and appropriate allocation of resources based on information from the disaster area.

Rapid building damage survey as a service will be provided at the emergency stage and it must be supplied to all people who own a house under the same conditions, according to the theory of public goods (Samuelson, 1954;Pacione, 2005).

The provision of this service should be allocated according to need for the welfare of society. "Needs are defined in relation to the requirements of an individual but also in relation to the prevailing morals or norms of the society" (Pacione, 2005), which are in this particular case needs in relation to the safety of the individuals and the condition of their houses according to the building code requirements.

This research is focus on the rapid survey, because it is oriented to save lives in short period, avoiding people to continue living in unsafe buildings. But this activity requires to be modeled in order to be effective and efficient, because according to authors as Benini and Conley (2007) "rapid assessment are one of the standard informational tools in humanitarian response and are thought to contribute to rational decision-making".

Pacione (2005) claims that the last decision about the allocation of public resources is a political one, localization optimizing models can play a useful role first by developing different combinations of equity and efficiency, and second by providing a range of "better" solutions to support a case against inefficient or inequitable proposals. The justness of patterns of collective consumption may be measured by comparing the distribution of resources among political or administrative units with some normative criteria, that in this case must be the equity and efficiency.

Nevertheless, other people as president Nyere of Tanzania considers that it is not possible to provide everything for everybody all at once and plans represents the result of a process of choosing which things should be attended at first (Sharifi, 2004).

Humanitarian agencies, like other types of service agencies, seek an internal equilibrium of activities (Niskanen, 1994; Teigland, 2005) - in terms of both scale and scope- that will allow them to regenerate their capacity even if the needs of clients sometimes require deferment or transformation (C. C. B. D. Z. W. Aldo Benini, 2008).

Ali Sharify (2004) pointed out that “planning involves making decisions about how to make the best use of the available resources. Consequently, the quantity and quality of these resources has a very important effect on the process of choosing between different courses of action. On the one hand, the fact that there are almost always limits to the quantity and quality of resources available, is the main reason why planning involves deciding which of a number of desirable courses of action should be given priority. On the other hand, where choices have to be made between alternative courses of action, the availability of resources plays an important part in determining both the ranges of alternatives available and the one which is likely to be most acceptable”.

Rapid building damage survey is a service that must be allocated according to a spatial decision support system based on a model which combines equity and efficiency, taking into account policies which set up priorities. The planning process is an activity of the preparedness phase that must be done because the event could happen in 20 years or tomorrow, and carried out this process under the conditions after an earthquake is not suitable and the risk of losing lives will increase. Planning and feedback are significant ingredients of an effective relief and rehabilitation program (Debarati Guha-Sapir, 1986).

Additionally, as it is known one of the consequences of disasters is the collapse of telecommunications infrastructures and their concomitant unavailability to the people in charge of emergency response (Patricelli et al., 2009); in consequence, it is necessary to design a model to address the problem of ensuring the communication and information flow after the earthquake happen, because “quick reactions based upon incorrect assumptions or incomplete information can lead to inadequate protective measures”(Perry & Lindell, 2003).

1.3. Research problem

Benini & Conley (2007) maintains that disasters pose unforeseen problems and an effective response requires “*administrative flexibility*”(Waugh, 2000). As Aldo Benini (2007) commented information requirements after a disaster are dense and are difficult to meet within useful time frames and with acceptable reliability and accuracy. The authors cast doubt on the quality of rapid assessments, according to them “There is an obvious conflict between speed and completeness, regularly compounded by lack of security and/or access”.

Zlatanova, van Oosteron, & Verbree (2006) declares that post-disaster activities present a variety of demands, such as: Consistent information in any environment; search, analysis and processing of information on the INTERNET and distributed databases; real-time data update; positioning, routing outdoor working teams; and individual and intuitive visualization o different devices to support decision-taking. Also the authors assert that although the potential of GIS tools for urban disaster management, the applications of this system are limited in countries in Africa, Asia and Latin America. The emergency management is usually done on rarely updated paper maps. One of the reasons is that spatial planning and decision support systems (SPSS/SDSS) are not enough familiar to the planners and decision-makers and another reason is that the software application do not fulfill all the expectations from them.

Other authors, as Sharify (2004) stresses that it is important to define planning as a mean of allocating resources, the term resource is used to refer to anything which is considered by those making decisions to be of potential use in achieving a particular objective.

Patricelli et al.(2009) state that GIS has been gaining importance in disaster response activities like analysis of transportation lifelines, resource mapping or identification of high degrees of damages, as it is described in Topping (1995) and Basoz and Kiremidjian (1998). Additionally, emergency response agencies use certain kind of software like SUMA (Pan American Health Organization, 1999), to classify the available resources; however, all these tools are planning tools but they are not decision tools. (Fiedrich F, 2000)

Research about decision support system for resource allocation in emergency response is the most of the times focus on: SAR task to put people out of collapsed buildings, stabilizing work (e.g. dam failures, fire, etc.) and immediate restoration of the transportation lifelines (Fiedrich F, 2000); schedule for the restoration of the transport lifelines(Yan & Shih, 2007); traffic assignment and departure schedule decisions for multiple priority group (the elderly, hospital patients, or nursing home residents, etc.)(Chiu & Zheng, 2007); demand, supplies and vehicle availability (Ozdamar, Ekinci, & Kucukyazici, 2004); vehicle routing problem (VRP) or in pedestrian evacuation and rescue within micro scale urban indoors spaces or areas (Lee, 2007); access to emergency shelters (Melanie, 2004); even, in the logistical domain has been studied guided decisions to deliver relief (food, water, shelter, construction materials, tools, clothing, etc.) to affected communities (C. C. B. D. Z. W. Aldo Benini, 2008).

Nevertheless, none of them has tackled the problem of allocating resources for carry out the building damage survey after an earthquake, in any of its modalities and in which there is a combination of two classes of resources: Human and material. The resources must be ideally distributed with equity which is feasible in the case of the material resources, but it not in the domain of human resources, because they are located according to the lifestyle and it is likely that they are not located in the areas where they will be mostly required. In this case, it is necessary to address the problem between the logistic and the needs factors.

Furthermore, the methodologies developed for building damage survey have been always dealing with techniques and tools to collect information, procedures to carry out the inspection taking into account if it is rapid or detailed, different ways to quantify the damage and set out the safe condition of the building, the content of the forms and announcement, the organizational structures in teams, committees and chiefdoms etc. However, there is no mention about how to take decisions about allocating human and material resources for carrying out the survey, according to different scenarios, parameters and variables; and as it is mentioned in one of the methodologies developed in Colombia, it is difficult to prepare maps, forms and plan the distribution of the teams under the difficult conditions that usually take place after an earthquake.

The communication within the disaster-struck area and with the agencies in charge of emergency management, constitute a critical problem because much of the information is derived from often incomplete communications, which do not show the entire condition of the ground situations and the consequences are operational and tactical errors. This situation beside to the collapse of telecommunications platforms and the congestion caused by the residential in- and outbound traffic, makes the situation more complex. (Patricelli et al., 2009)

Based on the above mentioned argument, it is found that there is a gap between how to estimate the quantify of required resources and the suitable allocation of the available resources. The flow of the information and the technological tools to collect reliable and accurate data in the operational time, according to seismic scenarios and priorities involves also the discussion about the different environments (digital and analogue) and which could be the more suitable according to the constrains related to a post-earthquake situation.

1.4. Research objectives

In order to planning a rapid building damage survey in a proper form, it is necessary to have loss estimation scenarios or at least hazard and vulnerability data, to make the calculation about the number of trained people required, the likely coverage of the city and the efficient way to capture, transmit and present the information.

1.4.1. Main objective

Design a procedure for the planning of a rapid building damage survey after an earthquake and manage the spatial information collected.

1.4.2. Sub-objectives

- To develop a process model to estimate the number of trained people required for making the building damage survey after an earthquake, according to different scenarios (return periods) in the time limit.
- To formulate a process model for the planning process to optimize the allocation of the resources to carry out the survey.
- To design a schematic model of information management between the different levels of the organization.

1.5. Research questions

1.5.1. Sub-objective 1: Estimation of the number of trained people required

- What are the elements that the model consists of?
- Which variables must be taken into account to carry out the estimation?
- How to combine the variables in order to have range of results?

1.5.2. Sub-objective 2: Allocation of trained people to service areas

- What are the parameters that must be taken into account in the methodology development?
- Which are the assumptions and uncertainties that must be considered to formulate the methodology?
- What are the criteria to allocate people?
- Can the model be adjusted to allocate the resources in a real-time after an earthquake?
- What are the indicators of the model application effectiveness?

1.5.3. Sub-objective 3: Development of Information management model

- What kind of data is necessary to manage?
- What are the options to collect the information?
- What is the desired information management procedure before, during and after the earthquake?

1.6. Conceptual framework

The conceptual framework consists of phases and elements, and each one has an identifier in the graphic, which allow looking for the respective explanation.

1. An earthquake is a “sudden motion or trembling that is caused by a release of strain accumulated within or along the edge of Earth’s tectonic plates” (FEMA, 2001).
2. Disaster management involves all the activities aim to measure, evaluate, understand, reduce, predict and control all the effects of the disasters.
3. Disaster management must be supported by a decision and planning support systems as a class of information systems that are based on decision-making and planning processes.
4. The intelligence phase is related to the hazard and vulnerability assessment aim to identify the risk, through the creation of different scenarios as in this case are the seismic scenarios (RP 250, 500, 1000 years).

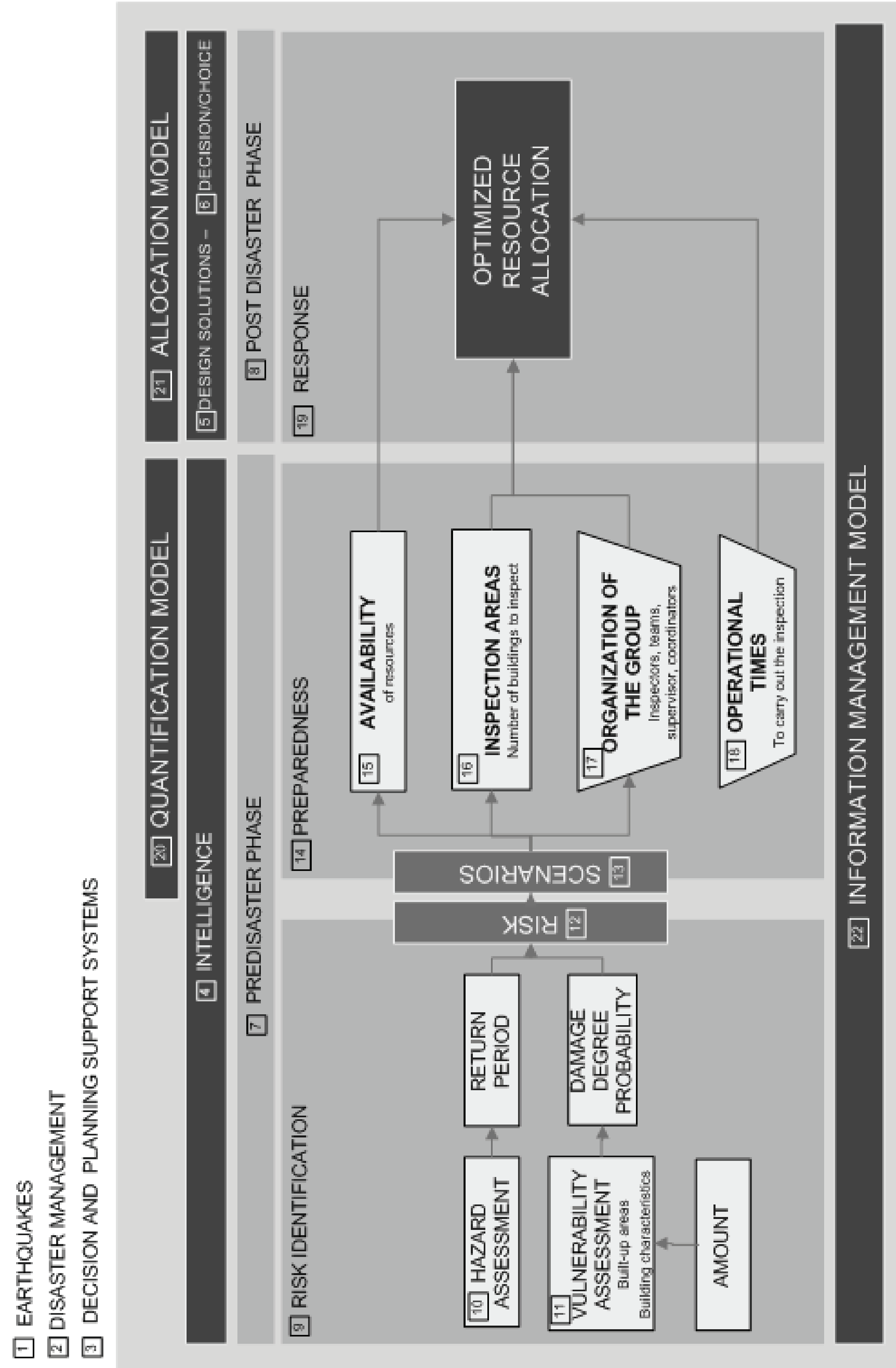


Figure 1-1 Conceptual framework

5. Design solutions, in this step is possible to appreciate different alternatives identified in the intelligence phase and the requirements that every alternative present. Every scenario has different estimations about availability, the large of the inspection area and the number of trained people required.
6. Decision/Choice is the phase when the variables are selected according to the requirements or conditions displayed in every scenario.
7. Disaster management has a pre-disaster phase, which includes risk identification and preparedness.
8. Post-disaster phase involves emergency response task, rehabilitation and/or reconstruction but the last two are not included in the conceptual framework, because they are out of the scope of the present research.
9. Risk identification is the phase made up of hazard, vulnerability and risk assessment.
10. Hazard assessment has three main approaches: Inventory, data integration and modeling.
11. Vulnerability assessment is the evaluation of the impact of the hazards on the elements at risk.
12. The term risk refers to estimated losses from a given hazard to an element at risk, over a specific time period. In this way, the risk assessment or loss estimation is done based on hazard and vulnerability data, to quantify the loss in terms of human lives, building and infrastructure.
13. Scenario is an archetypal description of alternative images of the culture, created from mental maps or models that reflect different perspectives on past, present and future developments (Flacke, 2008). The seismic scenarios are generated according to different seismic source, magnitudes, return periods and peak ground acceleration. Those scenarios combined with vulnerability conditions produce also an equal number of estimation of injuries and casualties. Furthermore, in the case of injured and dead people it is necessary to produce a scenario according to time (day or night) because the location of the people is different.
14. Preparedness "is a dynamic and contingent upon ongoing processes" (Perry & Lindell, 2003) that involve all the activities to train people and to have available all the resources to be ready for a disaster.
15. The availability of the resources depends on their location, the estimated degree of damage and in the case of human resources is also according to the estimation of injuries and casualties.
16. The inspection areas are defined considering the range of percentage of degree of damage that it is assumed to be inspected; because it is not worthy to pretend to inspect all the parcels in the city, when some of them could be totally collapsed and there will not be any structure to check; those areas must be allocated to SAR groups in order that they look for trapped people, which is out of the scope of this research.
17. The organization of the group is in the range of control between five and seven elements per units, as it is prescribed on the Incident Comand System (ICS) manuals; and also is related to the hierarchy in the group, where the basic cell is a team consisting on two inspectors.
18. Operational times establishes the time constrains under the rapid building damage survey must be done (three days), and the research must be define the ranges for the response time, operational time per day and the inspection timer per parcel.
19. Response is referred to the activities to tackle the effects of a disaster, it involves actions to save lives, protect property, and meet basic human needs.

20. Quantification model. The result of the estimation about the availability of the resources, the inspection areas, the organization of the group and the operational times will define a methodology to estimate the number of resources required to carry out a building damage survey after an earthquake.
21. The model to optimize the resource allocation will be the combination of the assumption from the loss estimation scenarios, the parameters set out in the methodology and the priorities that can be prescribed by the policy-makers.
22. Information management is the model which involves the concept about the kind of data that is relevant for the rapid survey, the constraint in data integration, the flow of the information and the different levels of the organization.

1.7. Research methodology

The methodology follows the sequence of the research objectives as shown in figure 1-2. The research methodology started with the selection of the topic. The first approach is the literature review and the selection of the case study city. Fieldwork consisted of surveys, interviews and the collection of secondary data.

The development of the first model started defining space and time parameters to estimate the number of people that must be trained. The space parameters define the size of the inspection area that in the present research is limited to the residential area.

To allocate people it is necessary to geocode them, based on the assumption that this inspection area must be close to the house of the trained people or building inspectors. To estimate the likely availability it is necessary to address the loss scenarios according the seismic scenarios, and formulate a set of assumptions according to the degree of damage, number of injuries and number of casualties in the area where they use to live and regarding to these assumptions, calculate how many could be alive if they were in their houses for the time of the earthquake. Using the last result and based on the data available, it is possible to experiment with different methods to allocate people to a service areas surrounding, estimate the covered and uncovered areas; and eventually try using different criteria and different weights to prioritize the attention areas, as well. In real time, the scenario will be made up of the information coming from fieldwork and remote sensing sources like aerial photography or satellite images.

The information management model was designed based on the state-of-the art related to manage big amount of general information, information specifically in the disasters domain; and also the collection of data on field in large scale.

The research methodology was designed based on the previous research carried out by me, in which the scope was calculate the number of trained people required but not using any spatial tool. This experience makes me feel conscious about the importance of the spatial data in the disaster management fiel.

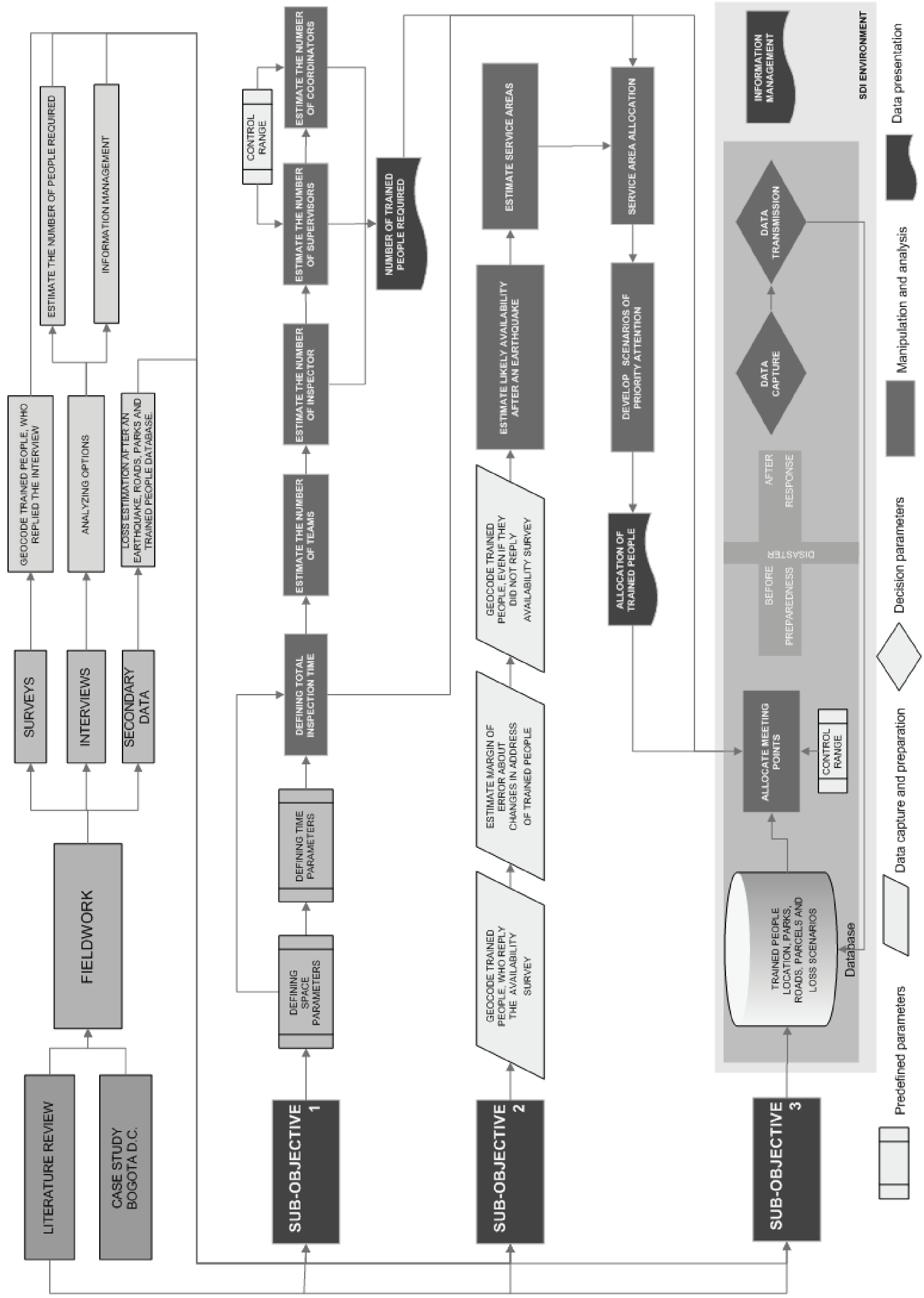


Figure 1-2 Research design

2. Literature review

This chapter covers the main concepts put forward in the conceptual framework. Section one, present the concepts, main components and procedures to make the hazard, vulnerability and risk assessment. Section two, reviews the methodologies used in the world to carry out a building damage survey. Section three elaborates on the basic concepts about planning and scenario development. Section four deals with the research studies about resource allocation for emergency attention and logistics in disaster management. Section nine addresses the topic of information management.

2.1. Assessment of the hazard, vulnerability and risk

The first step in a mitigation, preparedness or response planning process is to identify the hazard, which affect the area. A hazard is a potential occurrence of a physical phenomenon of natural, socio-natural or anthropogenic origin which might affect in a negative way people, infrastructure and economy. Every hazard is defined by its intensity, frequency and spatial probability.

Hazard analysis is the studying and monitoring of any hazard related to its origin, occurrence, magnitude, location, characteristics and behaviour. The input data for hazard analysis is the type of hazard, which in the present research is earthquakes, the analysis method, the scale of the study, the availability of the resources and the amount of available data. The types of hazard assessment are: Historical analysis, frequency analysis, process and landform mapping, participatory/community-based remote sensing based monitoring of hazards, empirical, etc.

The second step is to identify the elements at risk, which is done based on the information available about population, built-up areas, buildings features and infrastructure of the city. The propensity of the elements at risk to suffer damage and loss when they are impacted by an external physical phenomenon is vulnerability. The vulnerability evaluation is the process to estimate the susceptibility to a damage that the elements at risk have when a physical phenomenon struck them. The vulnerability of buildings in case of earthquakes is the relationship between any measures of seismic intensity (acceleration, velocity, movement or anything else, which could shows the best correlation) and the level of damage.

The third and last step is the risk assessment. The risk is the result of hazard multiplied by vulnerability and by the amount of elements at risk in a more explained form, it is understood as the expected human, physical, economic and cultural losses resulting from the combination between the hazard (natural or anthropogenic) and the vulnerable conditions, the procedure can be appreciate on figure 2-1. The loss estimation is a technique to estimate the potential losses from earthquakes and a key element to be integrated in the management and development of megacities (Bendimerad, 2001).

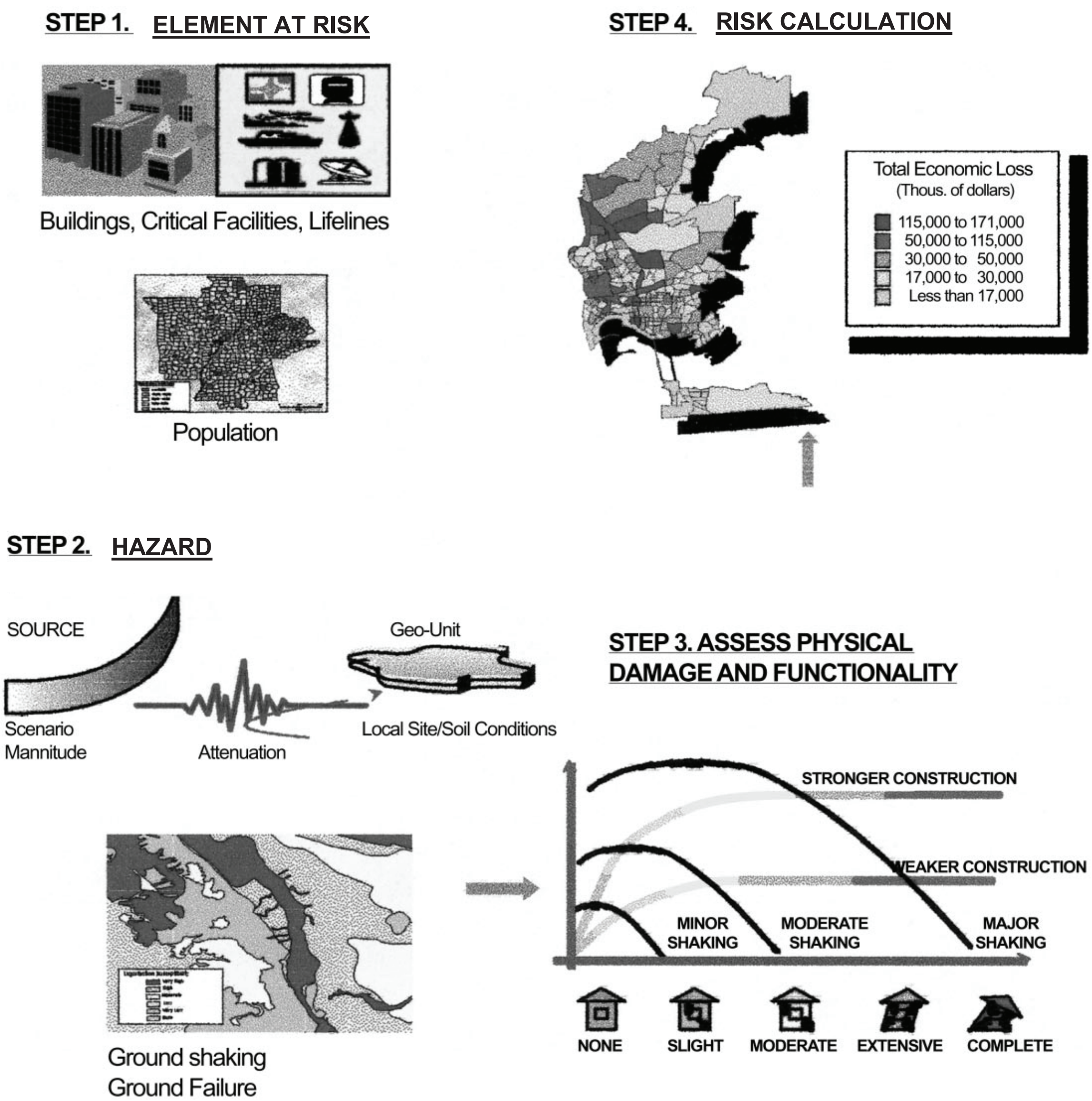


Figure 2-1 The building blocks in the damage and loss methodology.
Source: Bendimerad, 2001.

2.2. Assessment of the damage after an earthquake

There are two types of building damage surveys, rapid and detailed: the rapid survey is concentrated on saving lives through making a brief evaluation of the habitable condition of the buildings, and it must be done in a period of maximum three days, according to the international standards; the detailed survey is the search for buildings considered unsafe in the rapid survey, to decide if they must be demolished or repaired them; the maximum period of time to carry out this kind of survey is eight days.

Countries such as United States, Mexico, Japan, Colombia and Macedonia (Kiril and Metodij university in Macedonia , former Yugoslavia) have designed techniques to collect information after earthquakes and the first three have considered a rapid building damage survey and detailed , instead of a general building damage survey (Contreras, 2002)

2.2.1. American methodology

In The United States, mainly in California a method was developed since 1978 that later were compiled by the Applied Technology council in the report: “Procedures for post-earthquakes safety evaluation of buildings”. This report is known as ATC-20 and the second version was published on 1995 and it is referenced as ATC 20-2 (AIS, 2002).

It uses techniques to collect information including: aerial reconnaissance at low altitude, inspection in field in non visible areas from the air or in night time, sampling surveys on the ground, aerial photography and satellite images.

The methodology suggests three forms to register information: Rapid, detailed and family information supported by an evaluation guide. In the rapid building damage survey the aim is to discriminate the buildings which look apparently unsafe from the clearly unsafe; the form applied is shown in appendix A. The time for this survey is in the range between 10 and 20 minutes.

The buildings are classified into inspected, restricted entry and unsafe. The methodology suggests that the rapid survey must be done for a civil engineer or an architect.

2.2.2. Mexican methodology

In Mexico, Rodriguez and Castrillón reported in 1995 for the National Institute of engineers from the Universidad Autónoma de México (UNAM), the “Post-earthquake evaluation of building structural safety manual”. After that, there was a second version corrected and published in 1998 by the Mexican society of Seismic Engineering, the Public Works secretary and the District federal government services (AIS, 2002).

The main purpose of this methodology is to identify the buildings that look safe in a first impression and those which require a subsequent evaluation or present considerable damage.

In the rapid building damage survey, they point out the damage conditions that in an individual and in a collective way are enough to classify the building as unsafe or with doubtful safeness. The inspectors have to look for structural and non structural failures, and the condition of the ground around the building. Mostly, the revision is from outside, in order to reduce the time of evaluation.

As in the American methodology, it is observed that for the rapid survey are required civil engineers and architects. The forms developed can be observed in appendix B.

2.2.3. Japanese methodology

In Japan, it was developed a set of guidelines to assess the degree of damage in the buildings after an earthquake and a guidebook to recover the different kinds of structures.

The evaluation consists on two procedures: *emergency and immediate assessment of the level of hazard and risk*, and *assessment of the structural damage level and its classification*.

The principle in the first one is to identify the buildings that can be use as hostels, hospitals, and warehouses. It is based on an internal and external view of the buildings and it is done, as its name point up immediately after the damage happen.

The immediate assessment could be set out by people trained in construction. The structures using this methodology are classified, according to the degree of damage in light damage, minor damage, middle damage, serious damage and total failure. See the rapid building damage form in appendix C.

2.2.4. Colombian methodologies

In Colombia, the main advances were done in the cities such as Armenia y Pereira, where forms have been designed since 1992 based on the methodologies formulated by Ana Campos and Omar Dario Cardona. After 1995, the Mexican form was applied and Armando Ramirez went over it on 1996, in order to develop a new one; this form also was modified to be used after the earthquake in Armenia on 1999. Later, a fourth version was developed on 2000 by Andres Toro. The weakness in all of this process have been the lack of a complete manual which describe in a detailed way the inspection procedure and the criteria to qualify the safety of a building (AIS, 2002).

Looking at the methodology formulated to Bogotá D.C., it is important to point out that there is considered one general evaluation instead of the rapid and detailed set out in the methodologies already studied; however, in the last times this point has been discussed by DPAE. The general evaluation has as a main objective the evaluation of the damage level and the safe conditions of the buildings after the earthquakes, in order to design the restoration plan for the city. For the evaluation it was designed a single form to carry out the assessment as it is shown on figure 2-2.

In both methodologies, there is a damage classification and a global classification of the building. But, while Pereira's methodology use the same classification to the damage level, the methodology in Bogotá D.C. looked for a more clear explanation to the people who had to read announcement; thus, the output range varies from habitable, restricted use, not habitable and danger of collapse, as it is illustrated on figure 2-3.
The methodology developed for Bogotá D.C. mentions as techniques and tools to collect and evaluate information the next ones: aerial and ground reconnaissance, phone calls, collection of information from the media, remote sensing and analysis of information and measure of the impact of the event.

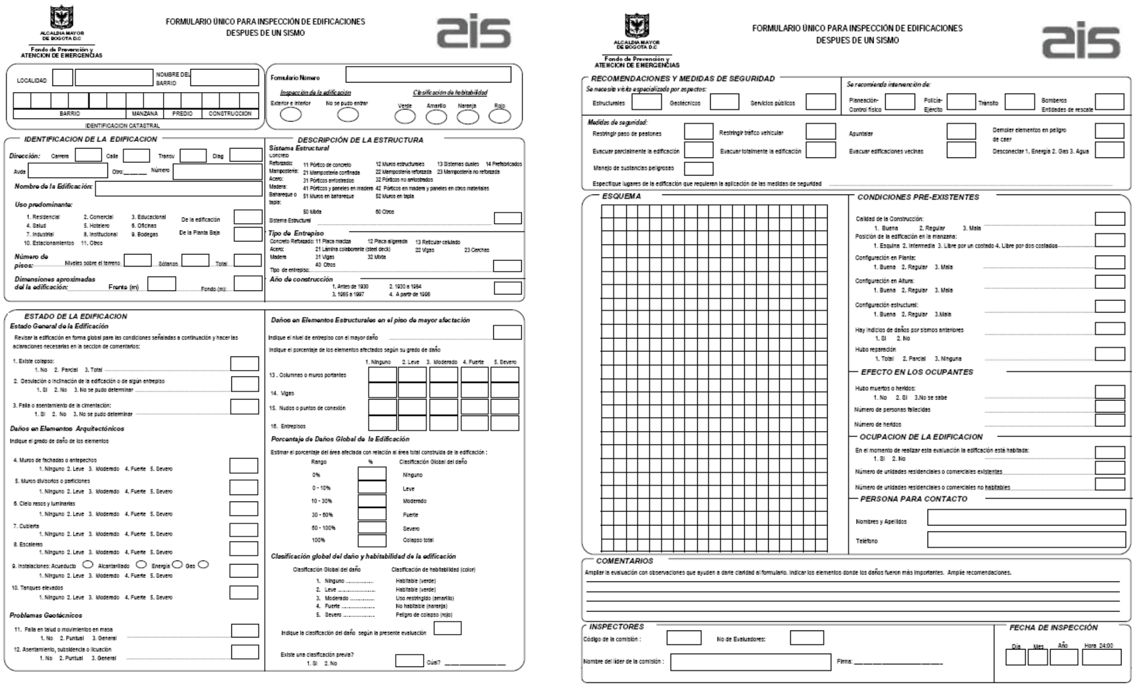


Figure 2-2 General building damage form in methodology formulated in Bogotá D.C.
Source: AIS, 2002.

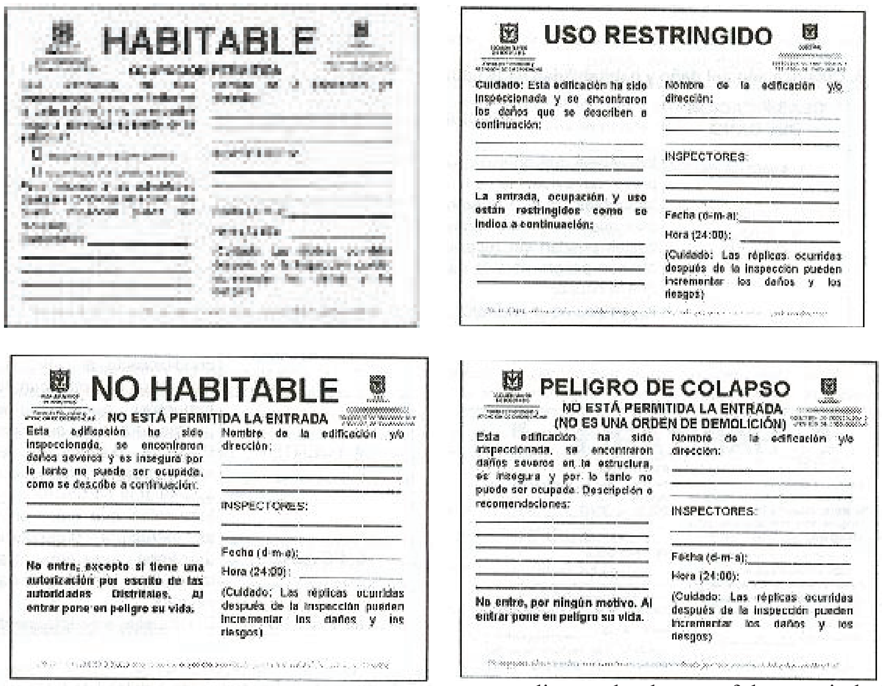


Figure 2-3 Habitability (safe condition) announcements according to the degree of damage in buildings in Bogotá D.C.
Source: AIS, 2002.

Finally, the document developed by AIS to DPAE (2002) concluded that there was no independent process and the experiences of some countries are the bases for late process in others. The first approaches in Japan and California were the bases for the ATC-20 methodology and the methodology designed by the earthquake engineering research institute – EERI. The methodology formulated on

Yugoslavia and Japan was applied on Mexico on 1985. And all of this process was taken into account for the methodologies designed and implemented in Colombia.

On balance, the overall methodologies developed for building damage survey as it was mentioned in the research problem address techniques to collect information, procedures to carry out the inspection, different ways to assess the damage, different survey forms and announcement, the organizational structures in teams, etc. Nevertheless, none of them suggest guidelines about the allocation of the human and material resources for carrying out the survey.

2.3. Planning and scenario development

The loss estimation mentioned in the first section of this chapter, are tools of the risk assessment and, they are presented using scenarios that in the case of the earthquakes correspond to the return periods – RP (probability) 250, 500 and 1000 years.

Hoard et al. (2005) state that emergency planners or decision-makers must be able to develop a range of scenarios, in order to plan for each, and formulate best practices that apply for all of them. There are uncontrolled variables, multiple actors and moving parts, when the field of disaster planning is considered (Hoard et al., 2005).

Due to the last, it is necessary start to talk about a system, because scenarios are generated based on the understanding of the system (Wollenberg, Edmunds, & Buck, 2000), they are defined as a "limited part of reality" and an urban region is an example of a socio-economic system which consist of a large number of variables and subsystems connected(Flacke, 2008). Hoard et al. (2005) suggest the use of System Dynamics, which is a computer-based simulation methodology for analyzing changing and unpredictable social environments, as disaster areas. The authors propos that system modelling could be helpful to understand the causality in disaster preparedness system and also to contribute to evidence-based policymaking (Gunning-Shepers, 1999; Kirschenbaum, 2002; Hoard et al., 2005). The system approach will be able to describe negative factor in the planning process and tackle this issue by means of computer-based simulation.

Hoard et al (2005) explain the concepts of systems approaches and system dynamics. In the case of the system approach, there is no a single definition, but the concept of "team-building facilitation and "learning organization" techniques that help multiple stakeholders work together more effectively" stated by Senge in 1990, is the concept that match better the purpose of the present research. System Dynamics-SD model is described by the author as a set of equations, formulated, tested and calibrated through an iterative process of scope and hypothesis definition, causal diagramming , validation and policy analysis (Sterman,2000; cited by Hoard et al., 2005).

After dealing with the system concepts, it is necessary to address the conception of model understood as a schematic representation of an object under investigation to research, study and make predictions about it; the object can be the urban region and the events that happen into it.(Flacke, 2008). Nevertheless, some authors claim that any model is able to illustrate in complete way the reality nor the future (De Geus, 1994;Hoard et al., 2005); others, maintain that a well-designed computer model can be a tool to understand the cause-and-effect relationships with the profundity that a complex issue require (Gunning-Shepers, 1999;Hoard et al., 2005). Hoard et al (2005) consider that models are suitable tools to address in a flexible way the circumstances that disaster planners have to deal with, such as tackle issues with fewer resources, resource allocation and effective collaboration between agencies and jurisdictions and the added value of the models and simulations is that they provide "evidence base for nationally consistent standards and guidelines".

In this stage, it is necessary to start talking in addition modelling and planning, as information-compilation process (Wei-Ning & Keith, 2003); Sharifi (2004) asserts that planning is a process which involves decisions, choices and alternative ways to achieve goals with the available resources and monitor changes. Resource is a word to denominate something to take a decision about it, or to be used to achieve a goal. In this particular research, the concept of planning coincides with the idea of making the best use of the available resources based on the quality and the quantity of them, in order to set up desirable courses of action, assign priorities and select the most acceptable.

Linked to that concept are the planning support systems, defined as a subset of computer-based geo-information instruments which incorporate data sets, computer algorithms,(meta-) information, storage and query tools, analysis methods, theories, indicators, abstract theoretical construct, knowledge and modelling capabilities and also display facilities; the mentioned components can be applied by the planners to explore and manage their particular activities (public or private planning process) in any scale within a specific planning context, and also to communicate information and generate solutions (Geertman & Stillwell, 2004).

Harris and Batty (1993) imply that in a PSS three sets of components are combined: The specification of the planning task, the system models and methods that elaborate on the planning process by mean of analysis, and the transformation of the basis data into the prediction and prescription modelled. One of the aims of the PSS is support strategic planning (Geertman & Stillwell, 2004), which is the issue in emergency management. The present research pinpoints the spatial planning support system as a scientific field which deal with demand and supply modelling, suitability assessment, site selection, location and allocation problems and the integration of bio-physical and socioeconomic models in scenarios. (Sharify & Flacke, 2008).

Studies on the topic mention software applications created as PSS like Planning System for Sustainable Development-PSSD to support diverse task of professional planners; SPARTACUS to support sustainable urban policies at different locations; Grow Allocation Model – GAMe identifies the implications of certain trend-based or plan-based scenarios on land development; Key to Virtual Insight - K2vI allows users to visualize, manipulate and analyse two-dimensional and three dimensional spatial data within virtual reality (VR) environment; MIGMOD is a tool to tackle strategic planning support at a national level; Building Infrastructure Potential Cost – BIPC incorporates the lifelines facilities (water, sanitation, electricity) cost considerations to assess land suitability (Biermann,2002;Geertman & Stillwell, 2004); WadBos assess the effects of policy intervention on the Wadden Sea; SketchGIS supports the first phase of a participatory plan-making process, based on the creation and evaluation of spatial scenarios for the future; What if?, is defined as a policy oriented planning tool to test what will happen according to different policy choices made, (Geertman & Stillwell, 2004); land use – transportation models-LUTM, multicriteria analysis – MCA, CAD, 3D GIS and Community-Viz, which is pointed up as one the most complete application, building on agent-based models, GIS, and 3D visualization. The classification of PSS depends on the allocated task which also define the technical planning process (Batty, 2007).

However, the aim of this research is not to compare the performance of software applications, but to produce planning scenarios using the most suitable according to the objetives; according to the last, it is necessary to elaborate on the topic of scenarios as one of the inputs and outputs in the present research. Wei-Ningh & Keith (2003) maintains that the concept of scenario was applied to “a series of strategic studies for military planning purposes” by Kahn et al., in 1950; ten years later, Kahn and Wiever define scenarios as a sequence of events to have a view of “causal processes and decision-points”, the prediction was stressed based on a trend (Wollenberg et al., 2000). Between the years 1980 and 1990 the tendency was to highlight the uncertainty and in the next decade, public discussion and shared decision-making was emphasized (Wollenberg et al., 2000).

Scenarios are the result of one combination process: Modelling and planning. In modelling, a scenarist collect information and external cognition aids into scenarios. Then, these are brought into a planning process by the scenario users, who in this case might be the emergency response planners, the decision makers or the Incident commander. Next, the scenarios are combined with more information to develop goals, strategies, plans and policies (Kaiser et al. 1995; pages 251-256, 261;Wei-Ning & Keith, 2003). Scenarios need to incorporate the planning concept to find the match point between the impacts and the interest of the groups.

Sharifi (2008) defines scenario as the “statement of assumptions about the operating environment (driving force) of a particular system at a given time”; but, there are also more simple definitions about scenarios as what might be or creative ways of thinking (Wollenberg et al., 2000). Even, some scenarist use the terms *alternative plans* and *scenarios* with the same meaning.

Sharifi (2008) emphasises that “a method of dealing with uncertain future” is one of the objectives to work with scenarios; others authors say in other words: “ the purpose of scenario process is to gain insights and to explore and assess strategies” (Wei-Ning & Keith, 2003) or explore “opportunities across drivers of change” (Wollenberg et al., 2000)

Loss estimation after an earthquake requires the use of scenarios to show different amount of loss, according to the different inputs in the model: Seismic source, magnitude, return period, peak ground acceleration, depth, distance epicentral average and in the case of injuries and casualties, also the specific time (night or day) is taken into account. This use of the scenarios match with the concept stated by Johannes Flacke (2008), who define scenarios as alternatives images of the future or descriptions of different futures.

Scenarios are key disaster management tools (Kleiboer, 1977;Fuad Aleskerov, 2005) which improve disaster preparedness by presenting a range of possible future states. This approach allow to model situations in advance to develop planning activities, include priority training programs and develop skills like time management, cognitive mapping mediation and team management, as well as the ability to make decisions under stress (Alexander, 2000;Fuad Aleskerov, 2005) . In conclusions, scenarios are key tools for policy planning and strategy development for agencies involved in disaster-related activities (Fuad Aleskerov, 2005).

Scenario analyses is one of the capabilities for risk management and mitigation provided by the loss estimation tools; the exploration of different scenarios offer the elements required by planners to develop disaster response and mitigations plans (Bendimerad, 2001).

There are not so much research studies that address the topic of spatial planning support system, scenarios, disaster preparedness or response and their respective logistic issues at the same time; but all of them solve similar problems using tools in an original way, which represent significant examples to solve the specific problem of the present research.

2.4. Resource allocation for Emergency response

As it was mentioned previously, planning is a process which implies decisions, to achieve certain goals with the available resources. In the present section, different methodologies are reviewed; in the methodologies, the decision issue is how to allocate resources, and the goal is to save lives or delivery humanitarian aids.

The research studies on the topic are grouped according to the classification purposed by Batanovic , Petrovic and Petrovic (2009) in their literature review also, which it is made up of four classes: General, approximate solutions and Stochastic/fuzzy and anti-covering models; however, the last class is not considered in the present literature review, due to no corresponded with the objectives, instead is considered a statistical model developed by (Benini, Conley, Dittemore, & Waksman, 2008) to evaluate the performance of the allocation resources, that in their research study is related to commodities delivery.

2.4.1. General models

General models pinpoint how to select locations for commodity distribution, logistic centres and places for emergency service facilities. The selection of the best location is a “problem of allocating customers to facilities with changing costs” (Drezner & Wesolowsky;Batanovic et al., 2009).

The first research study to be analysed is the *dynamic optimization model to allocate resources after an earthquake* developed by Fiedrich, Gehbauer, & Rickers (2000) their research pinpoints the problem of designing an optimal schedule to assign resources in space and time to the affected areas, taking into account their quality and quantity.

The model called ALLOCATE use five parameters: Survival rate for trapped victims, probability of secondary disasters, survival rate of rescued people without medical treatment, transportation time and time to complete the work (Fiedrich et al., 2000).

The model created by Fiedrich, Gehbauer, & Rickers (2000) includes a representation of the disaster area in an abstract form or undirected graphs with nodes and edges, which symbolize important locations and the links between the nodes. It also, contains a set of components of the goal function: Fatalities due to secondary disasters, fatalities due to duration of the rescue operation, fatalities due to lack of rescue attempts, fatalities due to delayed transport, fatalities due to duration of transport and fatalities due to lack of transport. Finally, it considers a resource restriction due to local conditions.

At first, they used a computer-based decision-support system and a mathematical model for the calculation of the optimized resource schedule, but later they observe that the model can not be solved exactly. Hence, they opted by apply heuristics Simulated Annealing (SA) and Tabu Search (TS) (Reeves, 1993;Fiedrich et al., 2000). To test the model, different possible damage-and-loss scenarios were developed in a fictitious city nearby mountains and divided by river and bridges and the best result was achieved by the use of SA algorithm (Fiedrich et al., 2000).

Yan and Shih (2007) develop a novel time-space network model aims to assist decision makers to design an emergency repair schedule in a fixed period of time. They define the research problem as a network flow problem with side constrains to be solved using a heuristic algorithm

The main idea is minimizing the length of time needed for emergency repair, according to operating constraints. The model is based on a set of assumptions about time, space, routes and work teams conditions, and four types of side constraints that should be considered: 1,One work team is necessary to repair a damaged point; 2, "if a work team is sent from intersection *e* to the damaged point *d* (route 1), thus damaged point d is repaired and segment *ew* passed (figure 2-4); 3, if a work team is sent from intersection *e* to damaged point *u*, next, from damaged point *u* to damaged point *v* (figure 2-5). Hence, the two damaged points are repaired and the highway segment *ew* can now be passed; and 4, to change a Minimax objective into a linear function, additional constraints are necessary.

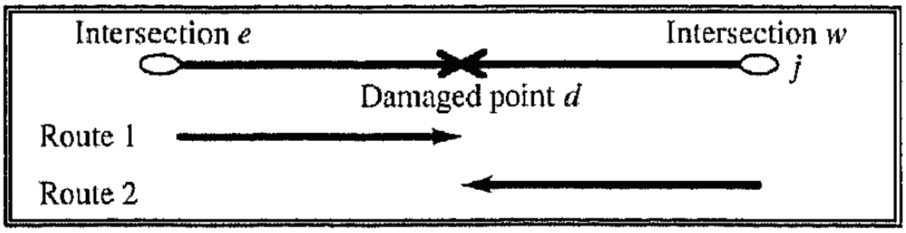


Figure 2-4 Passing a highway segment with a damaged point.
Source: Yan & Shih, 2007.

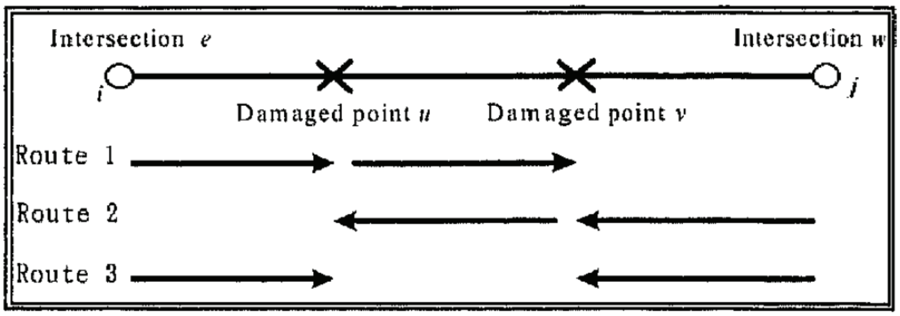


Figure 2-5 Passing a highway segment with two damaged points.
Source: Yan & Shih, 2007.

The solution method is to first create service areas associated with the nearest work station; each, service area is correlated with the number of work teams in the associated work station. Therefore, the number of service areas will be equal to the number of work teams in a work station.

To sum up, the model is designed to be a decision support tool to serve the decision-maker to set up an efficient emergency repair schedule in a limited time. The authors develop a heuristic algorithm using CPLEX, a mathematical programming solver, but they also conclude that if the size of the area is too large meta-heuristics techniques, Lagrangean relaxation or column generation may be applied.

Iannoni, Morabito and Saydam (2009) combine "extensions of the *hypercube model* with hybrid genetic algorithms to optimize the configuration and operation of EMS on highways". In their approach, they seek for minimizing the mean user response time, the imbalance of the ambulance workloads and the fractions of calls not serviced within a fixed threshold, through the analysis of the locations of the ambulance bases along the highway. The authors adjust the algorithm to make a trade-off analysis and generate a kind of "*Pareto* efficient frontier between these measures". The approach also elaborated on the decisions relative to the location of ambulance bases and the districting of coverage areas of ambulances along the highway "(location and districting GA/hypercube algorithm)". The conclusion of the study was that relocating the ambulance bases and defining a right size of the service districts (atoms) as it is illustrated on figure 2-6, it is possible to reduce the response time, the number of calls not serviced and improve the imbalance problem in the ambulance workload.

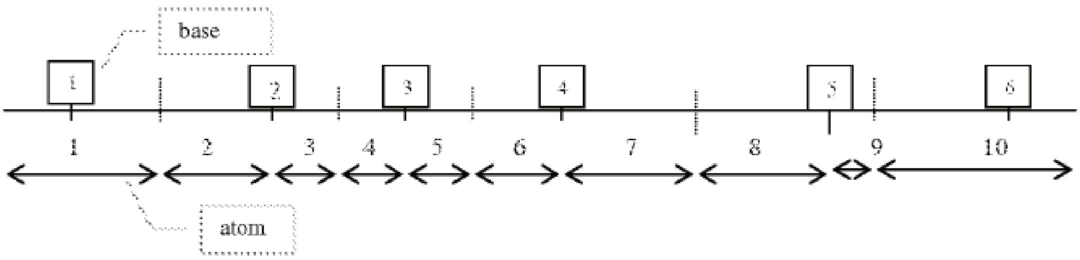


Figure 2-6 Ambulance bases and atoms along the highway
Source: Iannoni et al., 2009.

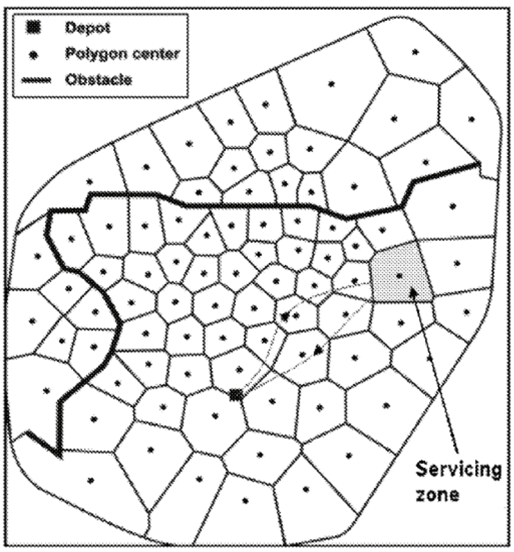


Figure 2-7 Power Voronoi diagram logistics districting with barriers.
Source: Novaes, Souza de Cursi, da Silva and Souza, 2009.

Novaes, Souza de Cursi, da Silva and Souza (2009) elaborates on the districting problem, mentioned in the previous model developed by Iannoni, Morabito and Saydam (2009). The difference between approaches is that, while the second authors work with a mathematical model, Novaes et al. (2009) apply *Voronoi diagrams* associated with continuous approximation, which is an optimization algorithms based on spatial density of demand to solve location-districting problems. The author started defining the concept of facility location problem as the location of some facility aim to optimize an objective function such as provide an equitable service to people in their buildings, as it is the case of the present research.

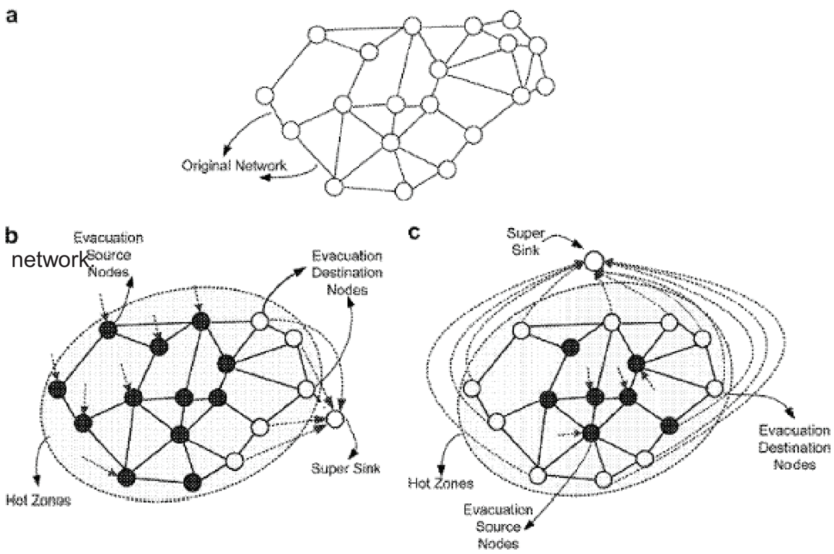
The voronoi diagram is the result of the allocation of some areas to a set of points, given a distance, which is a very similar concept to *euclidean allocation* and *service area* in *network analysis* (Arc Map) (Novaes et al., 2009). The authors also discuss *p-center* problem, which concept also match with the closest facility analysis in Arc Map and *Dijstra method* to know the shortest path between two points when there are barriers, which also could be done using route analysis also in Arc Map. A district solution applying *Voronoi diagram* is presented in figure 2-7.

2.4.2. Approximate solutions

Approximate solutions are usually nondeterministic polynomial NP-hard combinatorial optimization problems; and they are formulated for minimum covering problems where the case study is a sort of subset of facilities in order to "maximize the sum of weights associated with demand sites". The performance of the algorithms in this kind of models use to expend a lot of time and this constraint, limit their application in real time and in large scale problems (Batanovic et al., 2009).

Moving on linear/ non-linear programming, author as Chiu & Zheng (2007) formulate a model to solve "simultaneous mobilization destination, traffic assignment, and departure schedule for multi-priority groups (SMDTS-MPG)". The objective is developing strategies to mobilize groups of people, according to designated destinations, priorities chosen, and interactions within the traffic network. In the model, the area, within the mobilization is required, must be delineated (hot zone); then, it is necessary to indicate into that area some boundary nodes as destinations. The result is an "enhanced network" resulting from "connecting all the physical mobilization destinations to one hypothetical infinite-capacity safe node", it is shown on figure 2-8.

The SMDTS-MPG is modelled based on linear programming-LP formulation, which could have algebraic and matrix forms formulations. In the model, travel time is prioritized over the planning horizon according to some constraints that represent a cell transmission model-CTM "by solving for the optimal cell flow holding and existing strategies for all priority groups" (Chiu & Zheng, 2007).



b. Original network

a. Enhanced network for directional mobilization.

c. Enhanced network for radial.

Figure 2-8 Network transformation for the SMDT-MPG problem
Source: Chiu and Zheng, 2007.

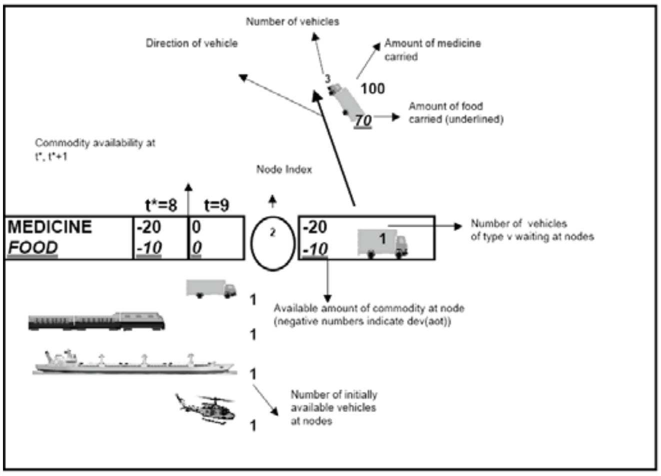


Figure 2-9 The graphical illustration of the partial optimal solution
Source: Ozdamar et al., 2004.

As it was suggested by Yan and Yu-Lin (2007), a Lagrangean relaxation is used by Ozdamar et al. (2004) in a planning model to be integrated into a natural disaster logistic Decision Support System. The model produce plans according to aid materials request, new supplies and transportation means; every plan show the optimal mixed pick up and delivery schedules, quantities and types of loads for vehicles in a time horizon. It is a mathematical model which integrates the multi-commodity network flow problem and the vehicle routing problem. The model is separated into two multi-commodity network flow problems, the linear (for conventional commodities) and the integer (for vehicle flows). The mechanism to link the network flow problems is an iterative solution algorithm based on Lagrangean relaxation (Fisher, 1981;Ozdamar et al., 2004). Figure 2-9 illustrates the movement of different vehicles by using arrows, a Gant chart displays the schedule where nodes is written in rows and time periods in columns, hence a multi-period movement chart is displayed for each vehicle type.

2.4.3. Stochastic/fuzzy models

Lau, Agussurja and Thangarajoo (2008) develop a decentralized optimization algorithm. The authors model a supply chain as a multi-agent system where agents are under an adjustable autonomy. Autonomy of an agent is defined as its potential to influence decisions within a multi-agent system and when they talk about adjustable autonomy, they refers to the autonomy of the agents during execution environment as response to changes in the environment (e.g. accidents, loss of resources, etc) or human interference. Agents plan and/or control activities such as acquisition, logistics, scheduling, resources, dispatching and transportation in the supply chain collaborately.

The authors consider suitable, the use of Fuzzy control due to its capability to tackle with poor quality data (e.g. incomplete, corrupted, etc.) and time constraint, because fuzzy system capture relationships between non-discrete data and handles incomplete data in an effective way. The role of the fuzzy framework in the solution approach formulated by Lau, Agussurja and Thangarajoo (2008) is capture sensor data from all the agents and translate it into new objectives according to the autonomy level of the agents. The authors listed five steps in the fuzzy process: Normalization, fuzzification, fuzzy inferencing, defuzzification and denormalization.

Lau, Agussurja and Thangarajoo (2008) put forward an algorithm which is made up of three parts: Initialization, coalition formation, and negotiation. In initialization, each agent construct an optimal assignment according to its variables that maximizes its given objective function; in coalition formation step, every agent go through external conflicts; then, if it is necessary to go to negotiation state, the agent with highest autonomy level will collect data from others agents in the coalition.

The approach was applied to supply management through a sudden crisis like a man-made disaster or disaster caused by a natural phenomenon and the main problem considered was how to reduce the delay cost through re-directing existing resources (aid supplies) towards the destinations. The objectives of the distribution agents might be: Maximize service level (percentage of demand satisfied) or minimize cost (e.g.storage, transportation, processing, etc.). The experiment was carried out in a period of 30 days and the results can be appreciated in figures 2-10 and 2-11.

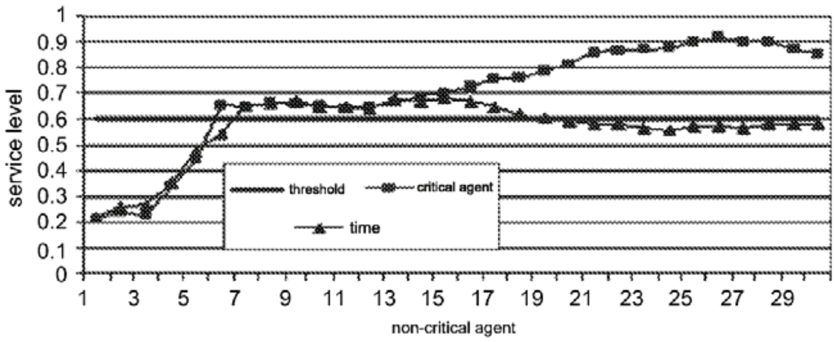


Figure 2-10 Demand satisfaction (service level) over time
Source: Lau et al., 2008.

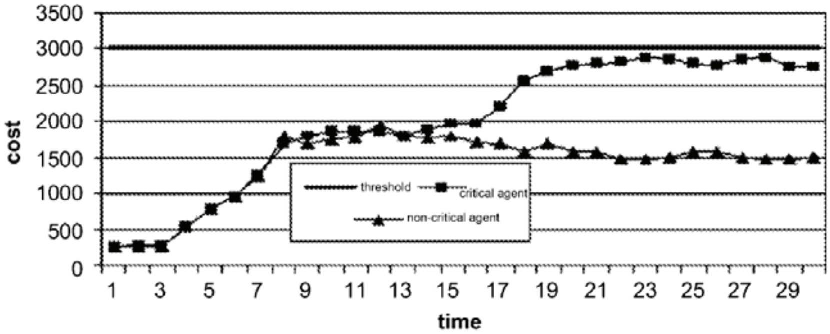


Figure 2-11 Cost over time
Source: Lau et al., 2008.

Figure 2-11 shows that while the service level of the critical agent increases, the service level of the non-critical agent decrease, and figure 2-12 display similar results related to the cost of re-direction agents. These graphs could be similar to the graphs of the building inspection service when the number of people available and the number of houses inspected are compared with the time.

Batanovic et al. (2009) elaborate on a maximum covering location problem based on a network, under uncertain environment. The problem is delimited as given a connected network with demand at nodes; locate one or more facility sites at nodes, in order to maximize the coverage of demand nodes. In the problem, there is a critical distance or a critical time within the demand is fully covered or not covered at all.

Three algorithms with the concept of fuzzy node coverage included are formulated for selecting the best facility location assuming: "(1) demands at nodes are equally important, (2) relative weights of demand at nodes are deterministic and (3) weights of demand at nodes are imprecise and described by linguistic terms, respectively".

Figure 2-12 illustrates the case of a distribution company with N=15 retailer and I= 3 potential locations for depots, spatially distributed on a geographical area and modeled by an undirected network. In this example, all demand nodes have equal weights. The problem is to determine the best location for a depot which maximizes the measure of belief that the largest number of retailers is covered. In this particular case, the result is solved applying algorithm 1 and it can be appreciate on table 1.

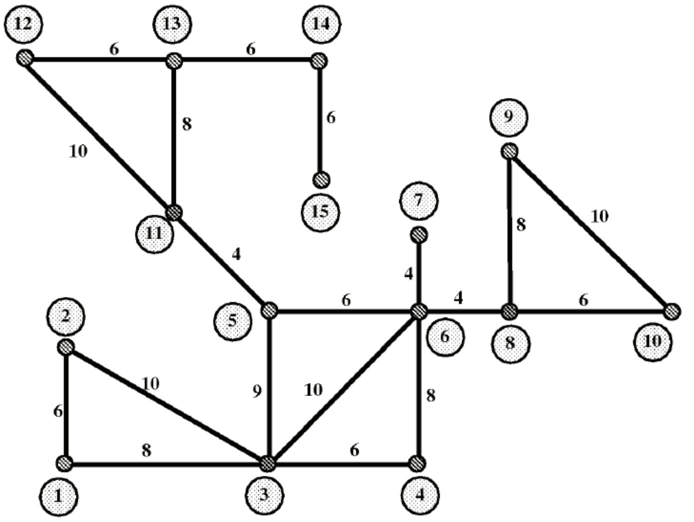


Figure 2-12 Undirected network with 15 nodes and 19 links.
Source: Batanovic et al., 2009.

Depot *i*	Distances (r_k, $\mu(r_k)$)							
	(20,1)		(24,0.8)		(28,0.5)		(30,0.3)	
	No. of retailers covered	% of retailers	No. of retailers covered	% of retailers	No. of retailers covered	% of retailers	No. of retailers covered	% of retailers
1	6	40	9	60	11	73	12	80
10	9	60	9	60	11	73	12	80
12	7	47	10	67	11	73	13	87

Table 2-1 Number and percentage of retailers covered.
Source: Batanovic et al., 2009.

The drawback is that the algorithms purposed are able to deal with just smaller networks, maximum ten demand nodes and/or equal number of potential facility sites(Batanovic et al., 2009).

2.4.4. Statistical model

Benini, Conley, Dittemore and Waksman (2008) study is different from the previous studies because it does not purpose a new algorithm to allocate any resource, instead, they applied a statistical model to demonstrate if survivor needs guided decisions to deliver aids to affected communities.

The challenge to formulate the model is that it is necessary that the model estimate the probability to send humanitarian aids and, if the decision is positive, the amount to be sent it according to the characteristics of the communities. Firstly, Heckman-type regression models (Sigelman and Zeng, 1999;Benini & Conley, 2007) was used, and then a semi-parametric Bayesian regression (Brezger et al., 2005;Benini & Conley, 2007).

They measure needs using a proxy indicators (population census, Mercalli Index and Rugosity) integrated on a Geographic Information System (GIS) platform with logistic and relief delivery data. They pointed out that needs orientation were representative, in spite of the strength of decision factors fluctuates between humanitarian aids (food, kitchen supplies and water, shelter and clothing and construction materials and tools) as well as over the response phases as it is shown on figure 2-13.

This is an interesting point in this research, because the priority attention scenarios also have to be based on proxy indicators as population density, estimated degree of damage, density of built-up area, etc.

The case study was located in Pakistan after the earthquake in 2005; Benini, Conley, Dittemore and Waksman (2008) suggest that go through the data there was not a suitable match between survivor needs and relief deliveries, mainly due to the difficult to allocate scarce aids material and logistic resources such as transport capacity and access.

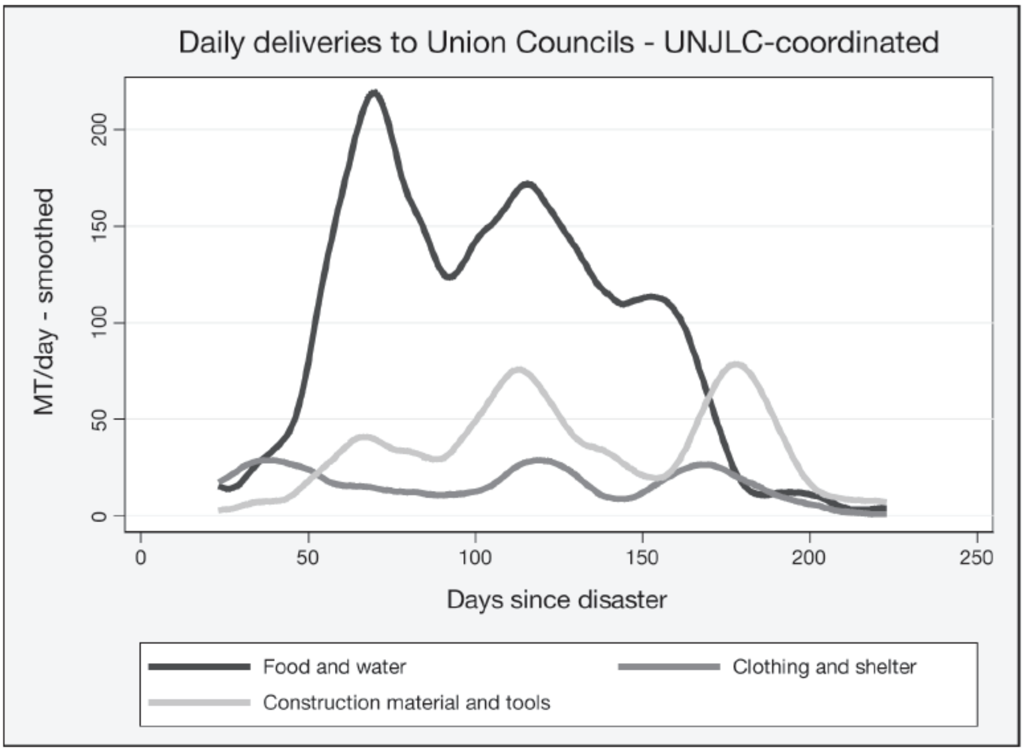


Figure 2-13 Deliveries over time of daily volumes shipped, by commodity groups.
Source: Benini et al., 2008.

2.5. Information management

People have to tackle natural and man-made events that sometimes have a high cost in lives and properties besides the indirect losses. Because of their scale and magnitude, the government needs to address their impact, and prevent or mitigate them. Due to the last, the information play an increasing significance in the mentioned effort (Wallace & Balogh, 1985).

According to Guha-Sapir and Lechat (1986) an information system is a combination of procedures and resources for collecting, processing and communicating data which has five key components: Indicators of needs; indicators of success; definition of objectives, logistics and operations, composition of necessary human expertise; and survey and questionnaire design. The concept is shown on figure 2-14.

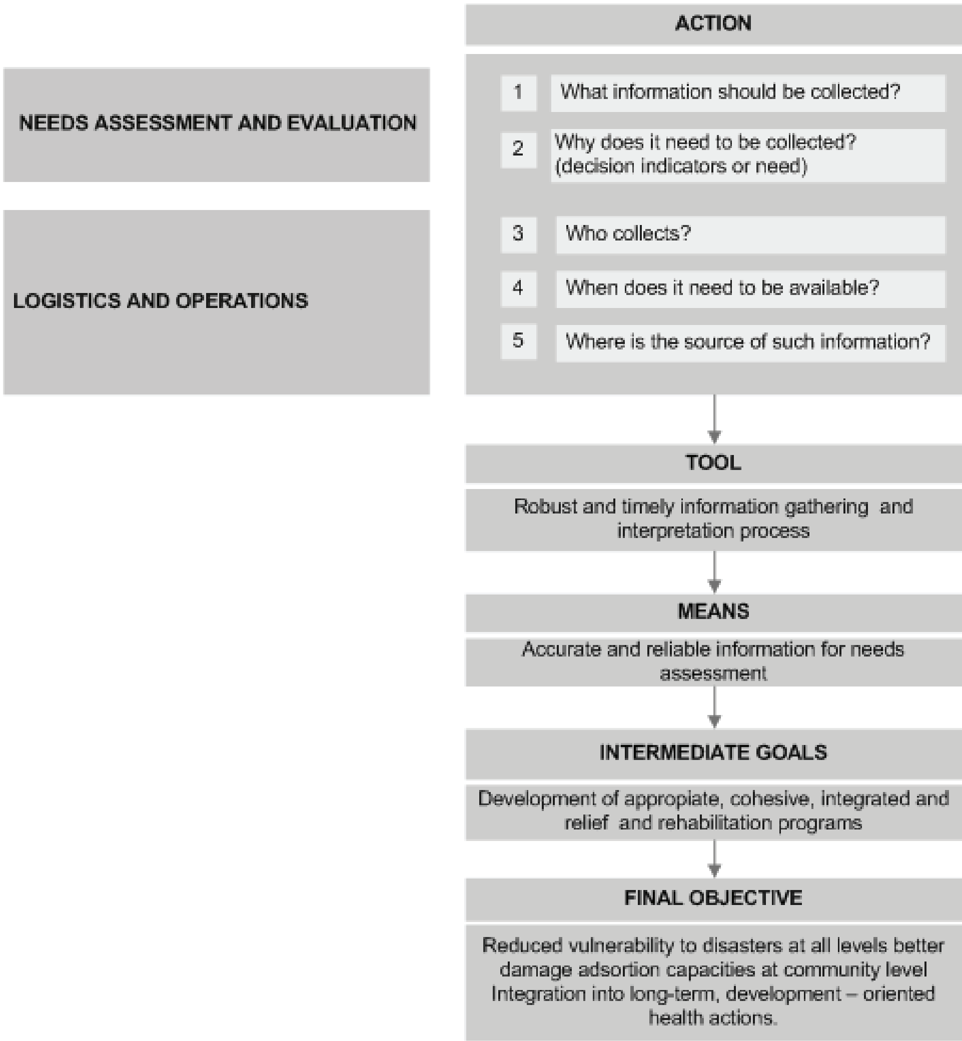


Figure 2-14 Procedures in an information system.
Source: Debarati Guha-Sapir, 1986.

"Techniques to gather information immediately after a disaster include quick visual surveys or consultation with community representatives and service providers"(W. Randolph Daley, 2001) However, as Daley suggests apply whatever sampling methodology is challenging, if there is not enough pre-existing geographic and demographic data.

Different types of information are required at different times for different objectives: The baseline information, post-impact information phase which is divided into two sub phases: Immediate or emergency relief and secondary relief, rehabilitation information and evaluation (Debarati Guha-Sapir, 1986). Building damage survey is in the phase of post-impact information as immediate relief information.

Mansourian et al. (2006) purpose an Spatial Data Infrastructure –SDI, like it is displayed on figure 2-15 as a "framework for the development of a web-based system as a tool for facilitating disaster management by resolving current problems with spatial data"(Mansourian, Rajabifard, Valadan Zoej,

& Williamson, 2006). The authors know the role that spatial data and the technologies plays in an effective collaborative decision-making in disaster management. One of the important information considered is the available resources that as they mention should be available to use in short period of time. “Any problem or delay in data and hence the quality of disaster response” (Mansourian et al., 2006).

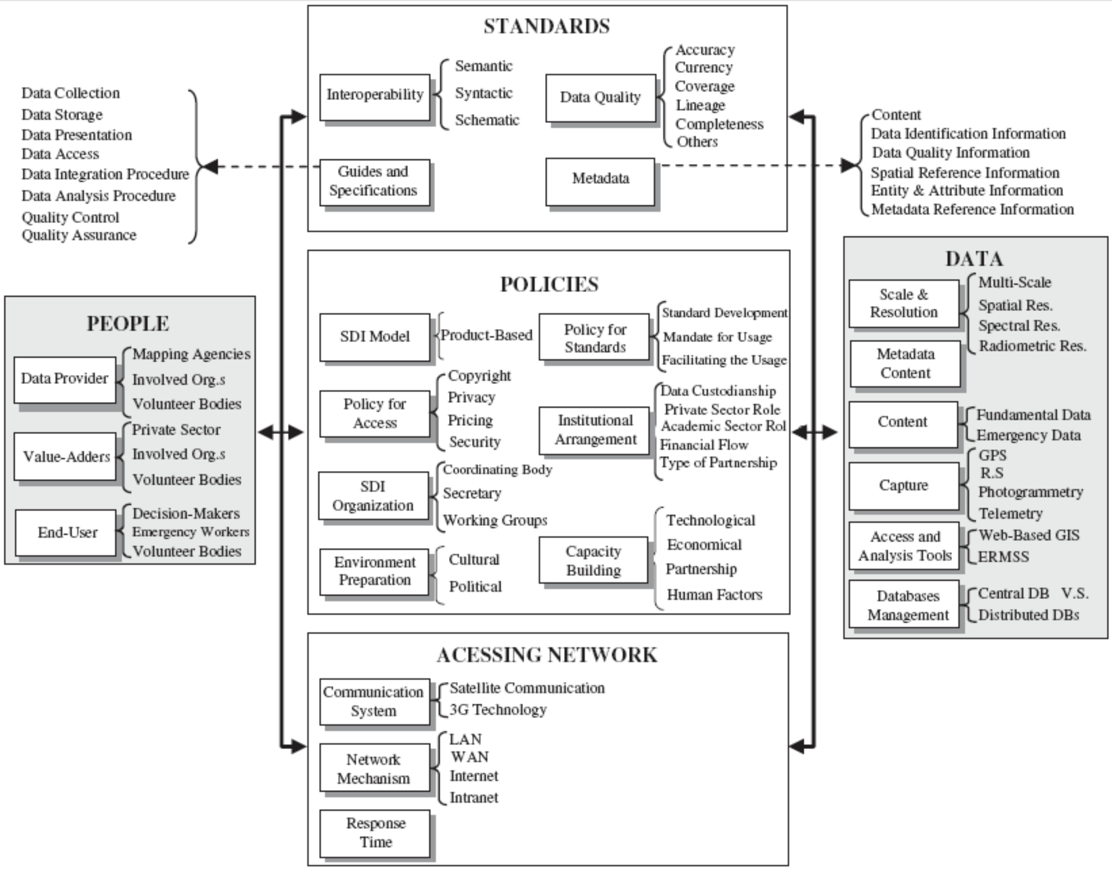


Figure 2-15 Schematic presentation of SDI conceptual model for disaster response.
Source: Mansourian et al., 2006.

Authors as Benini and Conley (2007) made a critical assessment of the cost of the information collected in rapid humanitarian surveys; and because of the environment in which the information is collected, it is similar to the conditions under the building damage survey will be carried out, it is included in the literature review of this research. They argues that the behavior of the assessment organization must be evaluated against the value and the cost of the information (“value of information produced versus the effort needed to produced it”) collected by them, and its ability to adapt the survey plan under unforeseeable conditions. In spite of the objective of a rapid assessment is to save lives, the discussion is not about the money but it is about the cost-effectiveness of the survey; the analysis can be appreciated in figure 2-16.

Benini and Conley (2007) conclude that the analysis show variable rational behavior under insecurity conditions like repeated regrouping and incomplete sampling frames.

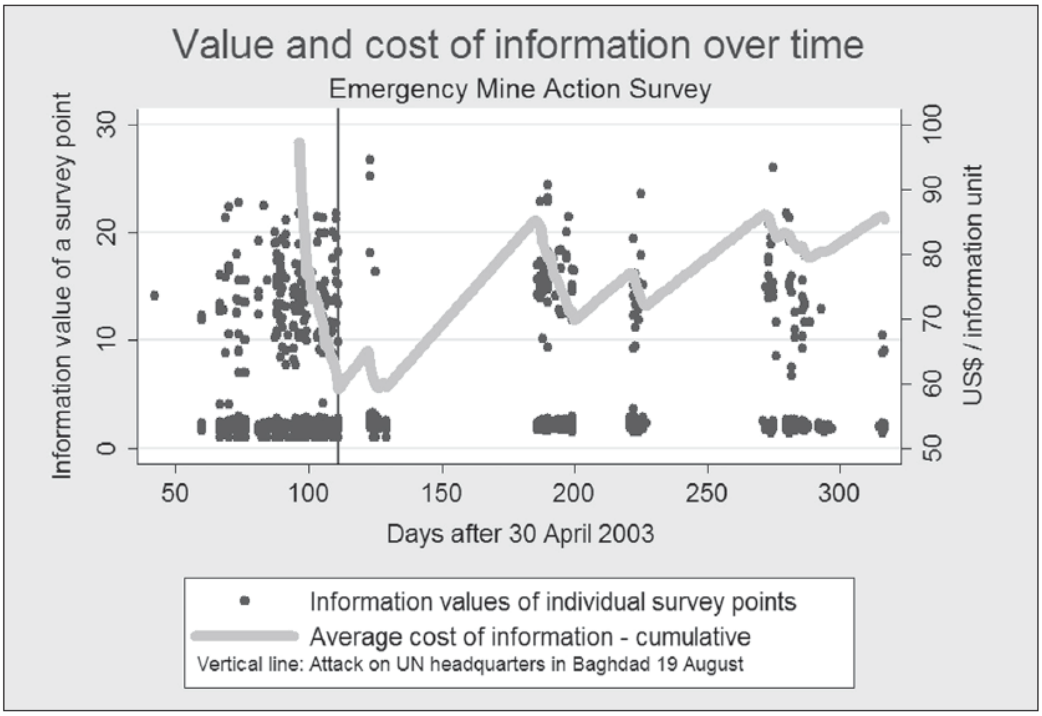


Figure 2-16 Information value and average survey cost.
Source: Benini and Conley, 2007.

2.5.1. Data capture

The information in disaster management comes from different organizations due to the wide domain of activities to carry out in the response phase e.g. fire and police departments; Red Cross society and Utility Companies. The information about damages after an earthquake usually comes from different sources: phone calls, aerial reconnaissance and the information collected by the people trained about building damage survey after an earthquake.

According to the methodology developed in the countries that have been dealing with the topic of the building damage survey after an earthquake., the information has been collected by using the forms as shown on appendices A, B, C and figure 2-2.

Nevertheless, the tendency in data capture in this kind of events must be change in order to have it in less time and make it helpful to carry out the need analysis. Due to this, in countries like Colombia, it have been considered the possibility to use mobile devices, as it is shown in figure 2-17 (a and b). Those mobile devices facilitate the data capture, and in the world the use of application as CyberTraker to capture information on field has been also used.

CyberTracker is a software application to capture a large quantity of geo-referenced data for field observation. It has a friendship environment with “a simple interface for viewing data, including tables, graphs, and map views showing point data, paths, observer effort and index of abundance”(CyberTracker, 2008). The mentioned characteristics makes easy collect data in a fast a detailed way.

The developers also designed a methodology that makes it possible to measure observer reliability in order to “ensure that field data can be validated with a high degree of confidence” (CyberTracker, 2008).

CyberTraker software runs on PalmOS and Windows Mobile, should also be compatible with other platforms, such as the Apple iPhone and Nokia Smart Phones (CyberTracker, 2008). Their application in disaster relief can be seen on figure 2-17 c.

Figure a. MTC 100 Handheld computer. Source: Motorola

Figure b. HP IPAQ 2411 Source: DANE

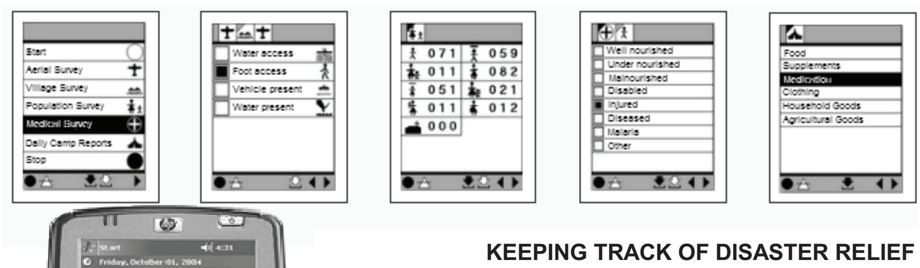


Figure c. CyberTracker application in disaster relief.

Figure 2-17 Field surveys for disaster relief using mobile devices.
Source: CyberTracker, 2008.

2.5.2. Data transmission and analysis

An *Emergency Operation Center* (EOC) or situation room is the place where the organizations involved in the emergency management meet. Each organization has a representative who “is in touch with its own organization in order to update itself and other EOC members about emergency situations”(Mansourian et al., 2006).

Masourian et al. (2006) consider that if every organization involved in the disaster response collects their spatial dataset during every business day, they must be available every time to the decision makers. Due to the last, they suggest to think in a SDI as a tool to share spatial data in an easy and secure way.

The mentioned authors had designed a web-based system for disaster management. In the model designed every organization has a database for their business, and another one for disaster response. There is also another database in the EOC with base maps and datasets for disaster management as it is shown in figure 2-18. Each organization is responsible to update the database after and before the disaster, but also they are allowed to use the data for their own purpose.

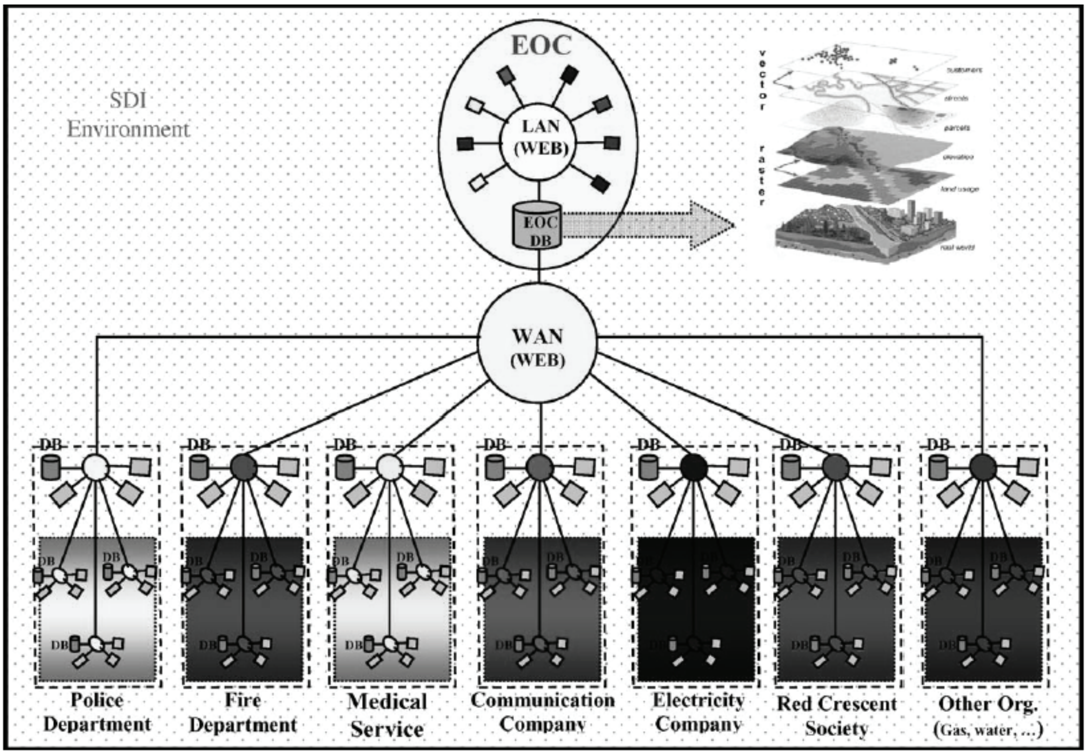


Figure 2-18 Overall picture of a web-based system to facilitate disaster management using a SDI environment. Source: Mansourian et al., 2006.

The research study carry out by Patricelli et al., (2009) draws some arguments from previous authors as von Lubitz and Wickramasinghe (2006), who consider that the organizations must be competent and capable of rapid synthesis and dissemination of Actionable Knowledge and also supported by a disaster-resilient telecommunications infrastructure used for exchange of information from outside and within the disaster area. Nevertheless, Patricelly suggested a *Network Enabled Capability* (NEC) as a more practical approach instead of a *network-centric-operation* (NCO) as a main component of mega-disaster management useful for join civilian/military applications.

The tools for the information management must “provide operational flexibility, require minimal operating and maintenance expertise, and finally, be readily deployable”(Frédéric Patricelli, 2008).

Patricelli et al., (2009) put forward the concept of *Next Generation Network* (NGN), which combines voice and data services (triple-play-Voice+Data+video). It works based on interoperating networks existing under the umbrella of roaming agreements (fixed-fixed, fixed-mobile, mobile-mobile) that permits mobility of the user (roaming) and user-associated services (nomadism).

The architecture of an NGN (De Nitto et al., 2004) is made up of four layers:user/acces, transport, control and application/services. See figure 2-19.

However this concept must be joined to a wireless technology as the most likely modality available after a disaster. "The reconstruction of functional post-disaster telecommunications architecture requires initial establishment of full connectivity among all field elements and their associated equipment, followed by a link to the NGN backbone, which, in turn provides connectivity to the rest of the world (systems, data/information/knowledge, people, organization). COTS Geosynchronous Earth Orbit (GEO) satellite-based triple-play solutions (…) can be rapidly transported (even by the helicopter when roads are not usable) and easy deployed by rescue and/or emergency teams (Youst and Mazzei, 1998) (Frédéric Patricelli, 2008). One example of fully mobile field telecommunication system (Tarabochia 2005), that Patricelly mention is the MOBSAT Satellite Access Point (SAP).

The advantage of the use of GEO satellite based technology, that Patricelli et all. (2008) observe is the possibility to cover large areas supported by the MOBSAT Satellite Acces Point (see figure 2-20); but also taking into account drawbacks such as high power needed to feed the antennas and the low throughput if it is compared with the terrestrial networks.

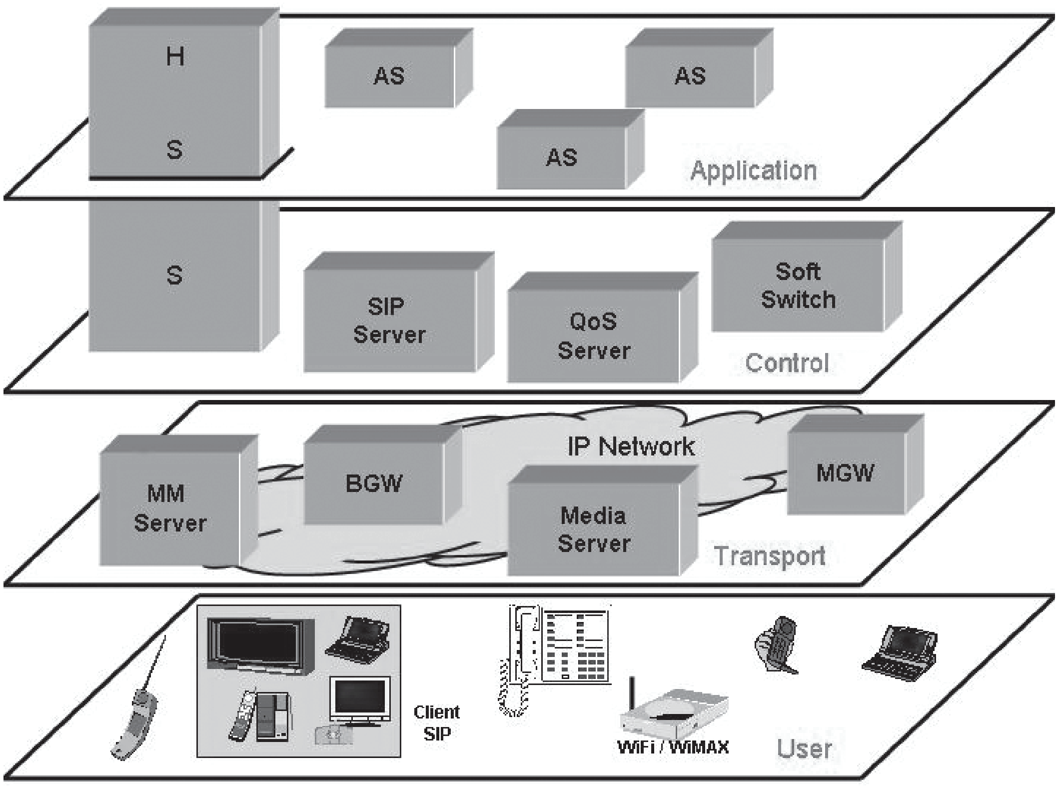


Figure 2-19 NGN layered architecture.
Source: Frédéric Patricelli, 2008.

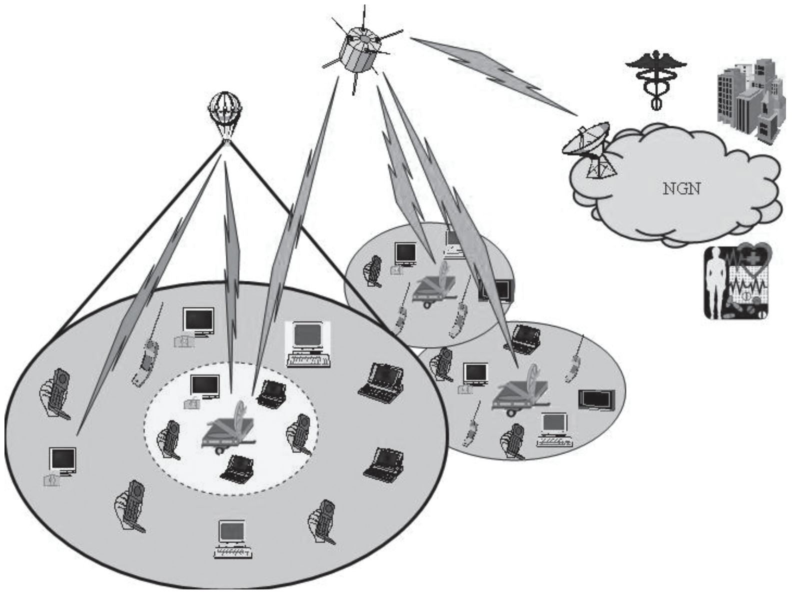


Figure 2-20 Three MOBSAT Access Points (one with dedicated air vehicles) configured to provide larger coverage
Source: Frédéric Patricelli, 2008.

In 2005, there was a population census in Colombia carried out by the National Administrative Department of Statistics (DANE). It was the first time that a government entity makes use of mobile devices to capture data in a large scale. The team in charge of organizing considered four options to transmit the data, which can be seen on appendix D and the flow of the information is shown in figure 2-18.

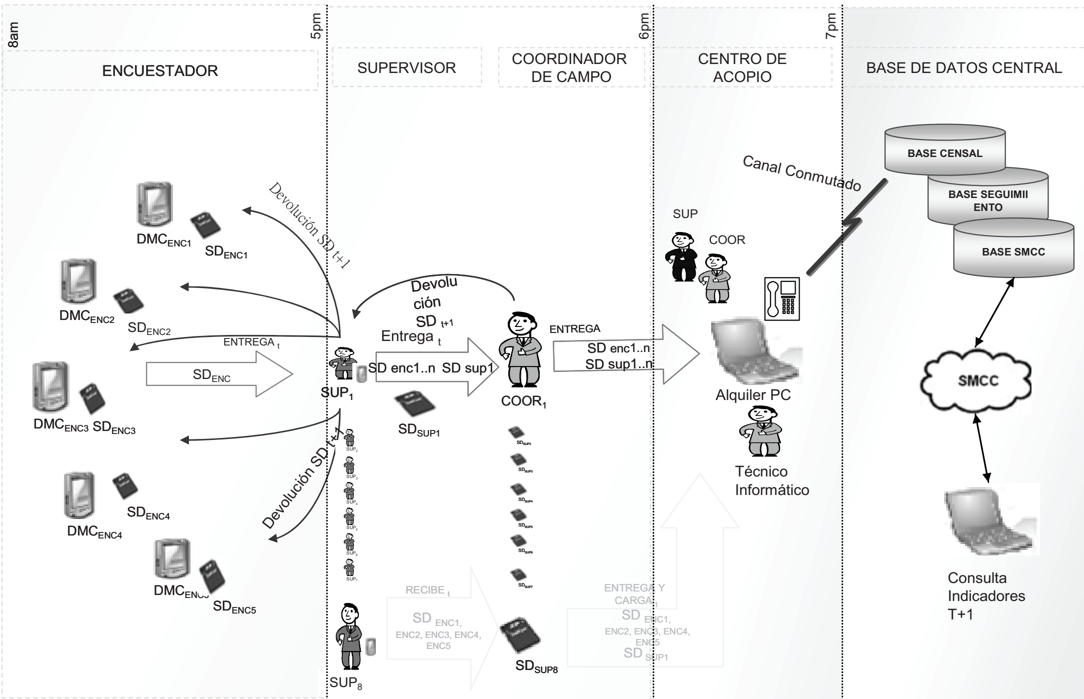


Figure 2-21 Information flow
Source: DANE.

3. Methodology

The aim of this research is to design a process model for the planning of rapid building damage survey after an earthquake, and manage the spatial information collected. The basic form in figure 3-1 presents the basic model, which involves all the elements relative to assessment of the damage after an earthquake, planning and scenario development, resource allocation for emergency response and information management discussed in literature review chapter.

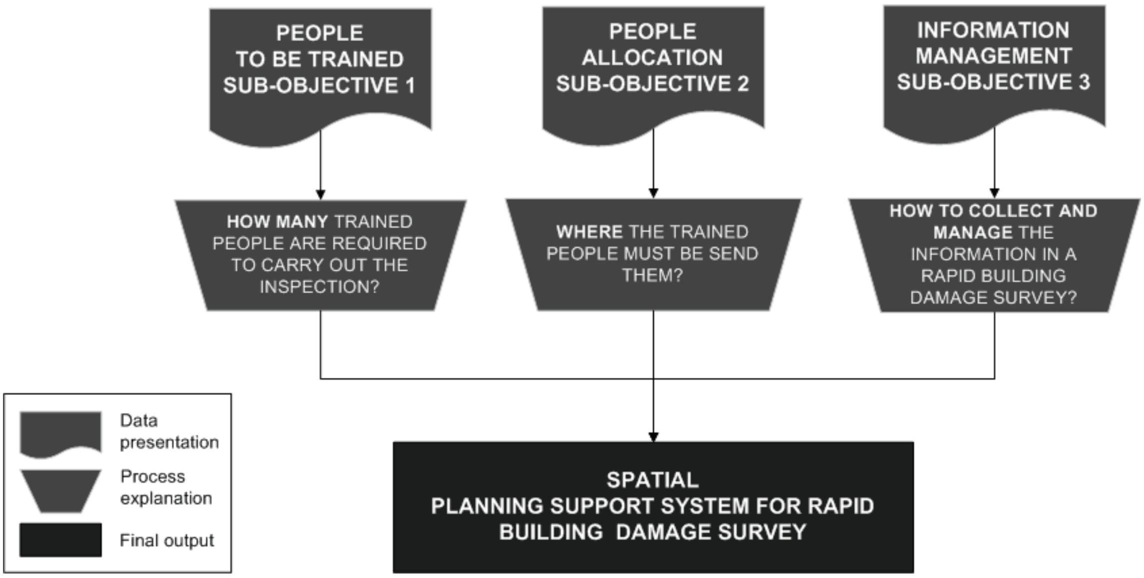


Figure 3-1 Basic model

In the next sections, the input data, the GIS operations, and the parameters included in the models are presented, and the analysis process is explained step by step. Every step has a number as identifier that also can be located in the graphs and in the tables.

3.1. Sub-objective 1: Estimation of the number of trained people required

In the present model, it is possible to detail the input *space* and *time- parameters* in the spatial planning support system (SPSS) and how to combine them with the organizational variables to estimate the number of trained people required.

The extended model can be seen in figure 3-2 and it was divided in three stages: In the first stage, the *space-parameters* are defined, in the second stage *time-parameters* are determined as well; and in the third and last stage, the parameters and the variables are combined to calculate the ranges of values of people required according to the different inspection times, operational times and control ranges. All of the last concepts will be explain in the next section.

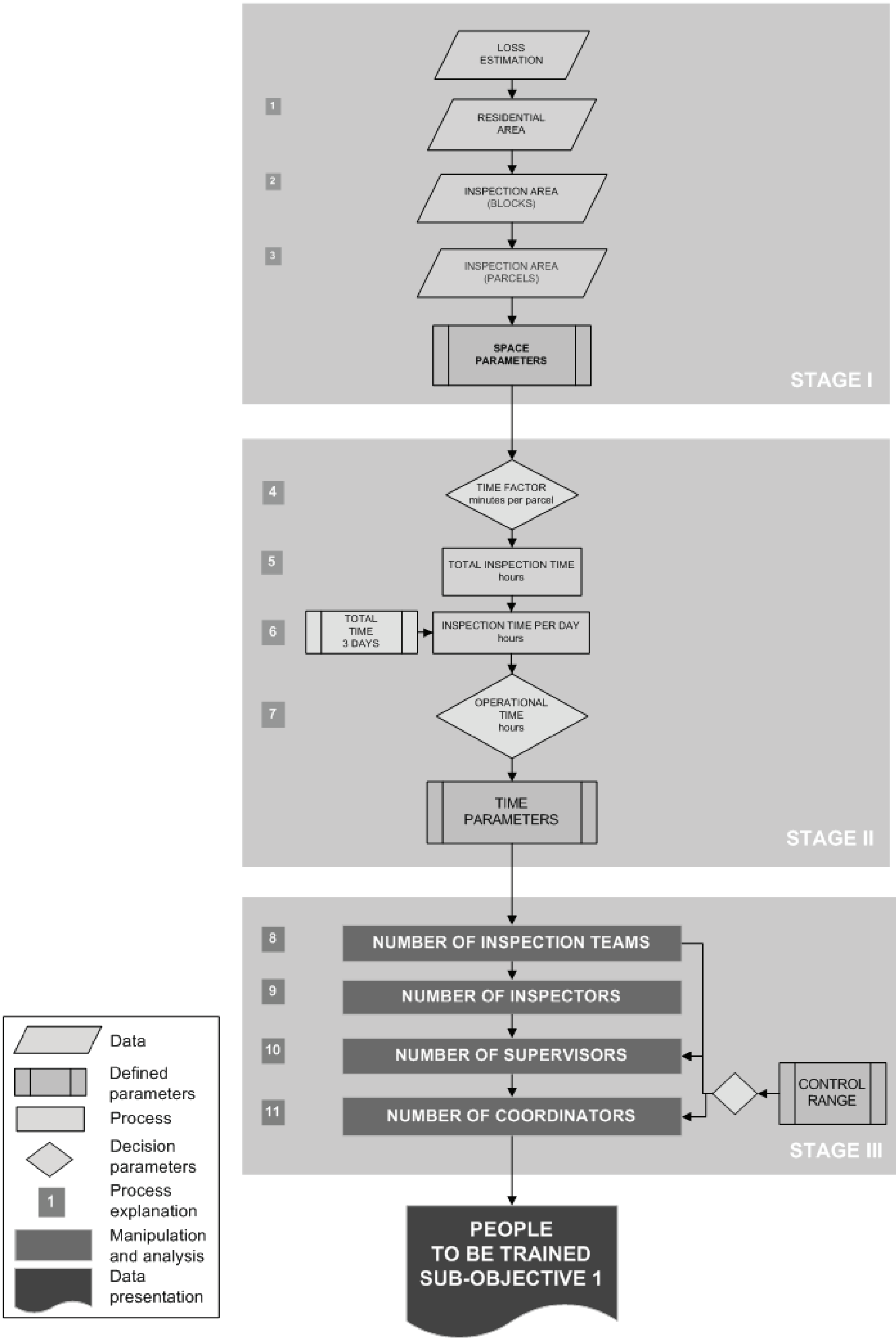


Figure 3-2 Sub-objective 1: Model to estimate the number of trained people required

Defining *space-parameters*: Stage I

Space-parameters are the spatial fixed conditions of the area where the model is applied. The partial model can be appreciated on figure 3-3.

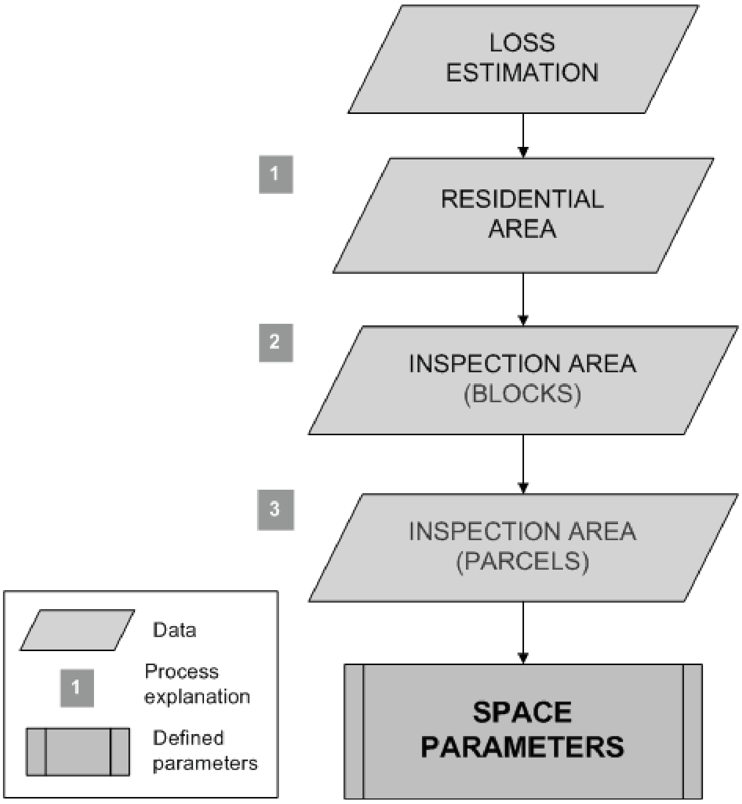


Figure 3-3 Sub-model - *Space-parameters* (Stage I).

The procedure has the following steps:

1. Select by attribute the residential areas, which is the target of the survey. Other land use categories like offices, commercial or industrial is supposed that they have other kind of mechanism as insurance appraisal to assess their condition of safety. Create a polygon layer with the previous selection of the residential area.
2. Delimitate the inspection area in the city according to a selected range of degree of damage. It can be done applying a GIS query to select and create a layer with the inspection area for the different return periods that the emergency response planners or decision makers consider necessary. The output is usually given per blocks.
3. In order to define the number of parcels to inspect included in the inspection area and to disaggregate the degree of damage to the parcel level, two steps are required: firstly, it is necessary clip the parcel layers, using as a clip feature the inspection area for every return period; and then, make a spatial join between the parcels layer and the inspection area, in order than every parcel got the attribute of the percentage of damage according to every return

period. However, the information about the degree of damage per block could be enough, because usually the degree of damage of the parcels must be equal to the degree of damage of the block where they are located**.**

The output in the *space-parameters* model is the input to define the *time-parameters*, which are developed in Stage II.

Defining *time-parameters*: Stage II

Time-parameters are the periods of times in the subsequent stages of the rapid building damage survey. The partial model used to defining the *time-parameters* is shown in figure 3-4.

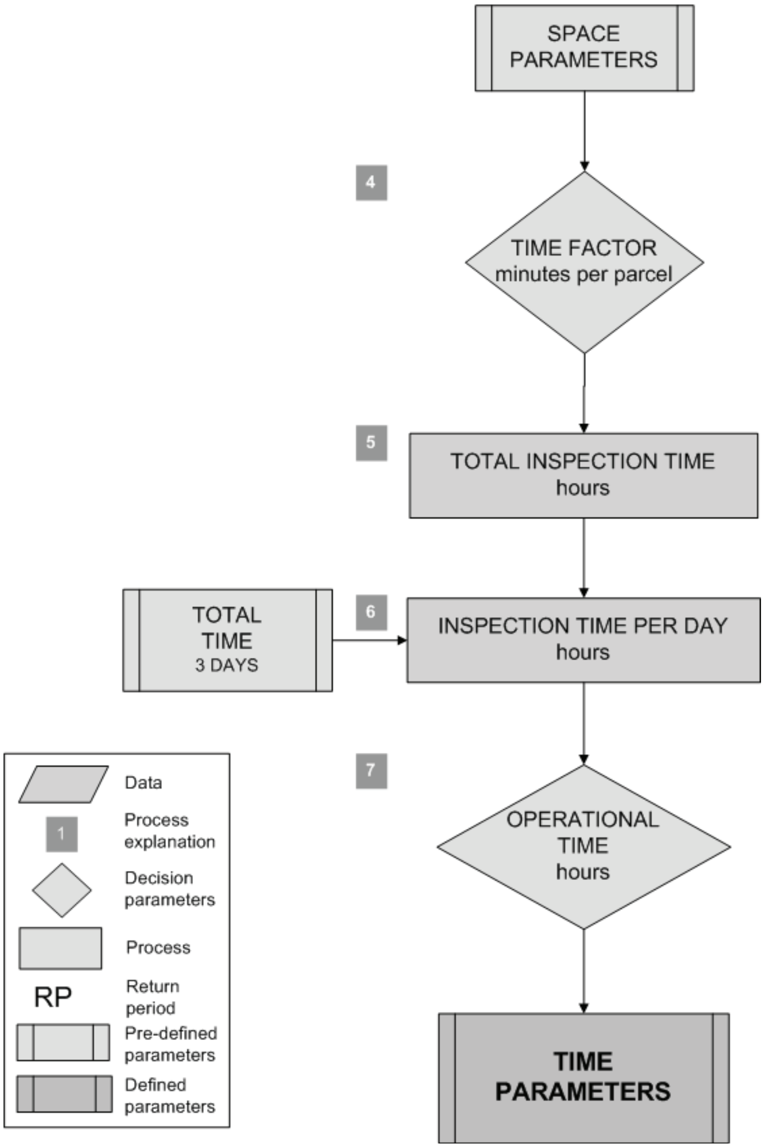


Figure 3-4 Sub-model - *Time-parameters* (Stage II).

- *Response-time:* 1 day. This is the time that takes for every inspector to be ready to start the building inspection task. In this period, the trained people about building damage survey have to check the condition of their family and their properties; the non-affected inspectors should go to the meeting points.
- *Operational-time:* 8, 10 and 12 hours. The operational time is the number of hours in the day to carry out the building inspection. The ICS (Incident Command System) suggest 8 hours as a maximum threshold in search and rescue operations (SAR), due to the stress conditions under which kind of operations are usually done; in spite of the building damage survey is a different activity, the environment is the same. To consider the operational time, it is necessary also take into account the day-light-hours in the city where the building inspection is carried out, to make easy to take the cracks or the fissures in, given that the power facilities could be out of order and the use of another kind of lighting devices might be dangerous, and also because of the security of the surveyors.
- *Total-time:* 3 days. It is the international standard to carry out a rapid building damage survey and also authors as Fiedrich et al. (2000) contends that this time period after an earthquake is crucial to the performance of the relief efforts and they consider that the stabilizing work, defined as the evacuation of people located on areas prone to e.g. damaged dams or damaged building with high risk of collapse, is a high priority task during this term.

4. In order to estimate the inspection time, the total inspection time is determined by using the number of parcels, times predefined inspection times (10, 15, 20, 25 and 30 minutes per parcel), which give different options to look ahead the survey according to the available people and the number of parcels to inspect, in real time.
5. The total inspection time is obtained in minutes and it is necessary to convert it into hours; according to that, the last result is divided by 60 to have the total inspection time in hours.
6. The total inspection time in hours is also divided in 3 (standard number of days to carry out a rapid building damage survey). The output is the inspection time per day based on the assumption that the inspection will be done by the same surveyors all the three days.
7. The inspection time per day could be divided into the different operational times that the emergency response planners or the decision makers consider suitable or necessary. In the purposed model, it will be considered three operational times: 8, 10 and 12 hours. The output of this operation will be the number of teams that is necessary to have for every day in the three days.

The *time-parameters* output is the input to start the calculation of the number of trained people required, in stage III.

Estimating the number of teams, inspectors, supervisors and coordinators required: Stage III

In this stage, it is necessary to explain that a team is a group made up by two trained people in building damage survey or building inspectors, those people must be civil engineers or architects, or students in those fields. Every team must have one supervisor and also every supervisor must have one coordinator, who is in charge to make that the information will be displayed in the Emergency Operation Center- (EOC) to the Operations chief and the Incident Commander.

Every supervisor has a limited number of teams and every coordinator has a limited number of coordinators under their control, this number depends on the control range, concept that will be explained below. The organizational chart can be appreciated on figure 3-5.

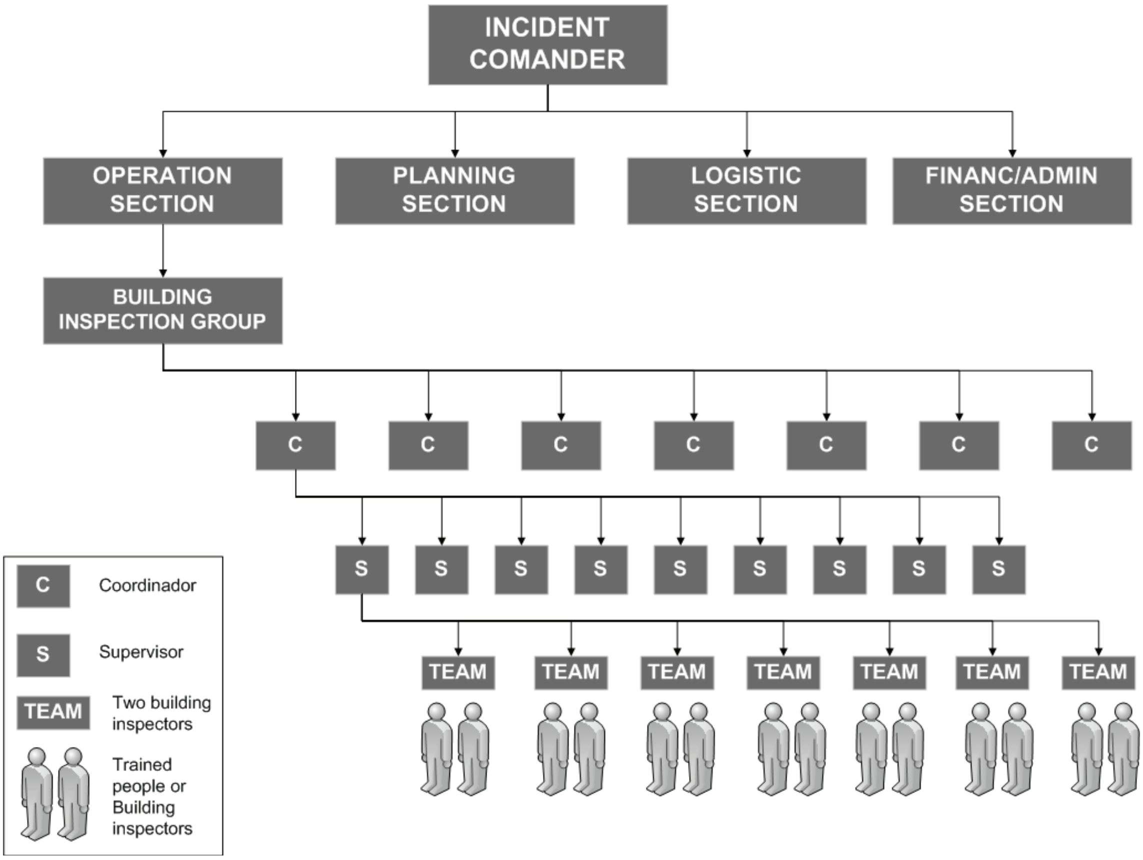


Figure 3-5 Building Inspection group organizational chart

8. The number of teams necessary to carry out the inspection comes from the combination between space and *time-parameters*.
9. To calculate how many inspectors will be necessary to train, the number of teams is multiplied by 2, because every team is made up of two inspectors.
10. In this stage, the control ranges to manage the operation must be decided; the control range in emergency operations is the number of teams or people who can be coordinated or supervised just by one person. Related to the control range, the ICS suggests than an effective span of control ranges from 3 to 7 reporting elements per supervisor, but the present research considers a range from 5 to 9 as the number of elements that it is possible to manage by the human mind at the same time. The number of teams required is divided into the chosen control ranges, for estimating the number of supervisors needed.
11. Additionally, the number of supervisors estimated in the last step is also divided into the different control ranges, for knowing the number of coordinators required for them.

Eventually, it is possible to visualize as the main elements of the model: Space-parameters and time-parameters and the variables that must be taken into account are: Number of parcels to inspect, inspection time per parcel, control ranges and operational times. The space variables are the main input of the time parameters and according to this output the estimation of the number of people is done.

3.2. Sub-objective 2: Allocation of trained people to service areas

The model to be developed in this section aims to create service areas, defined as the inspection areas made up by a certain number of parcels assigned to every inspector in the period of the rapid survey. The main purpose is make an efficient distribution of the resources and the work load between them, in this particular case, the resources are trained people or building inspectors and the aim is to avoid uncovered areas and visit houses twice. The model is presented on figure 3-6.

It is assumed that inspectors will be at home for the time of an earthquake; or at least, this is the first destination of them after the event, in order to check the conditions of their families and properties. Therefore, the allocated service area must be around their houses.

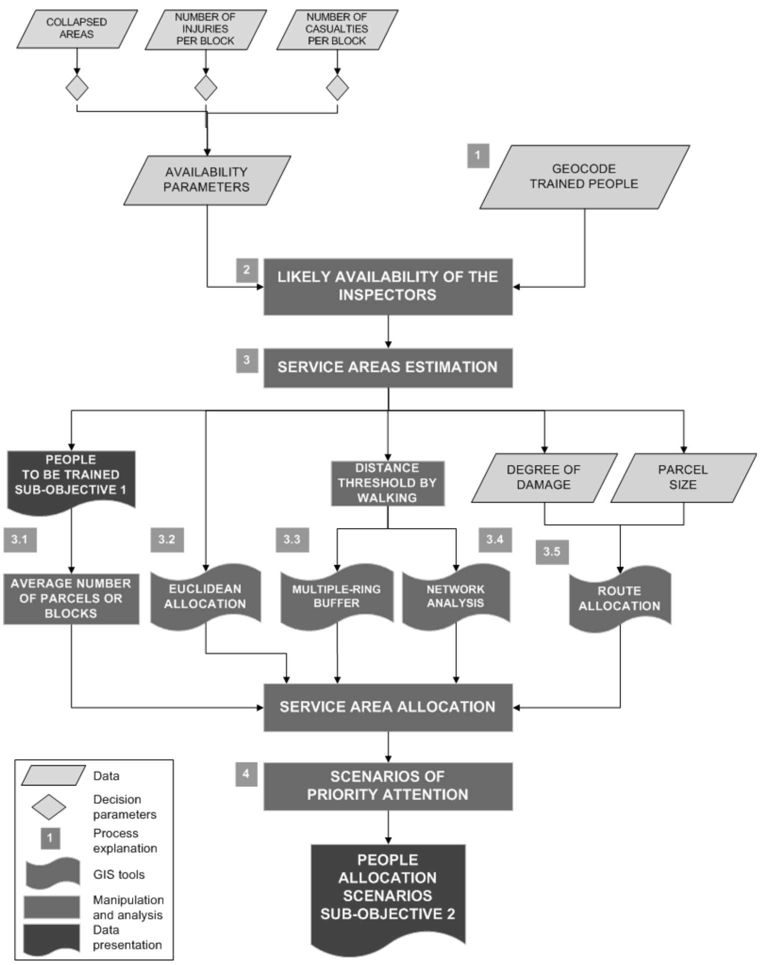


Figure 3-6 Sub-objective 2: Model to allocate trained people.

1. Geocode trained people.
2. Estimate likely availability after an earthquake, by comparing location of trained people with areas with a high degree of damage or a high number of injuries and casualties:

- Collapsed areas (blocks where the degree of damage is greater than >65%). It is assumed that trained people located in those areas will not be available to carry out the inspection and from this assumption it could be possible to have an estimation of the available inspectors.
  To make the estimation of the available inspectors after the earthquake according to the collapsed areas, these are selected by attribute; and later, it is added to this selection the inspector features which intersect with the collapsed areas or are in a buffer of 10 meters. It is considered that inspectors included in these selections, will not be available to carry out the inspection.
- Blocks where the number of injuries is greater than >20. Next, to estimate the number of trained people available according to the number of injuries per block, it is selected by attribute the blocks where the number of injured people is greater than >20; and after that, it must be added the inspector's houses which intersect with that selection or are in a buffer of 10 meters from the preselected area. It is considered that inspectors included in this selection will not be available to carry out the inspection.
- Blocks where the number of casualties could be greater than >15. Then, to estimate the number of trained people available according to the number of casualties per block, it is selected by attribute, the blocks where the number of injured people is greater than > 15 and after that, it is added the inspectors' location which intersect that selection or are in a buffer of 10 meters from the pre-selected area. It is considered that inspectors included in this selection will not be available to carry out the inspection.

Finally, it is necessary to take the loss scenarios layers (collapsed area, number of injured people per block and number of casualties per block) and chose from them, the highest value about not available people; or in another way to say, the lowest value of availability, as the worst case.

3. In this step, it is possible to use different methods to estimate the service area, according to the data and the accuracy level that decision makers or emergency planners need. The accuracy level is understood in the present research as the degree of uncertainty that the number of parcels grouped in a service area by the application of this model, will be similar to the number of parcels that can be inspected in the reality.

3.1. *Average number of parcels or blocks to inspect*: the total number of parcels to inspect in every return period is divided in 3 (the standard time to carry out the rapid building damage survey), to know how many parcels must be inspected every day. The number obtained is divided into the number of teams calculated for every return period and according to the different operational times and time factors. The result is the numbers of parcels that every team (two inspectors) will have to inspect in one day. The result is the same for every return period, because it is based on a constant time and a constant number of parcels, just the number of team change to achieve the goal to inspect the number of affected parcels. It is also possible to inference the number of blocks to inspect in one day, through dividing the number of parcels into the mean of parcels per block. Nevertheless, in the real time the estimation have to change because the constant will be the number of inspectors available and the number of parcels to inspect and the variable will be the inspection time in order to achieve the goal of inspect the parcels required in the three days.

3.2. *Euclidean allocation*: in this option a nearest source (inspector location) is calculated for each parcel and it could be a starting point to allocate a service areas. The Euclidean raster is converted to a polygon, in order to know how many parcels are covered and uncovered in every seismic scenario. The number of parcels is estimated selecting by location the parcels included in the inspection area, which intersect or not with the polygons.

Distance threshold by walking: Aim to estimate the service areas, it is compulsory to decide the maximum distance threshold or "the acceptable service distance" (Batanovic et al., 2009) that the inspectors must walk to inspect the farest buildings in their allocated service area; the inspectors have to cover the inspection areas by walking and the maximum travel time must be one hour (origin – destination and destination-origin) as an "acceptable travelling service time" (Batanovic et al., 2009), because the idea is not spend more time walking than in the inspection task; taking into account the average walking speed in the humans (4 to 5 Km/hr), the idea is to use the value of 5 Km as a maximum threshold distance to fix the boundaries of the service area and divide the service areas per day along the three days based on it as it is explained in table 3-1. In this alternative there are two methods applied: A multi-ring buffer or service area using network analysis.

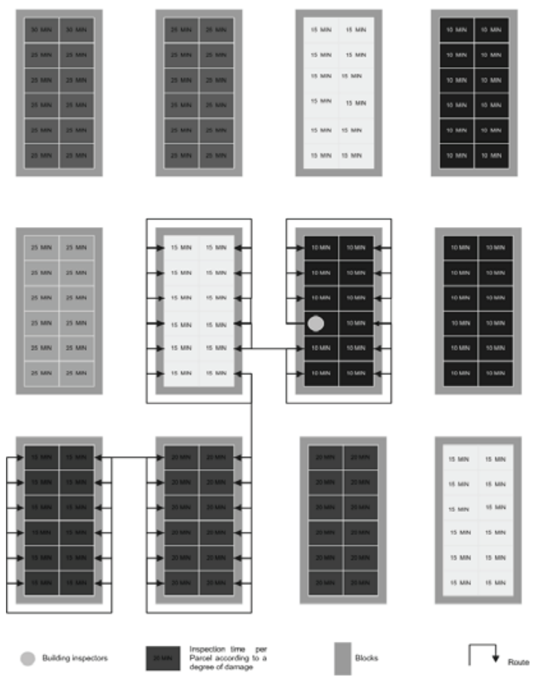
PERIOD	TOTAL DISTANCE (origin – destination and destination – origin) meters	DISTANCE (origin-destination)	DISTANCE (destination -origin)	TOTAL TRAVEL TIME (origin – destination and destination – origin) minutes
First day	1667	833	833	20
Second day	2500	1250	1250	40
Third day	5000	2500	2500	60

Table 3-1 Walking distance in a service area.

3.3. *Multi-ring buffer*: the distance-to-walk every day could be used as the first approach; or as the only alternative when the data about roads is not available. To estimate the coverage level, it is selected by location the parcels that intersect with the buffers and then to know the covered areas, and then switch the selection to have a view of the uncovered areas.

3.4. *Network analysis (service area)*: when the data about roads is existing, the allocation of the service areas can be figured out using network analysis, but to see in a clear way the boundaries of the service areas it is important in the polygon generation tab check *Not overlapping* option.
This method allow to know how many people do not have any allocation; in order to do it, it is selected by location the features from trained people available that are completely within polygons (service areas) to see people with service area allocated; then, it is necessary to switch the selection, to appreciate people without allocated area. To know the coverage of the service areas, it is also necessary select by location the parcels which intersect with the polygons (service areas) to see the covered areas and; then, switch the selection to know how many parcels do not have anyone who inspect them, in order to later allocate people to those areas.

3.5. *Route allocation*: the route allocation is the route of every inspector. The route is designed according to the inspection time that every house may require according to the degree of damage estimated. The seismic scenarios estimate a degree of damage per block in each return period and it is possible to make an assumption of the inspection time required per parcel according to their respective degree of damage, as it can be observed in table 3-2. The path start on the inspector's house and when they head off their own house, they will continue in a clock wise direction during the operational time (8, 10 or 12 hours). The inspection time per house included in the route will define the size of the inspection area. The analysis to design the inspector route is based on a *network analysis (the best route)*; First, the polygons of the parcels must be converted into centroids; second, the attribute of the inspection time must be added to the attribute table of the parcel-centroids; third, a new route layer must be created; fourth, the centroids of the parcels with the attribute of the inspection time are loaded to the stops; Fifth, a stop must be put in every parcel to inspect in the day according to the value already calculated in the method of *Average number of parcels or blocks to inspect.* Next, the program calculates the route and symbolizes the stops, it is possible to know the total inspection time in a day from the attribute table of the route layer, and the same procedure it is done for the next two days. It is necessary reorder the stops, aim to the starting point will be the inspector's house and the order of the stops follow the clock wise logic. Figure 3-7 shows a schematic example of a route allocation to one inspector based in the inspection time, when the operational time is a period of 12 hours.



DAMAGE DEGREE	**INSPECTION TIME** minutes
15% - 25%	10
26% - 35%	15
36% - 45%	20
46% - 55%	25
56% - 65%	30

Table 3-2 Required inspection time per parcel according to the degree of damage.

Figure 3-7 Schematic allocation route according to the inspection time (operational time: 12 hours)

4. Display the different priority scenarios. Priority is something that must be dealt with, as soon as possible. In a rapid building damage survey after an earthquake, some areas in the city must be inspected first. The priority could depend of the degree of damage in some areas or the size of the population located there, or even because of the occurrence of secondary effects, like landslides or fires.

In this research, four priority scenarios are displayed using Community Viz. This application is a multi-dimensional GIS decision-making software, which it is used to analyze choices about development, growth and change in the future and also make and share decisions about geography, community and land; but in the present research it is used to display areas to be inspected with priority according to some pre-defined criteria.

The tool of *suitability wizard* in *CommunityViz* is applied to make the attention priority analysis, in order to have a view of the different attention priority over the areas in the city, and especially in the uncovered areas, to later allocate them to building inspectors. To carry out the analysis using this software application, two kinds of layers are necessary: one *suitability layer* and *other layers*. The *suitability layer* is the dynamic layer that contains the features whose suitability or attention priority, it is necessary to be measured in the present research. The *other layers* are the layers used to measure the attention priority that in this case correspond to proxy indicators as it was done in the research carry out by Benini et al. (2008).

The parameters that must be taken into account in the model are related to the availability of the inspectors according to their location compared with the collapsed areas and the blocks with a high numbers of casualties or injuries. The assumptions are regarding to the location of the inspectors and their likely availability. The main criteria to allocate people is avoiding displacements into the city and according to that, the allocation of the service area is made around their houses without taking into account the time of the earthquake (day or night) because, even if they are not in their houses, it will be the first place to go after it. The model could be adjusted in the real time according to the data available at the moment, and the criteria that decision makers decide in order to give priority to some areas. The indicators of the effectiveness of the model application are the coverage of the building inspectors in real time, because it will possible to inference which allocation method represent in the best way, the real operation on fieldwork (accuracy level), and this result is the input to calibrate and validate the model.

3.3. Sub-objective 3: Development of Information management model

The information must be a concern before, during and after the event to ensure that updated data, tools to capture information, logistic to transmit the information collected and the database to calibrate the models always will available. In the present research was designed the flow to manage the information before and during the event.

The present model presents the way to manage the information before and after the earthquake happen, because the conditions (completeness, updating and sharing) under the information are handled before will determine the flow of the information after the event and the actions that decision-makers implement in the recovery phase.

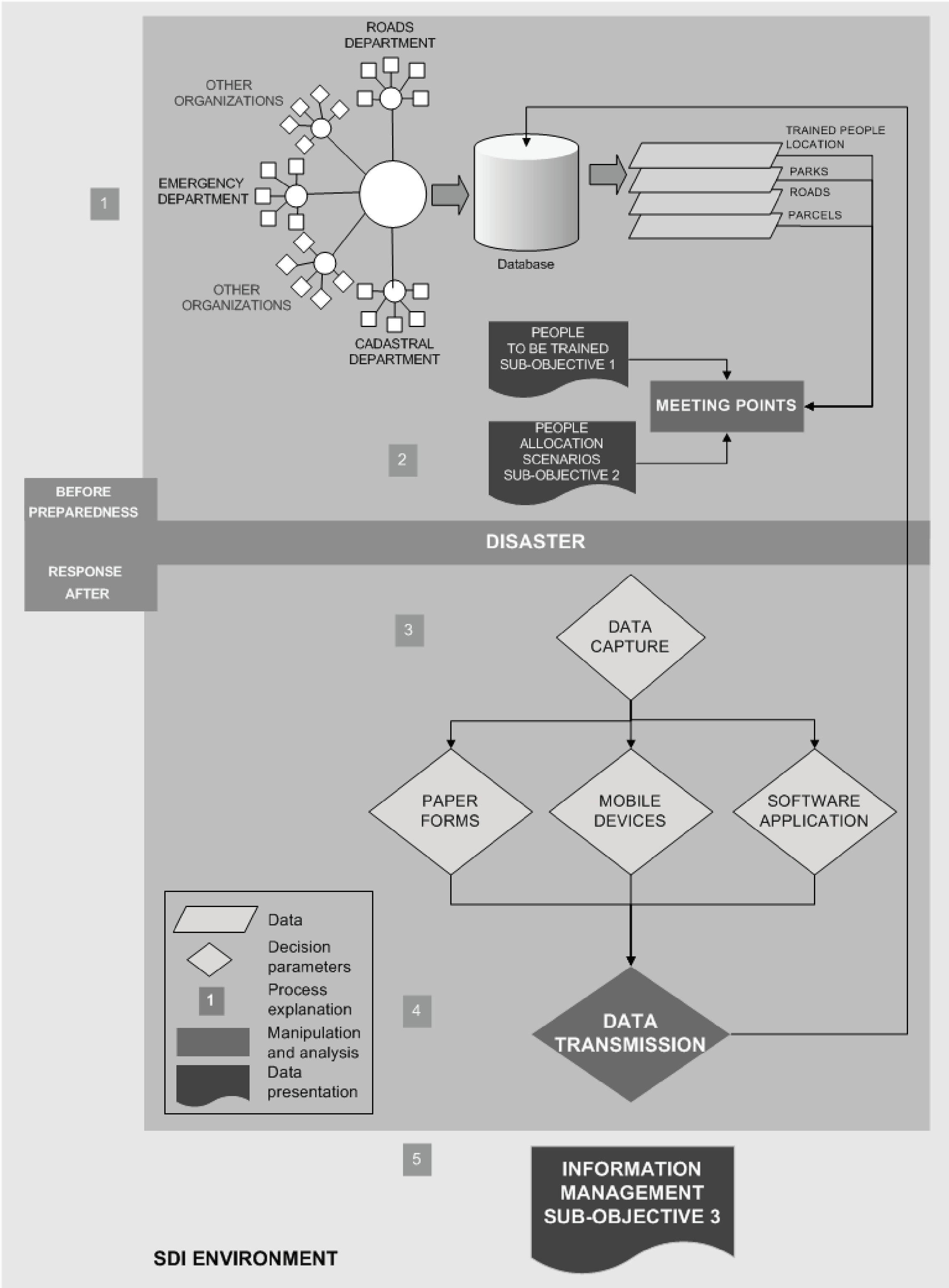


Figure 3-8 Sub-model 3: Information management

1. The model is based on a Spatial Data Infrastructure – SDI, as a concept of partnership in "data production, sharing and exchange"(Mansourian et al., 2006). The model is developed in a SDI environment as a framework for the development of total web-based system; in spite of its

design is beyond the scope of the present research. It is considered due to the importance that all the entities involved in the emergency response task have a framework to collect, store, access, update and the most important share information before, during and after any disaster. Every organization involved in disaster management have the responsibility of producing, updating, and maintaining required spatial datasets for disaster response (Mansourian et al., 2006) in the preparedness phase

During the response phase, the data to be collected in a rapid building damage survey must allow to the emergency management staff or incident command staff: check the information from remote sensing sources about the most affected areas, know in detail the habitability conditions of the houses in the city, estimate how many temporary shelters are required and where building materials are required to repair houses, determine where a detailed building damage survey is necessary and which kind of skills could be necessary (geotechnical, structural or relative to lifelines) to carry out the detailed survey in those parcels. The extended model is displayed on figure 3-8.

2. The spatial datasets of trained people, service areas and parks must be combined to define the meeting points. In the present research, it is considered the parks as the best places to be meeting points, not only because they are identified in a easy way for the community, but also because they are not built-up areas, it means that there is no possibility that they collapse due to the earthquake or the aftershocks. The meeting points must be equidistant points to the service areas or the location of certain numbers of inspectors according to a pre-defined control range.

   The first criteria to allocate a meeting point is to look for a way to district or zoning the city, to group the inspection teams, that can be also figure out grouping the service areas already estimated in districts or zones. The analysis starts selecting by location the parks located in every zone, in order to identify how many they are, and to have a view of their spatial distribution. The analysis continues looking at the inspector location. From the last selected features, two methods can be used:

   - Central feature: This method is going to identify the most centrally located inspector between the group defined in the control range; and according to the result, the nearest park of the output feature will be selected as a meeting point. The input feature class is the inspector's location and there are two distance methods: euclidean distance (the straight-line distance between two points) and Manhattan distance (distance between two points measured along axes at right angles).
   - Mean Center: Before using this method, one step must be done before and it is to convert the polygons of the parks into centroid points. The input feature class is the centroids of the parks and the output is the geographic center of the parks included in the zone; from this point, the nearest park to that geographic center is selected as the meeting point. Another way is also to use as input feature the location of the inspectors and also from the output to select the nearest park to be the meeting point.

3. The data capture could be done in paper forms, mobile devices or using a software application that could run on PalmOS, or be compatible with platforms such as Smart Phones (iPhones, BlackBerries, Nokia, etc.). Information from the second model must be retaken, relative to service areas and route allocation in order to define meeting points.
4. The conditions to select the efficient way to transmit data depend on the media to collect the data and the conditions on field. In the case that data were collected using mobile devices, the technical specifications of them must be also taken into account to decide how to transmit data. If the data is collected manually, it is necessary calculate also in model the number of people required to digitize the information. The information collected must go to the database that the entities involved in the emergency response have in common, in order to during the emergency stage re-distribute resources (building inspectors, ambulances, fire engines, etc) and after the emergency stage, make a feedback; and in the case of the model developed here, calibrate it and validated
5. The tools used to capture and transmit data must be combined with the organization detailed in the model 1 to design the information flow.

It is necessary to have hazard and vulnerability data updated or the elements that are usually included in a vulnerability assessment such as population census, cadastral data and roads; additionally, to carry out the building damage survey it is necessary to have the location of the trained people and the parks, as well. This research consider three options to collect the information on field: Paper forms, mobile devices and a software application that can be run on handheld computers or smart phones. The information management should be done in a SDI environment and a web-based system to be sure that there will be shared information at the moment of the event. It is desirable to have indicators since the first day, not only about the safety of the buildings but also about the implementation of the operation itself. The last information will be the input to calibrate the model for the next day; and eventually, the total database with the performance indicators of the operation will be useful to validate the entire model.

4. Results

This chapter presents the outputs of the research process. The first part presents the characteristics of the case study city. The second provides a vision of the work done and the results obtained on field and the next three sections display the results of applying the methodology described in the last chapter.

4.1. Case study area

The study area is Bogotá D.C., the capital city of Colombia. The city is located in the centre part of the country, on a plateau (elevation of 2.640 meters above sea level) of the Eastern mountain range of the Andes, as it is shown in figure 4-1.

The area extends from 3°41'24"N latitude to 4°49'54"N and longitude 74.3 °W. Bogotá D.C. has an area of 1.587 square km and it has approximately 6.776.000 inhabitants; but the metropolitan area has a population of 7.881.2000, according to the census made by DANE in 2005.

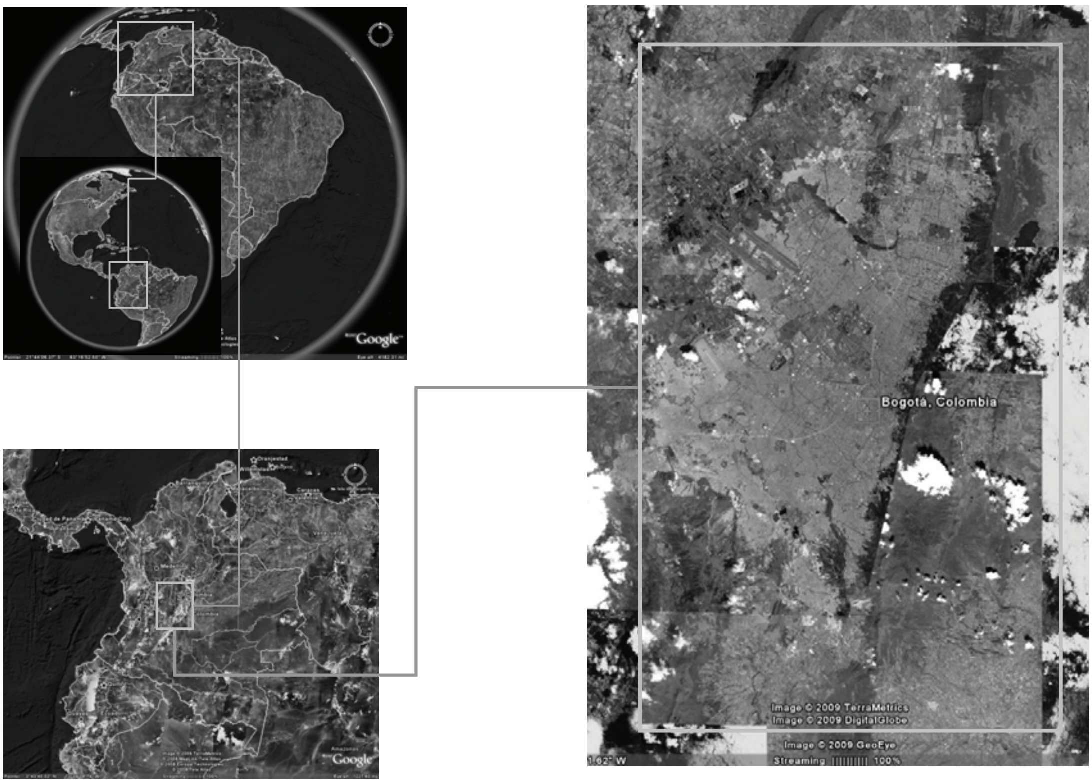


Figure 4-1 Study area location
Source: Google Earth

Bogotá D.C. is the most populated city in Colombia and is the political, financial, administrative, commercial and cultural centre of the country.

This city was selected as a case study because it is located in a medium hazard seismic zone in a country close to the meeting point of four tectonic plates: Suramericana, Nazca, Cocos and Caribe; and included along the “Pacific Ring of Fire”, reason to have a high seismic activity. This city has not been struck by a strong earthquake since 1928 (Unidad de Prevención y Atención de Emergencias - UPES, 1997), which means that there is a high probability of that a strong seismic event occurring in the coming years.

Taking into account the last, the Major of Bogotá D.C. through DPAE has been studying the seismic hazard and the vulnerability and the risk condition of the city, based on scenarios (RP 250, 500 and 1000 years). The mentioned scenarios are the input of this research and it is also a reason to select this city as the location of the case study, because it is not easy to find a place where the government had made too many investments to know the risk condition looking ahead to take up the preparedness labor.

The total number of parcels in Bogotá D.C. is 887.727, which includes 675.588 (76%) residential parcels. Every parcel might be made up of more than one building but for the research purpose, it is assumed that one parcel just contain one building. The relationship between the seismic scenarios and the number of parcels affected can be appreciated in table 4-1.

The advances in the training process about building damage survey as preparedness activity was another reason to select the city as the case study place. This training has been done at first between 2002 and 2003 by DPAE, and later from 2007 until now by the Universidad Distrital under DPAE.

This research is part of the Emergency prevention and attention plan in Bogotá D.C. (PDPAE) in the sector management agenda relative to construction issues. The plan looks for supporting research studies, related to improve the knowledge in the emergency preparedness and disaster response domain. The methodology of this research is going to be considered in the Emergency Plan of the city.

S	SEISMIC SOURCE	MAGNITUDE (Ms)	SEISMIC RETURN PERIOD	PEAK GROUND ACCELERATION (Cm/S^2)	DEPTH (Km)	DISTANCE EPICENTRAL AVERAGE (Km)	RESIDENTIAL PARCELS AFFECTED
1	Frontal Cordillera Oriental	6.8	250	109	23	39.5	106.838
2	Frontal Cordillera Oriental	7.4	500	170	23	39.5	318.945
3	Frontal Cordillera Oriental	7.6	1000	200	23	39.5	362.898

Table 4-1 Seismic scenarios

4.2. Fieldwork results

4.2.1. Surveys

In the period between 2002 and 2003 and since 2007 until now, DPAE trained around 1000 people in the procedure to inspect buildings after an earthquake, as a preparedness measure. The database was organized by changing the order of the attributes, the useless data was removed and the remain was updated.

The original database of trained people between 2002 and 2003 was reduced from 1064 items to 751 (29%) because some people were registered twice; others left Bogota to live in another city, while others migrate to others countries; another people use to live in towns near to the city, which is not useful for the exercise; in some cases, there was not enough information to contact people; other people were trained, but they did not have the right academic background to carry out the building inspection, e.g.: economist, electrician, administrators, etc. and finally, people who did not remember to have been trained, were removed.

A questionnaire was designed and translated into Spanish (appendix D). The survey asked if people remembered to have been trained, the topics discussed in the presentations and if they still keep the material given at that time (the technical booklet for building damage survey after an earthquake, the operational booklet for the building inspection group and the general building damage survey form); this questions in order to introduce the person in the topic. However, the most important question for the purpose of this research was in the end, to test the desirability of the person to carry out the building damage survey, in the case it was necessary.

For the survey, people were contacted via e-mails and phone calls, 824 e-mails were sent, 986 phone calls were made to home or business phone; it depended if the call were made on a business day or in a weekend. Phone calls were made to trained people with wrong e-mail address (bad written or nonexistent), to sent the message again and update the database with the right e-mail address; afterwards, phone calls were made to people who did not have any e-mail address registered in the database; finally, after three days since the message was sent, every person who did not reply to the message with the survey, were also called.

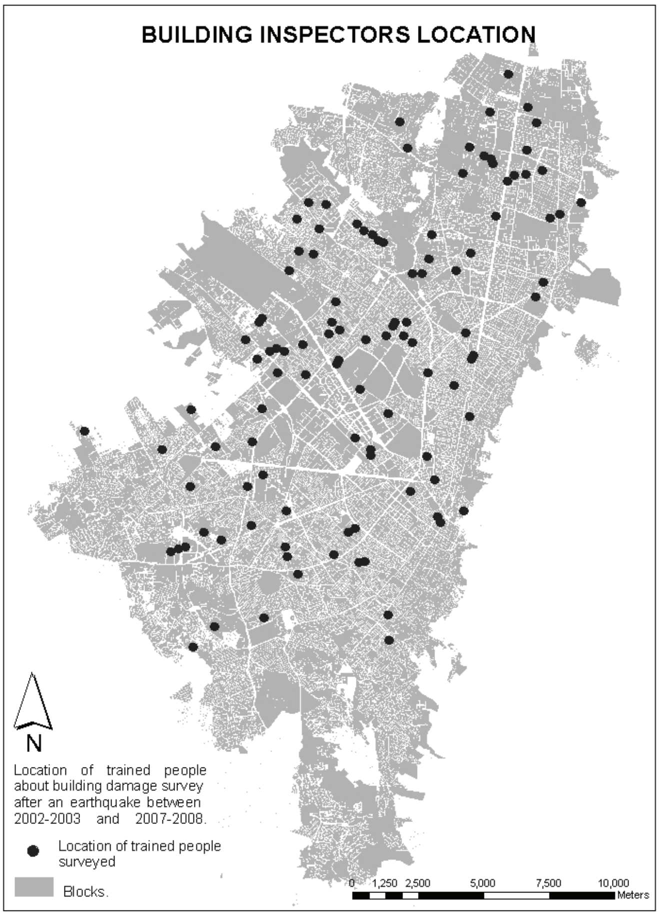
121 (15% of the total study population) people answered the survey, based on a total database of 791 people. 99 (13%) people trained from 2002 to 2003 answered the survey from a total of 751. 22 (55%) people trained between 2007 and 2008 answered the survey, from a total of 40 people. See the characteristics of the survey and the sampling on table 4-2 and the survey results in appendix E.

The sample size is defined by the trained people who answered the survey. The sample size from the study population 2002-2003 is made up of 99 people, 13% of the study population. The sample size from the study population 2007-2008 made up of 22 people, 55% of the study population. Eventually, 121 trained people answered the survey, it represents (15%) of the total study population.

TRAINED PEOPLE 2002- 2003 (Study population)	751 trained people
STUDY POPULATION 2007-2008 (Study population)	40 trained people
SAMPLING DESIGN	Non-random / probability sampling
	Accidental sampling: People who respond the survey sent by e-mail or by phone. Quota: 10% sample size (79)
OBJECTIVE	To test the amount of people available to carry out the building damage survey.
E-MAILS	824
PHONE-CALLS	986 (Home phone/ business phone)

Table 4-2 Characteristic of the survey and sampling

The survey allows to have a view of the spatial distribution of the people available to carry out the inspection and the estimated coverage of the city.



After geocoded, it is possible to conclude that trained people is spread out over the city in an apparently equitable way; there is just a light concentration in some areas in the North-East. However, we can say that there will be an acceptable coverage in case that the service of the building damage survey will be needed. It is illustrated on figure 4-2.

In the sampling, 97% of people show availability to participate in the building damage survey, meaning that there is a big interest in the topic.

Most of the people surveyed remembered to have been trained (97%), but less people (25%) remember all the topics discussed in the lecture and only 32% say to keep the material that were given in the lectures.

Figure 4-2 Location of the trained people who answer the survey.

Trained people in the survey who expressed their availability are almost 100%, this result is the main input to estimate service areas and make the route allocation.

Fieldwork results point to significant availability to carry out the building inspection between people, even if the training was done some years ago but a few of them remember the content of the lectures and the material given for that time, which is not suitable because also the aim of the survey is to have a standard criteria to determine the safety condition of the building.

4.2.2. Interviews

People were contacted in DPAE, the office in charge of emergency management in Bogota D.C; also, in IGAC (Agustín Codazzi Geographic Institute), the institute which address all the issues related with the cadastral information in Colombia, and finally in DANE (National Administrative Department of Statistics), the department who dealt with the statistics data in Colombia.

In DPAE, people were contacted in the departments of Direction, Emergency, Territory, Sector and Research and Development; and in the two last departments mentioned, mainly the construction and the geo-information system group were required for information. Before travelling to fieldwork, a brochure was sent to them, introducing the proposal document and the defense presentation translated into Spanish. Presentation of the research project to people in DPAE was done for every department.

An interview was done with the preparedness group manager in DPAE, to discuss about the topic of tools and technologies needed to the right flow of information collected in the rapid building damage survey and the existent problems about the information management in the emergency response fields; see remarks on appendix G. Another meeting was done with the person in charge of managing the emergency response, who presented the plan that DPAE already have for the buiding damage survey from which I made a comparison with mine; see remarks on appendix H.

The aim of contacting people in IGAC was to inquire about the preparation process of the cartography to carry out the census 2005 in Colombia, the kind of information required by DANE, the formats, the mechanism to upload the data in the mobile devices, the technical specification of the devices, the time to have ready the information, the update level required and the cadastral information management in the case of Bogotá D.C. It is because the process is similar to the preparation of cartography for making the survey about damage on buildings after an earthquake. See the remarks on appendix I

People in DANE were interviewed about the preparedness to the census, the time needed, the basic information required, the entities involved, the tools and technology used to capture and transmit data, why they took the decision to capture the data using mobile devices instead of paper, as it has been done always; the logistic conditions to delivery material resources and to train people for carrying out the survey, which was the result of using a new technology, which kind of problems they had, and eventually which was the learning about the next census on 2015, in Colombia. See the remarks on appendix J.

4.2.3. Secondary data

The data utilized was mainly the data collected by the Universidad de Los Andes (ULA) in charge of doing "*The risk and loss study scenarios after an earthquake in Bogota D.C.".* The study drew its hazard data from the seismic microzonation study carried out on 1997 by the ULA, DPAE and the Colombian Institute of Geology and Mining (INGEOMINAS). The methodology to calculate the hazard in every scenario utilize the *Poison* seismicity model to determine the activity rate, and to evaluate the effects related to seismic intensity that every seismic source produce in terms of seismic intensity, the attenuation laws deduced to Colombia by Gallego and Ordaz (1999) were used. Then, the dynamic response of the ground is evaluated, the seismic hazard is calculated and the nearest seismic sources to the city are selected, but in the present research just the scenarios when the seismic source is the Falla Frontal de la Cordillera Oriental were taken into account for the analysis.

To evaluate the effects on the main structural types, it is calculated vulnerability functions based on parameters such as estimated seismic acceleration, velocity and displacement at the field level. To establish these functions curves already published in peer-reviewed papers or developed curves in similar projects are applied. In this particular case, it was used results of experimental testing and advanced projects with analytical tends, previously done (CEDERI, 2005).

They mainly collected primary data of the elements at risk: Buildings (built-up date, number of floors, built-up density, etc) and population density. According to this information they produce losses estimation scenarios, which are the one of the main input of this research.

Another data collected was about land use, roads, parks, landslides hazard areas and administrative divisions of the city. To have a view of the requirements about information, documents as well as facilities to make the survey, see appendix K.

4.3. Sub-objective 1: Estimation of the number of trained people required

To identify the areas needed to inspect in the city for every seismic scenario (Return period-RP: 250, 500 and 1000 years) a query was used. In the present research is applied: select by attribute all the buildings in a range of damage between 15% and 65%; this assumption was taken from *"The risk and loss study scenarios after an earthquake in Bogota D.C"* (2005) carried out by ULA (Los Andes University) according to DPAE's requirements. The study states that "*The structures with a loss, less than 15% will not collapse, hence collapse factor FC=0; while structures with a loss greater than 65% will have a degree of collapse, it means (FC=1)"* (CEDERI, 2005). Figure 4-3 illustrate the spatial result of the query in the seismic scenario with a return period (RP) of 1000 years, where is possible to see the size of the inspection area and its degree of damage; the comparison with the others seismic scenarios can be seen on appendix N. The total residential area in Bogota can be seen on figure 4-4.

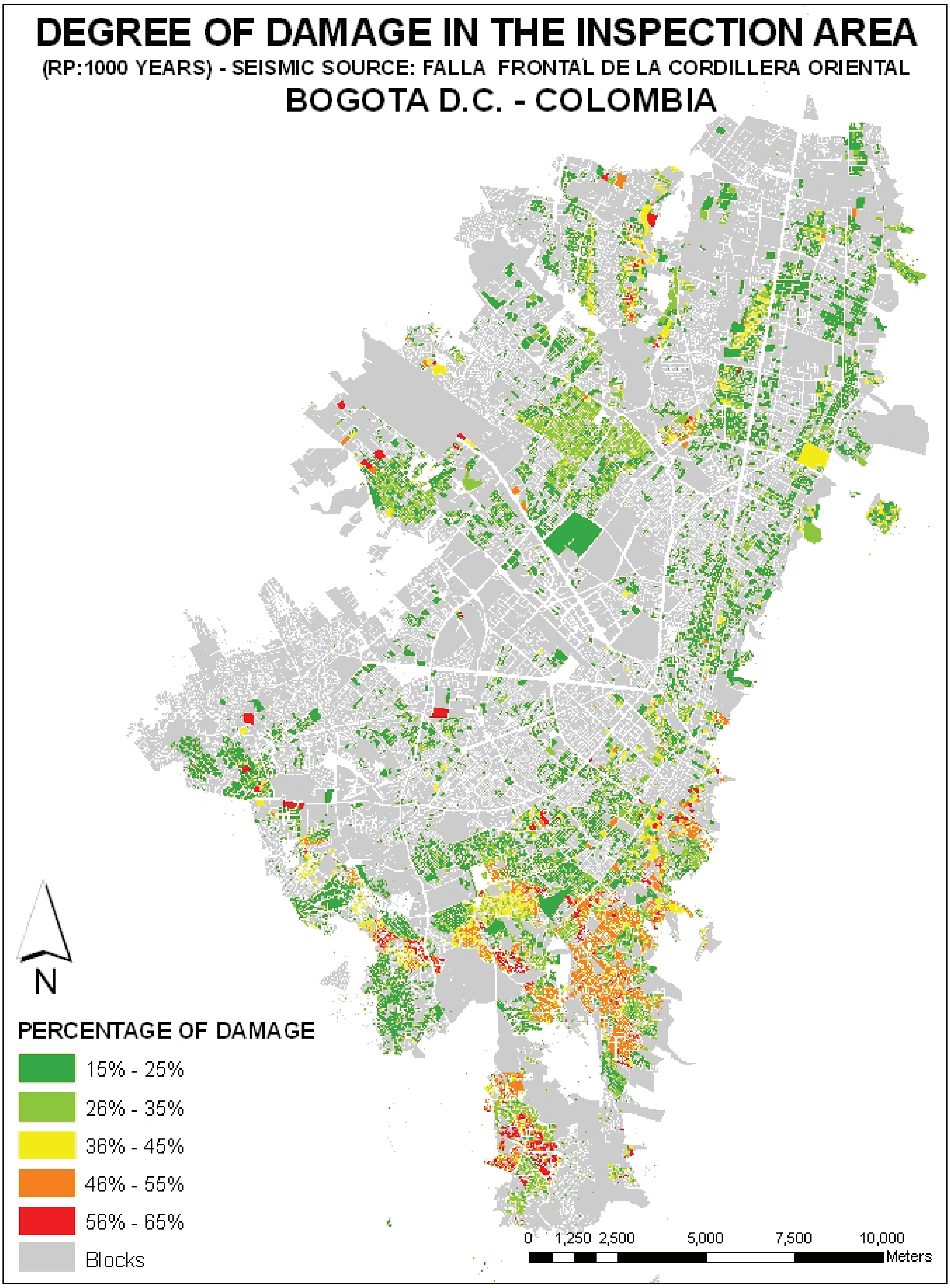


Figure 4-3 Degree of damage in the inspection area for the seismic scenario (RP) 1000 years.

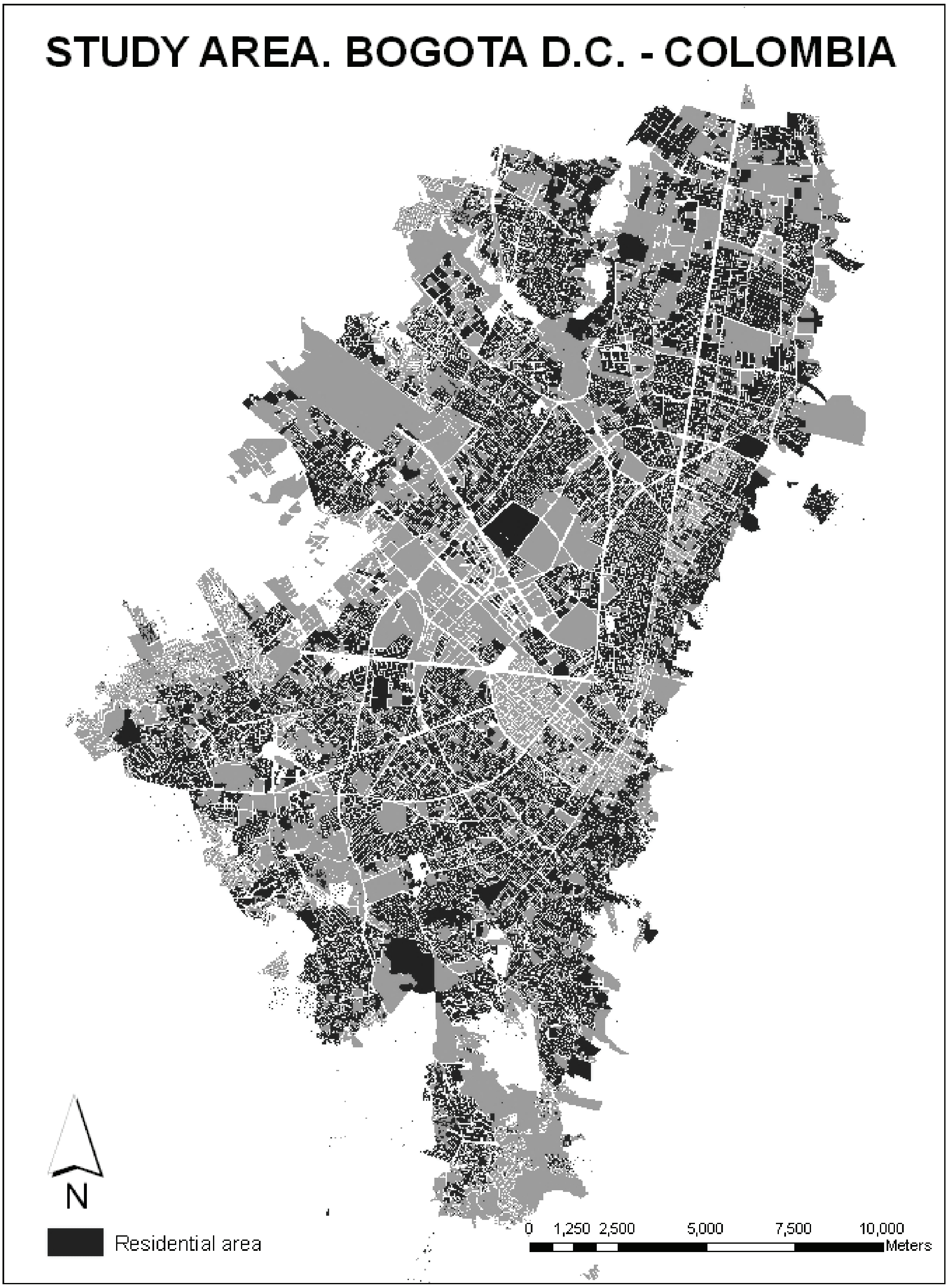


Figure 4-4 Residential area in Bogotá D.C.

The analysis to estimate the *space-parameters* gave as a result that the inspection area is made up of 675.588 residential parcels. Within these residential parcels, the loss estimation scenarios point out that in a seismic scenario of 250 years the number of parcels affected are 106.838 (16%) , in the scenario of 500 years 318.945 (47%) and in the scenario of 1000 years 362.898 (54%).

The time range changes according to the different inspection times per parcel in each seismic scenario, and it goes from 17.806 till 181.449 hours. The inspection time per day to inspect all the parcels required in the three days varies between 5.935 and 60.483, according also to the estimated inspection times per parcel in each seismic scenario.

The number of people to be trained is in a range which also varies from 1.111 people to 18.750. The average number of trained people, taking into accounts the three control ranges (5,7 and 9) is 7.059 people. Table 4-3 show an example of the calculation of trained people required with a control range of 9 units per person. The headings in the table have the numbers, which correspond to the step with the same number, in the model; and the last three columns of the tables show the number of people to be trained or required to inspect according to different inspection times and operational times for every return period (RP). The other tables with the calculation of trained people required according to the different control ranges can be detailed in appendix L (tables 1, 2 and 3).

												CONTROL RANGE - 9 UNITS								
SPACE PARAMETERS		TIME PARAMETERS				7 - OPERATIONAL TIME (HOURS)														
PARCELS TO INSPECT		4 -TIME FACTOR	MINUTES	5- HOURS	6 - HOURS PER DAY	8	10	12	8	10	12	8	10	12	8	10	12	8	10	12
		min per parcel		min/60	Hours/3	8 - TEAMS NUMBER			9 - INSPECTORS NUMBER			10 - SUPERVISORS NUMBER			11 - COORDNATORS NUMBER			NUMBER OF PEOPLE TO TRAIN		
RP 250	**106,838**	10	1,068,380	17,806	5,935	742	594	495	1,484	1,187	989	165	132	110	18	15	12	1,667	1,334	**1,111**
		15	1,602,570	26,710	8,903	1,113	890	742	2,226	1,781	1,484	247	198	165	27	22	18	2,501	2,000	1,667
		20	2,136,760	35,613	11,871	1,484	1,187	989	2,968	2,374	1,978	330	264	220	37	29	24	3,334	2,667	2,223
		25	2,670,950	44,516	14,839	1,855	1,484	1,237	3,710	2,968	2,473	412	330	275	46	37	31	4,168	3,334	2,778
		30	3,205,140	53,419	17,806	2,226	1,781	1,484	4,452	3,561	2,968	495	396	330	55	44	37	5,001	4,001	3,334
RP 500	**318,945**	10	3,189,450	53,158	17,719	2,215	1,772	1,477	4,430	3,544	2,953	492	394	328	55	44	36	4,977	3,981	3,318
		15	4,784,175	79,736	26,579	3,322	2,658	2,215	6,645	5,316	4,430	738	591	492	82	66	55	7,465	5,972	4,977
		20	6,378,900	106,315	35,438	4,430	3,544	2,953	8,860	7,088	5,906	984	788	656	109	88	73	9,953	7,963	6,636
		25	7,973,625	132,894	44,298	5,537	4,430	3,691	11,074	8,860	7,383	1,230	984	820	137	109	91	12,442	9,953	8,294
		30	9,568,350	159,473	53,158	6,645	5,316	4,430	13,289	10,632	8,860	1,477	1,181	984	164	131	109	14,930	11,944	9,953
RP 1000	**362,898**	10	3,628,980	60,483	20,161	2,520	2,016	1,680	5,040	4,032	3,360	560	448	373	62	50	41	5,663	4,530	3,775
		15	5,443,470	90,725	30,242	3,780	3,024	2,520	7,560	6,048	5,040	840	672	560	93	75	62	8,494	6,795	5,663
		20	7,257,960	120,966	40,322	5,040	4,032	3,360	10,081	8,064	6,720	1,120	896	747	124	100	83	11,325	9,060	7,550
		25	9,072,450	151,208	50,403	6,300	5,040	4,200	12,601	10,081	8,400	1,400	1,120	933	156	124	104	14,156	11,325	9,438
		30	10,886,940	181,449	60,483	7,560	6,048	5,040	15,121	12,097	10,081	1,680	1,344	1,120	187	149	124	**16,988**	13,590	11,325
		AVERAGE	**5,257,873**	**87,631**	**29,210**	**3,651**	**2,921**	**2,434**	**7,303**	**5,842**	**4,868**	**811**	**649**	**541**	**90**	**72**	**60**	**8,204**	**6,563**	**5,469**

Table 4-3 Estimation of trained people required according to a control range of 9 units per person.

4.4. Sub-objective 2: Allocation of trained people to service areas

At first, only the trained people who answered in a positive way the availability survey, were geocoded; but later, it was also geocoded people who did not answer the survey. For geocoding, the percentage of changes in address of trained people between 2002 and 2003 who did not answer the availability survey or it was not possible to contact them, must be estimated to know the level of uncertainty; due to the last, it was inferred from the percentage of changing address in the sampling of people who replied the message, and the result pointed to a margin error of 30% in the location of trained people.

The analysis of the trained people location in the study area show that in the case of an earthquake with a return period of 250 years, there will be a lack of coverage in the South East, in the scenario of a return period of 500 years the problem will affect the South East and the North West; and in the scenario of 1000 years, the problem of coverage will worsen in the South and the West. The distribution can be appreciated on figure 4-5.

In the same way, distribution of trained people do not match with the areas where percentage of damage and the location of the number of injuries or casualties is high; it means that the trained people will not be affected largely, therefore the availability will be high; however, a more detailed analysis will be carried out in the methodology of the second model to estimate the likely availability.

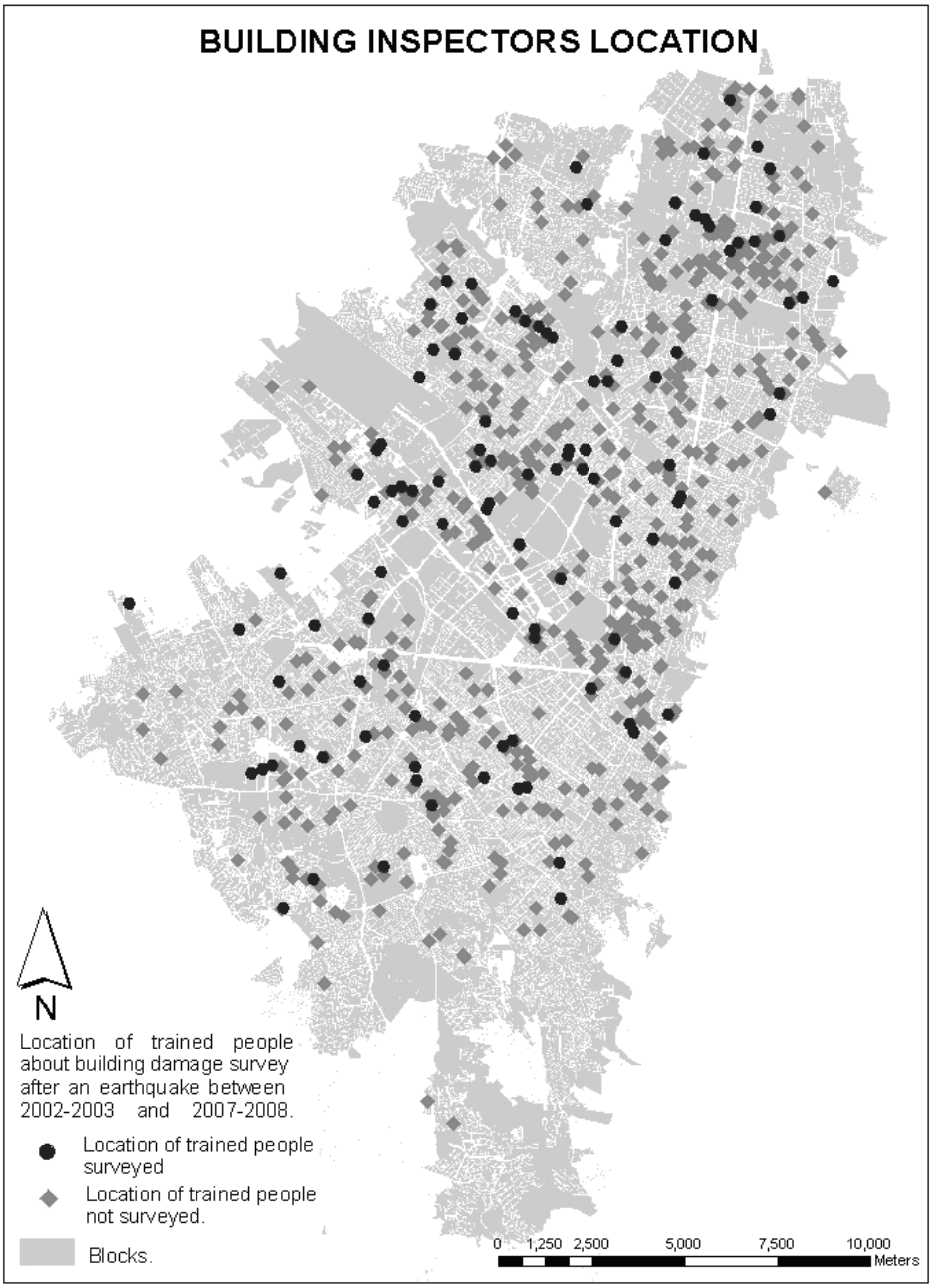


Figure 4-5 Shows in a discriminated way the location of people who answered and who did not answer the survey

The results of the analysis on likely availability estimation according to the collapsed area, number of injuries and number of casualties described in the methodology, show a high availability. In this case, the highest value (23 people) of non available people is chosen and it is observed in the loss scenario related to casualties per block after an earthquake in a RP of 1000 years. Therefore, it is assumed that the number of available people in the scenario will be 712 (97%). In table 4-4 is possible to see the numeric results of the availability analysis of the estimation according to the collapsed area (figure 4-6), number of injuries (figure 4-7) and number of casualties (figure 4-8). The final result of the likely availability is displayed in figure 4-9. The comparison between all the scenarios can be appreciated on appendix N.

LOSS SCENARIOS	SEISMIC SCENARIOS (RP)	NUMBER OF NOT AVAILABLE PEOPLE	PERCENTAGE OF NOT AVAILABLE PEOPLE	NUMBER OF AVAILABLE PEOPLE	PERCENTAGE OF AVAILABLE PEOPLE
COLLAPSED AREA 10 meters Figure 4-6	250	0	0%	735	100%
	500	1	0%	734	100%
	1000	3	0%	732	100%
NUMBER OF INJURED PEOPLE PER BLOCK 10 meters Figure 4-7	250	0	0%	735	100%
	500	8	1%	727	99%
	1000	17	2%	718	98%
NUMBER OF CASUALTIES PER BLOCK 10 meters Figure 4-8	250	2	0%	733	100%
	500	20	3%	715	97%
	1000	23	3%	712	97%
AVAILABILITY AND NOT AVAILABILITY AVERAGE		**8**	1%	**727**	**99%**

Table 4-4 Inspectors availability according to the seismic and loss scenarios

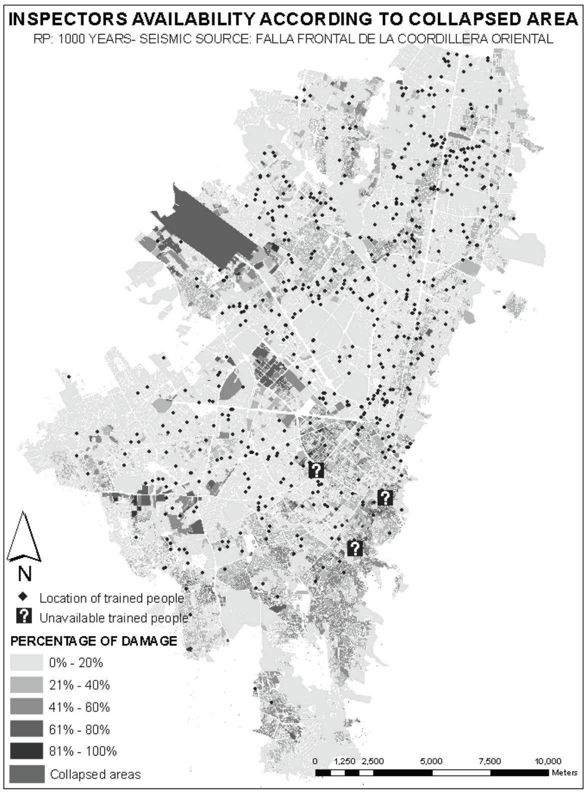


Figure 4-6 Inspectors availability according to collapsed area in the seismic scenario RP 1000 years

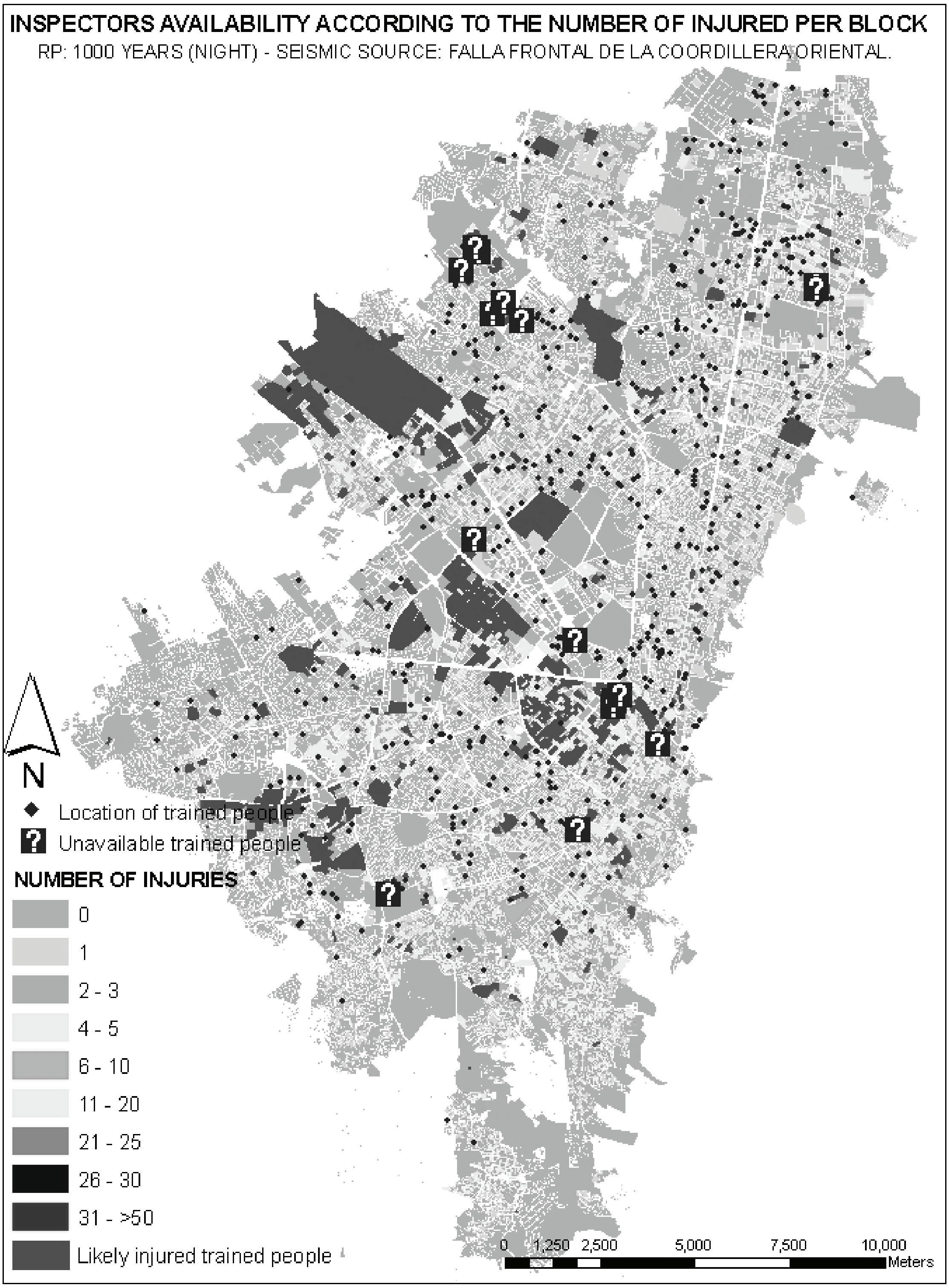


Figure 4-7 Inspectors availability according to the number of injuries per block in the seismic scenario RP 1000 years

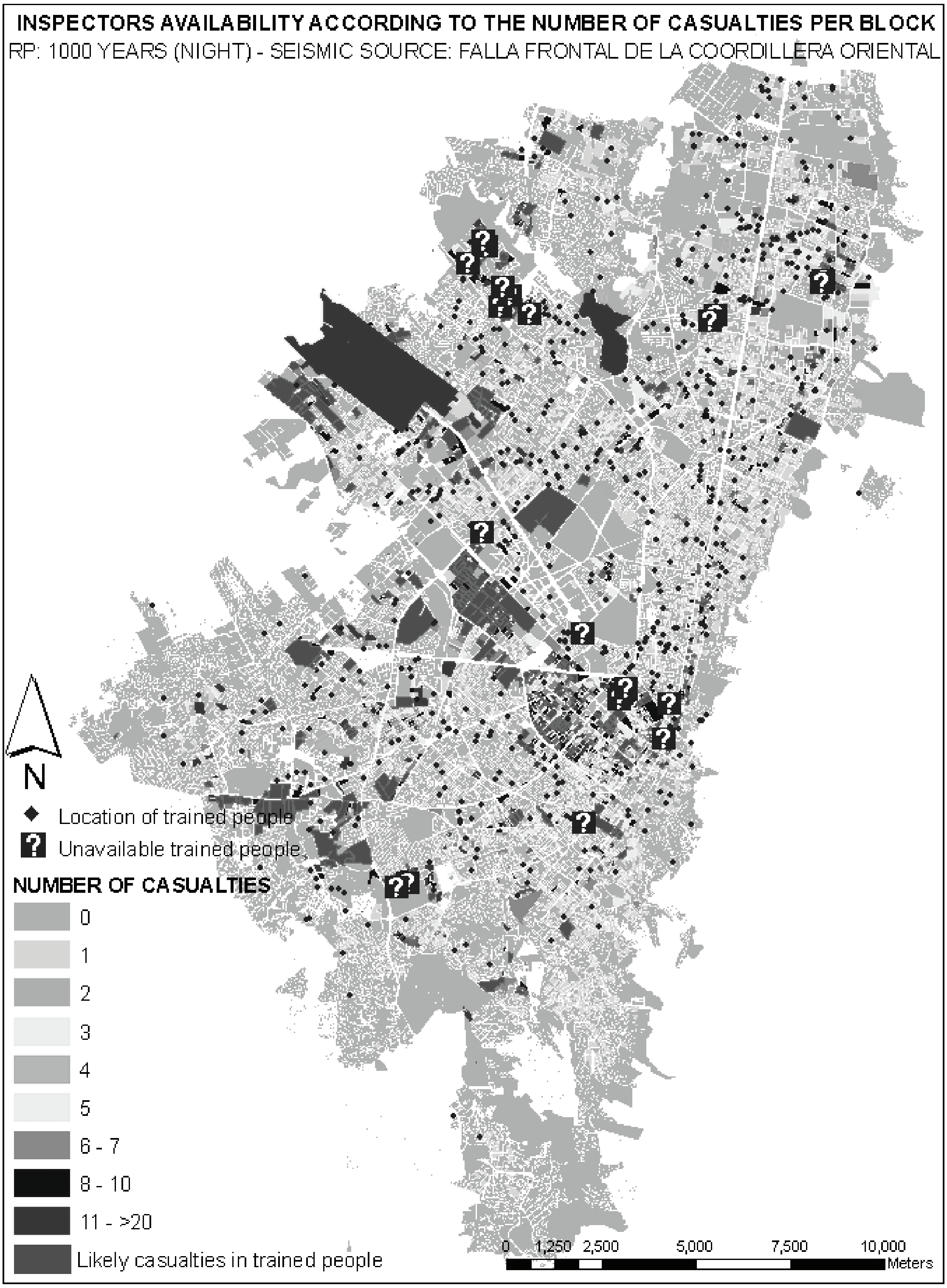


Figure 4-8 Availability according to the number of injuries per block in the seismic scenario RP 1000 years

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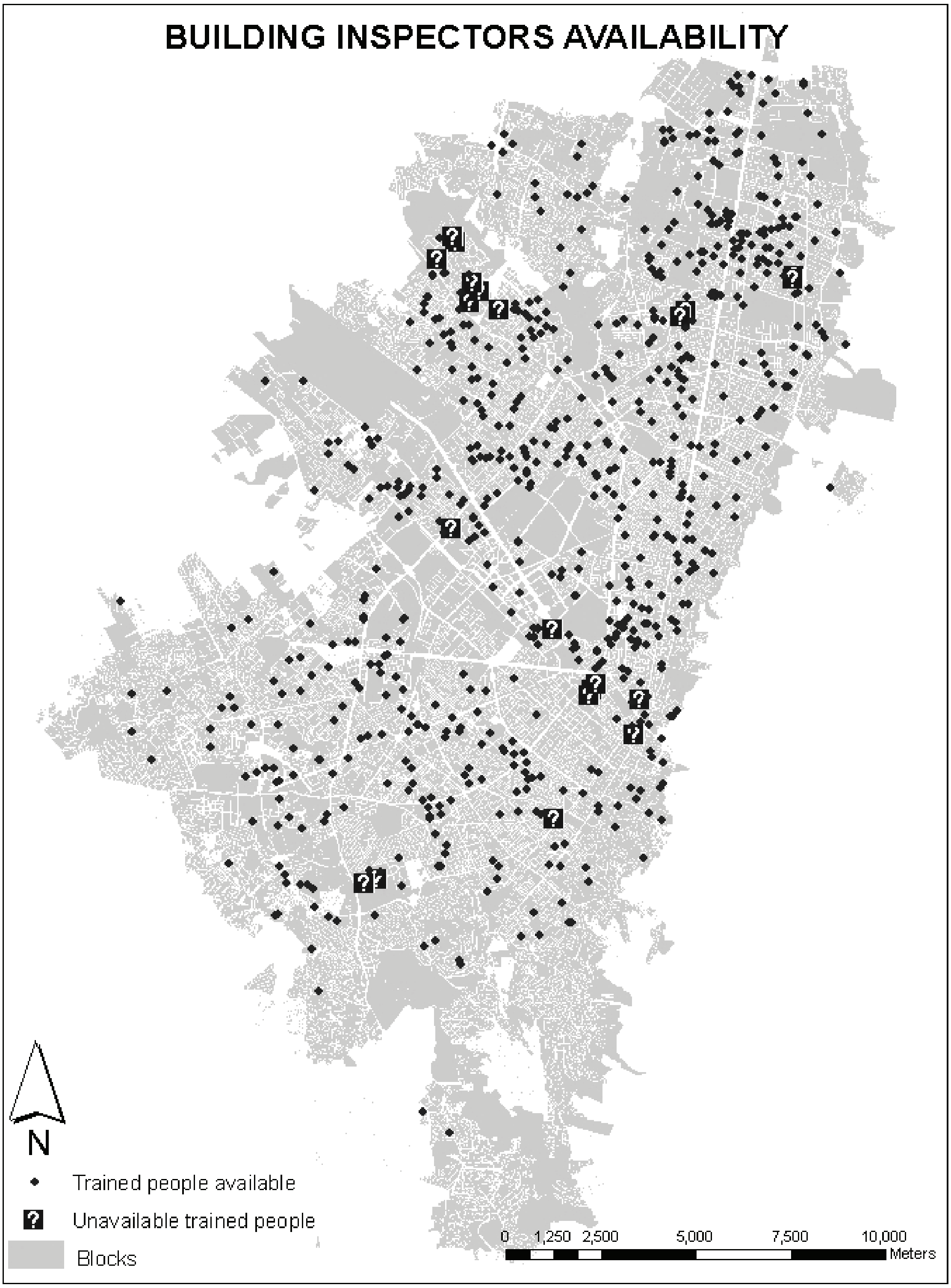


Figure 4-9 Location of trained people available to carry out the building damage survey

The results of the service area estimation are not only the allocation of the inspection area, according to every return period, but also the visualization of the covered and uncovered areas and the zones where the concentration of trained people makes difficult to estimate an equitable service area. Four approaches were applied: One, *average number of parcels or blocks to be inspected for a team in one day;* second, *Euclidean allocation;* third, *multiple-ring buffer, and* fourth*, network analysis (service area)* under the concept of *distance threshold by walking;* and eventually*, route allocation.*

The *average number of parcels or blocks to be inspected for a team in one day* is obtained by using the output of model 1, related to the number of teams and inspectors required, see the result of the estimation on table 4-5. However, it is noted that the result of applying this method is not spatial and it must be used to support the other spatial approaches like *route allocation*.

SPACE PARAMETERS			TIME PARAMETERS			7 - OPERATIONAL TIME								
PARCELS TO INSPECT		PARCELS TO INSPECT PER DAY	4 -TIME FACTOR		5 - HOURS	8	10	12	8	10	12	8	10	12
		Parcels/3	min per parcel	Total minutes	min/60	8 - TEAMS NUMBER			PARCELS TO INSPECT PER TEAM IN ONE DAY			BLOCKS TO INSPECT PER TEAM IN ONE DAY		
RP 250	106,838	35,613	10	356,127	5,935	742	594	495	48	60	72	3	4	5
			15	534,190	8,903	1,113	890	742	32	40	48	2	3	3
			20	712,253	11,871	1,484	1,187	989	24	30	36	2	2	2
			25	890,317	14,839	1,855	1,484	1,237	19	24	29	1	2	2
			30	1,068,380	17,806	2,226	1,781	1,484	16	20	24	1	1	2
RP 500	318,945	106,315	10	1,063,150	17,719	2,215	1,772	1,477	48	60	72	3	4	5
			15	1,594,725	26,579	3,322	2,658	2,215	32	40	48	2	3	3
			20	2,126,300	35,438	4,430	3,544	2,953	24	30	36	2	2	2
			25	2,657,875	44,298	5,537	4,430	3,691	19	24	29	1	2	2
			30	3,189,450	53,158	6,645	5,316	4,430	16	20	24	1	1	2
RP 1000	362,898	120,966	10	1,209,660	20,161	2,520	2,016	1,680	48	60	72	3	4	5
			15	1,814,490	30,242	3,780	3,024	2,520	32	40	48	2	3	3
			20	2,419,320	40,322	5,040	4,032	3,360	24	30	36	2	2	2
			25	3,024,150	50,403	6,300	5,040	4,200	19	24	29	1	2	2
			30	3,628,980	60,483	7,560	6,048	5,040	16	20	24	1	1	2
		AVERAGE	20	1752624	29210	3651	365	30	28	35	42	2	2	3

Table 4-5 Estimation of average number of parcels or blocks to be inspected for a team in one day

The use of the *euclidean distance* method have the advantage that every trained person has an area allocated to inspect, the drawback is that the resulting service areas do not have an equal size and the road data is not considered, hence the accuracy level is low. The results of the application of this method can be seen on table 4-6 and figure 4-10.

SEISMIC SCENARIO	TRAINED PEOPLE AVAILABLE			PARCELS TO INSPECT		
RP 250	**ALLOCATED**	**712**	**100%**	**COVERED**	**100392**	**94%**
	NOT ALLOCATED	**0**	**0%**	**UNCOVERED**	**6446**	**6%**
	TOTAL	712	100%	TOTAL	106838	100%
RP 500	**ALLOCATED**	**712**	**100%**	**COVERED**	**305272**	**96%**
	NOT ALLOCATED	**0**	**0%**	**UNCOVERED**	**13673**	**4%**
	TOTAL	712	100%	TOTAL	318945	100%
RP 1000	**ALLOCATED**	**712**	**100%**	**COVERED**	**348377**	**96%**
	NOT ALLOCATED	**0**	**0%**	**UNCOVERED**	**14521**	**4%**
	TOTAL	712	100%	TOTAL	362898	100%

Table 4-6 Percentage of coverage using *euclidean allocation* method in every scenario

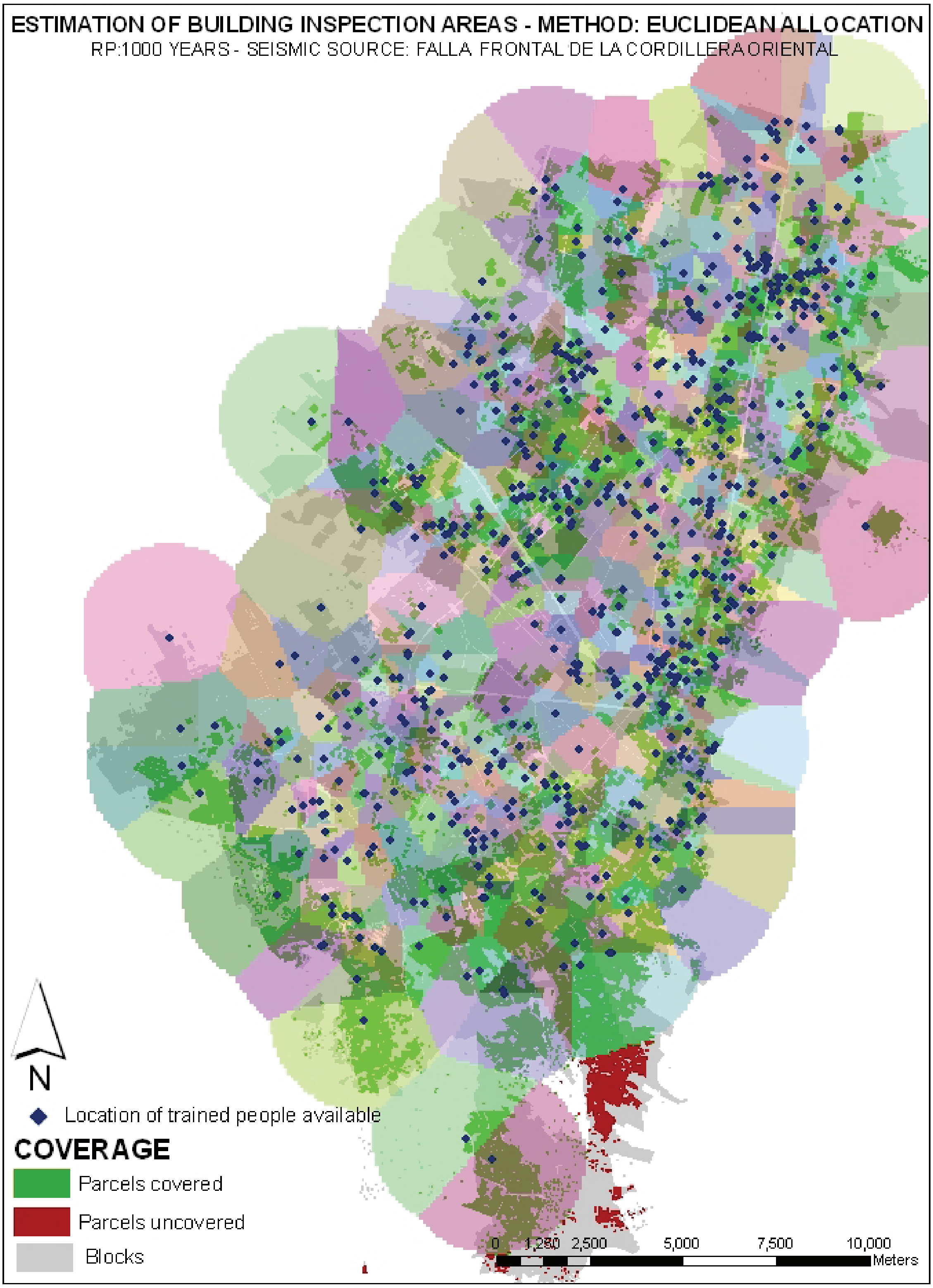


Figure 4-10 Estimation of service areas based on *euclidean allocation method* in the RP 1000 years

The concept about *distance-to-walk every day* is applied by using two methods: *multiple-ring buffer* and *network analysis* (service area).

Multi-ring buffer method also allocate service areas to the 100% of the trained people and it is the first approach to estimate the coverage based on the maximum threshold *distance-to-walk* per day; nevertheless, the disadvantage of this method is that the most of the times boundaries between the service areas are not clear, even using any of the two dissolve options (*all* or *none*); eventually, in the present analysis the dissolve option *all* is chosen, as in spite that the features are merged, at least, it is possible to distinguish in some cases the service area in the first day and to have a view of the areas that just can be inspected in the second or in the third day according to the *distance-to-walk* every day; using *none* dissolve option, the service areas overlap between them and it is not possible to differentiate any, in this sense it is unusable. To sum up, the problem with the merge and overlap in this method is that there is a high risk that some parcels will be allocated twice and hence re-visited, making a bad use of the likely scarce resources (building inspectors), in the real time. Another drawback about using this method is that the *distance-to-walk* is measured in a straight line and not taking into account the road network, which also decreases the accuracy level. The result of allocation and coverage after using this method can be observed on table 4-7 and figure 4-11.

SEISMIC SCENARIO	TRAINED PEOPLE AVAILABLE			PARCELS TO INSPECT		
RP 250	**ALLOCATED**	**712**	**100%**	**COVERED**	**100415**	**94%**
	NOT ALLOCATED	**0**	**0%**	**UNCOVERED**	**6423**	**6%**
	TOTAL	712	100%	TOTAL	106838	100%
RP 500	**ALLOCATED**	**712**	**100%**	**COVERED**	**305160**	**96%**
	NOT ALLOCATED	**0**	**0%**	**UNCOVERED**	**13785**	**4%**
	TOTAL	712	100%	TOTAL	318945	100%
RP 1000	**ALLOCATED**	**712**	**100%**	**COVERED**	**348265**	**96%**
	NOT ALLOCATED	**0**	**0%**	**UNCOVERED**	**14633**	**4%**
	TOTAL	712	100%	TOTAL	362898	100%

Table 4-7 Percentage of coverage using *multiple-ring-buffer* method in every scenario

The use of *network analysis* **(**service areas) method to allocate the service area is more appropriate than the last methods, because it considers the distance-to-walk per day ased on the road network and this tool allows knowing who does not have any service area allocated because the person is in the middle of other service areas. After using this methodology and examining the attention priority scenarios, it will be possible to allocate free people to uncovered areas according to the attention priority scenario chosen, and then the service area network can be updated, taking into account the new location of the inspectors. However, the level of accuracy is not enough because they do not take into account the degree of damage or the inputs from the first model about the numbers of parcels that must be inspected every day to cover all the parcels in every seismic scenario. The result of allocation and coverage after using this method can be observed on table 4-8 and figure 4-12.

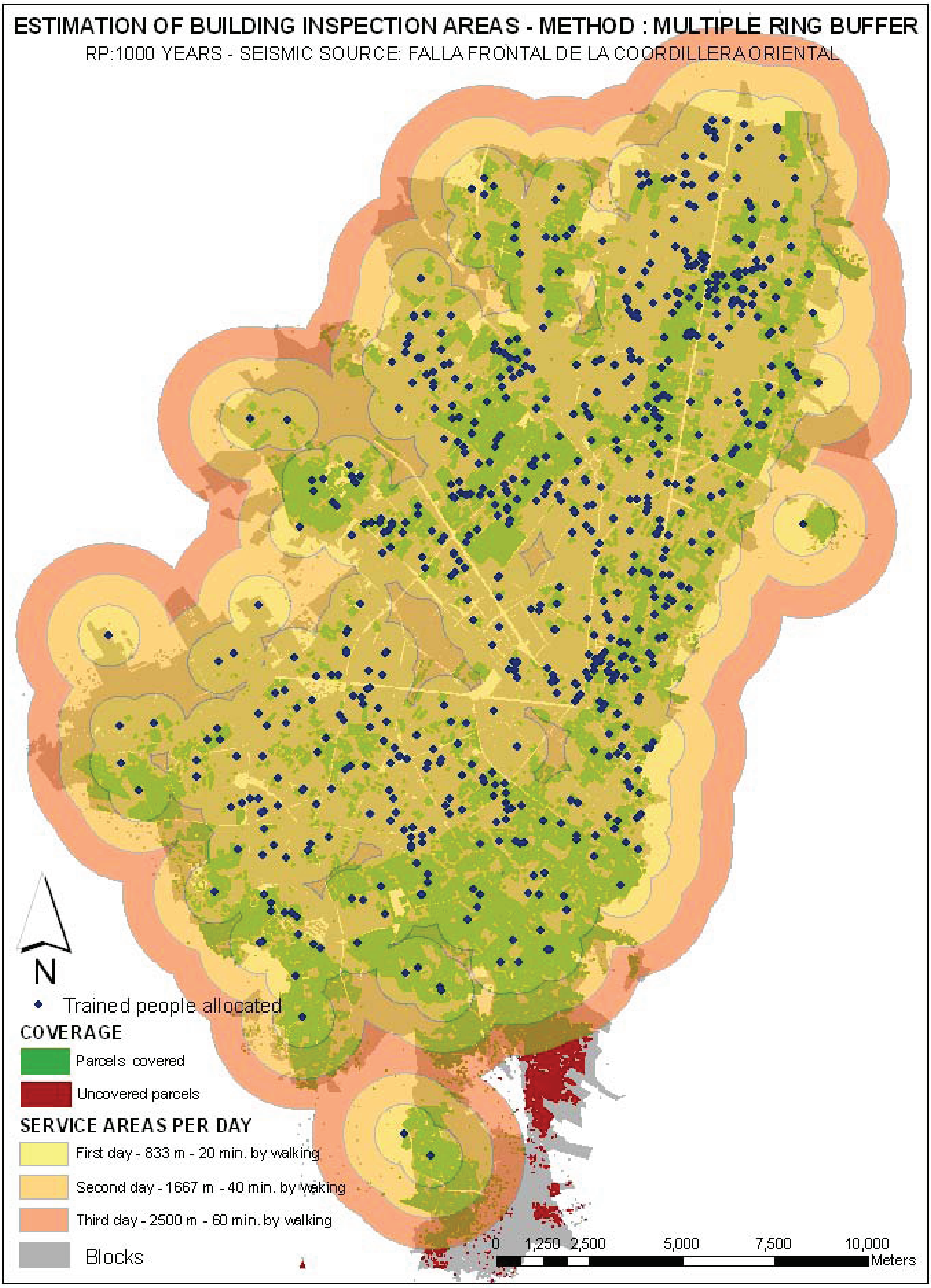


Figure 4-11 Estimation of service areas based on *multiple ring buffer* in the RP 1000 years

SEISMIC SCENARIO	TRAINED PEOPLE AVAILABLE			PARCELS TO INSPECT		
RP 250	ALLOCATED	701	98%	COVERED	92522	87%
	NOT ALLOCATED	11	2%	UNCOVERED	14316	13%
	TOTAL	712	100%	TOTAL	106838	100%
RP 500	ALLOCATED	696	98%	COVERED	286510	90%
	NOT ALLOCATED	16	2%	UNCOVERED	32435	10%
	TOTAL	712	100%	TOTAL	318945	100%
RP 1000	ALLOCATED	696	98%	COVERED	327918	90%
	NOT ALLOCATED	16	2%	UNCOVERED	34980	10%
	TOTAL	712	100%	TOTAL	362898	100%

Table 4-8 Percentage of coverage using *network analysis* (service area) method in every scenario

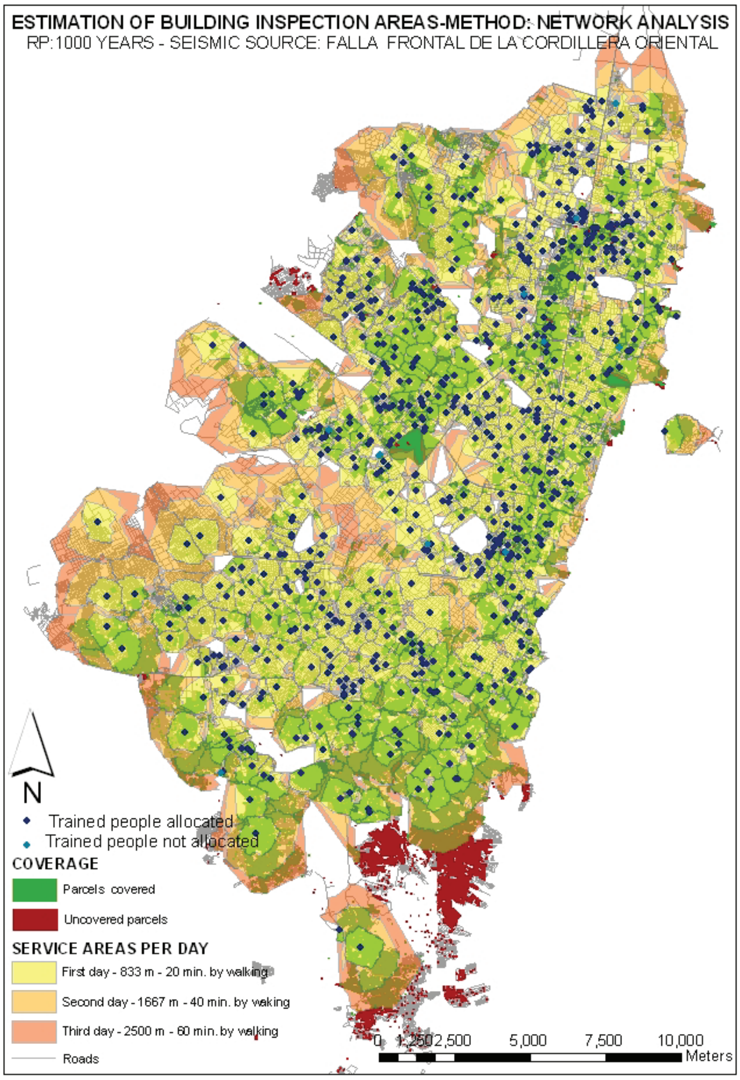


Figure 4-12 Estimation of service areas based on *network analysis* in the RP 1000 years

However, the highest level of accuracy in service area allocation is done through the route allocation method, because it considers the time per parcel, the number of parcels and the parcels in the block.

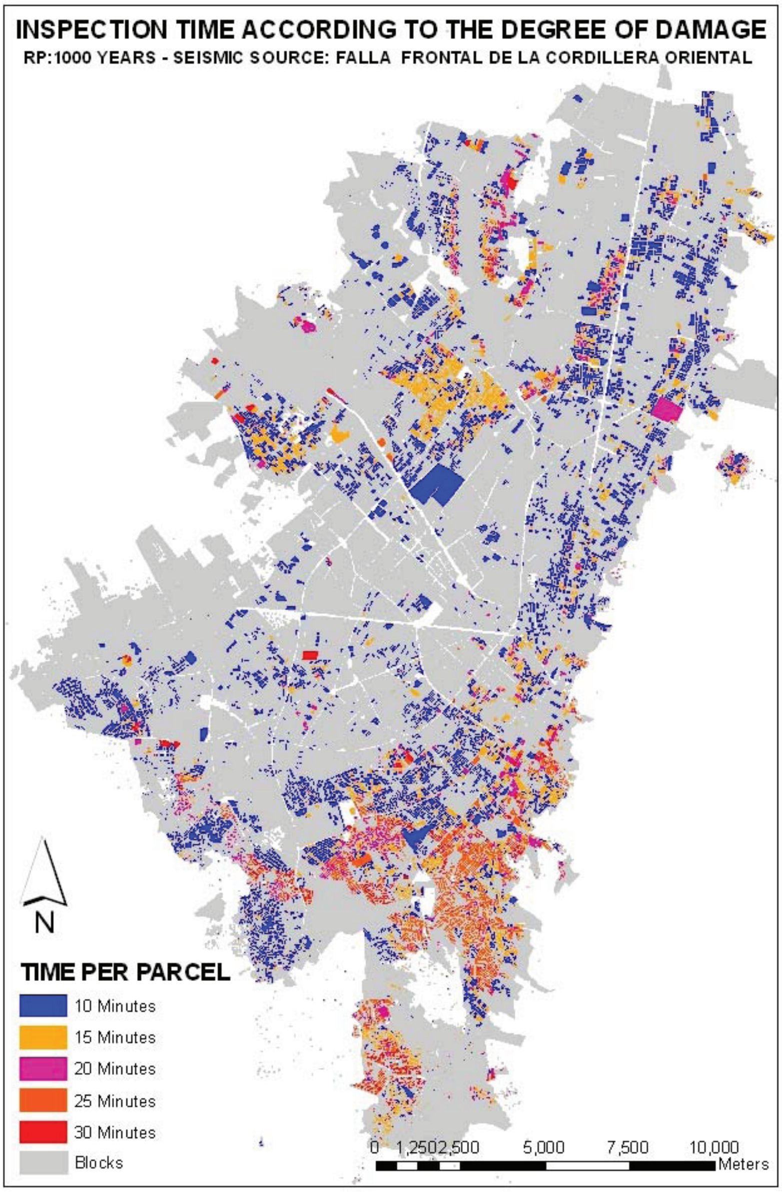


Figure 4-13 Inspection time according to the degree of damage in the RP 1000 years.

The route allocation per day also can be the first approach, but the limitations are the uncertainty in the inspection times, and due to the irregularity in the number of parcels per block, it is necessary to estimate the route allocation to every inspector one by one; it is done because sometimes the route of parcels to inspect, according to the inspection time and the operational time chosen, finish in the middle of a block, and the advisable procedure is that the whole block will be inspected in the same day to avoid confusions. This allocation model integrates the first method: *average number of parcels or blocks to be inspected for a team in one day*.

The route allocation could be designed estimating the inspection time based on the damage degree, as it is done in the present research, taking the advantage that there is a degree of damage already calculated; or based on the size of the built-up area and its estimations can be calibrated in both cases through a simulation exercises. To make the service area estimation using route allocation, it is necessary to do one step before and it is related to the estimation of the inspection time according to the degree of damage, as it was described in chapter 3 (table 3-2). The result can be appreciated on figure 4-13 and the respective tables with an example of a new estimation of trained people required for every scenario (control range: 9 units per person) could be seen on appendix M.

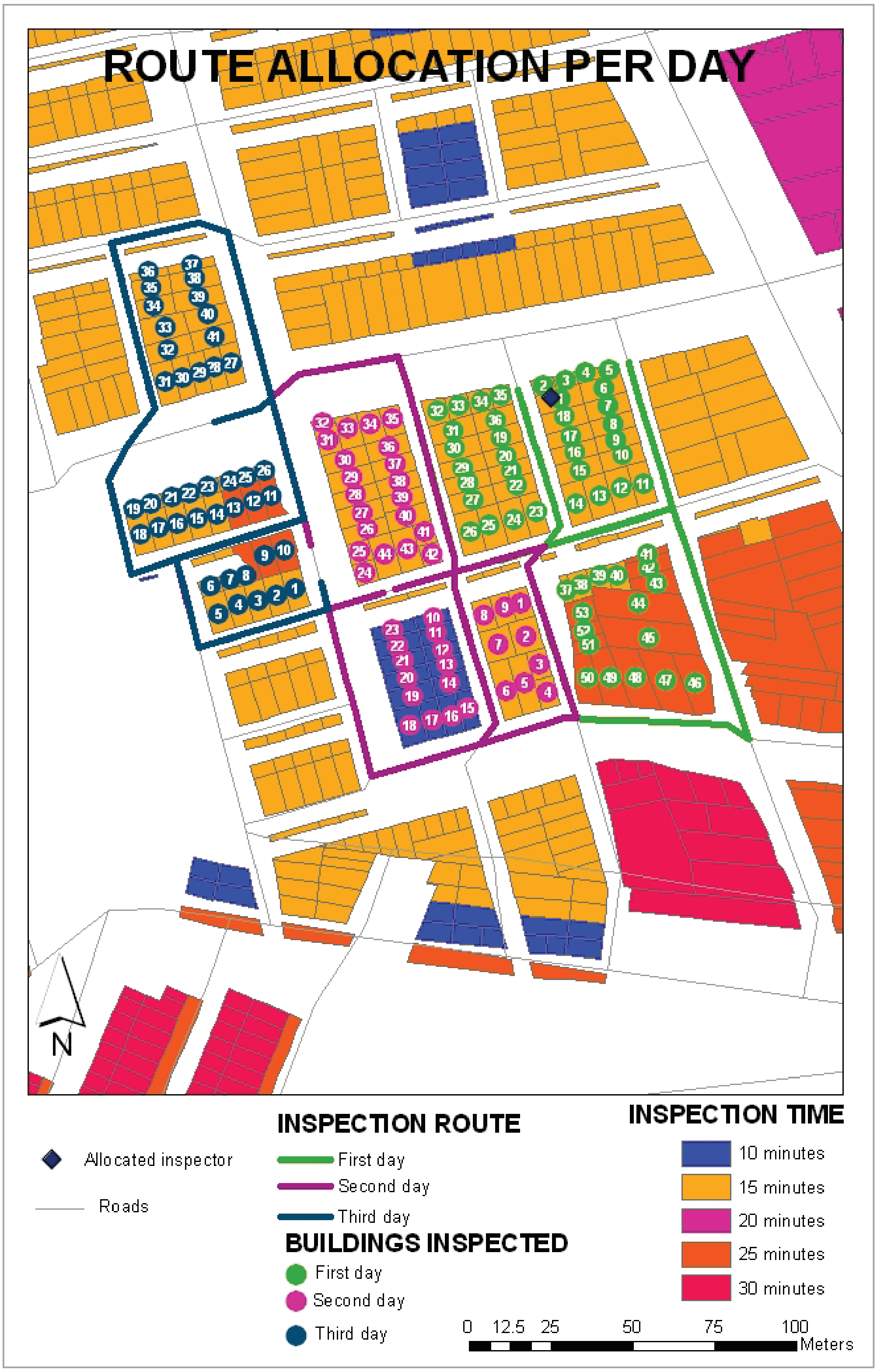


Figure 4-14 Estimation of one service area per day according to the inspection time

An example of the route allocation method to estimate one service area, is presented in figure 4-14. In fact, in spite of the allocation is referred to a certain number of parcels, eventually, the service area is made up of blocks, because a route inspection can not stop in the middle of a block, because it will be confuse.

But based in the observation that route allocation is the more accurate approach, two methods can be combined, in order to test the coverage for the city in a more realistic way *route allocation* and *buffer analysis*. Therefore, it is necessary to measure from the results of the *route allocation*, the distance between the house of the inspector and the farest points in at least three directions, to have an average distance and according to this result; it could be possible to have a more realistic approach. In this particular case the measure of the three points gave as a result: 122.02 m, 128.85 m and 131.47 m, respectively and the average is 131.47, but for the exercise it is assumed a value of 130 m. The result of allocation and coverage after using this method can be observed on table 4-9 and figure 4-15.

SEISMIC SCENARIO	TRAINED PEOPLE AVAILABLE			PARCELS TO INSPECT		
RP 250	**ALLOCATED**	**712**	**100%**	**COVERED**	**7052**	**7%**
	NOT ALLOCATED	**0**	**0%**	**UNCOVERED**	**99786**	**93%**
	TOTAL	712	100%	TOTAL	106838	100%
RP 500	**ALLOCATED**	**712**	**100%**	**COVERED**	**30866**	**10%**
	NOT ALLOCATED	**0**	**0%**	**UNCOVERED**	**288079**	**90%**
	TOTAL	712	100%	TOTAL	318945	100%
RP 1000	**ALLOCATED**	**712**	**100%**	**COVERED**	**36125**	**10%**
	NOT ALLOCATED	**0**	**0%**	**UNCOVERED**	**326773**	**90%**
	TOTAL	712	100%	TOTAL	362898	100%

Table 4-9 Percentage of coverage using *route allocation* and *buffer analysis* method

As it is observed the allocation is 100% but the coverage is low, showing opposite results to the other methods (tables 4-6, 4-7 and 4-8), but according to the accuracy level maybe this result is more realistic.

The comparison between the sizes of the service areas using different methods is applied in a typical urban planning zone (UPZ) of Bogotá D.C. and it can be appreciated on figure 4-16. The smaller service area allocated is estimated using the *route allocation* method, the second in size is the service area estimated using network analysis, the service areas estimated by using the methods of *euclidean allocation* and *multiple ring-buffer* have similar size, bigger than the others mentioned before.

An UPZ is a group of neighbourhoods which have similar characteristics related to roads width, amenities and facilities, floors number of houses, building materials, building structural types, etc. There are 112 urban UPZ's and 5 rural UPZ's, in total there are 117.

The comparison of the spatial results for every scenario related to the application of *Euclidean allocation, multiple-ring buffer network analysis and route allocation-buffer* method can be seen on appendix O.

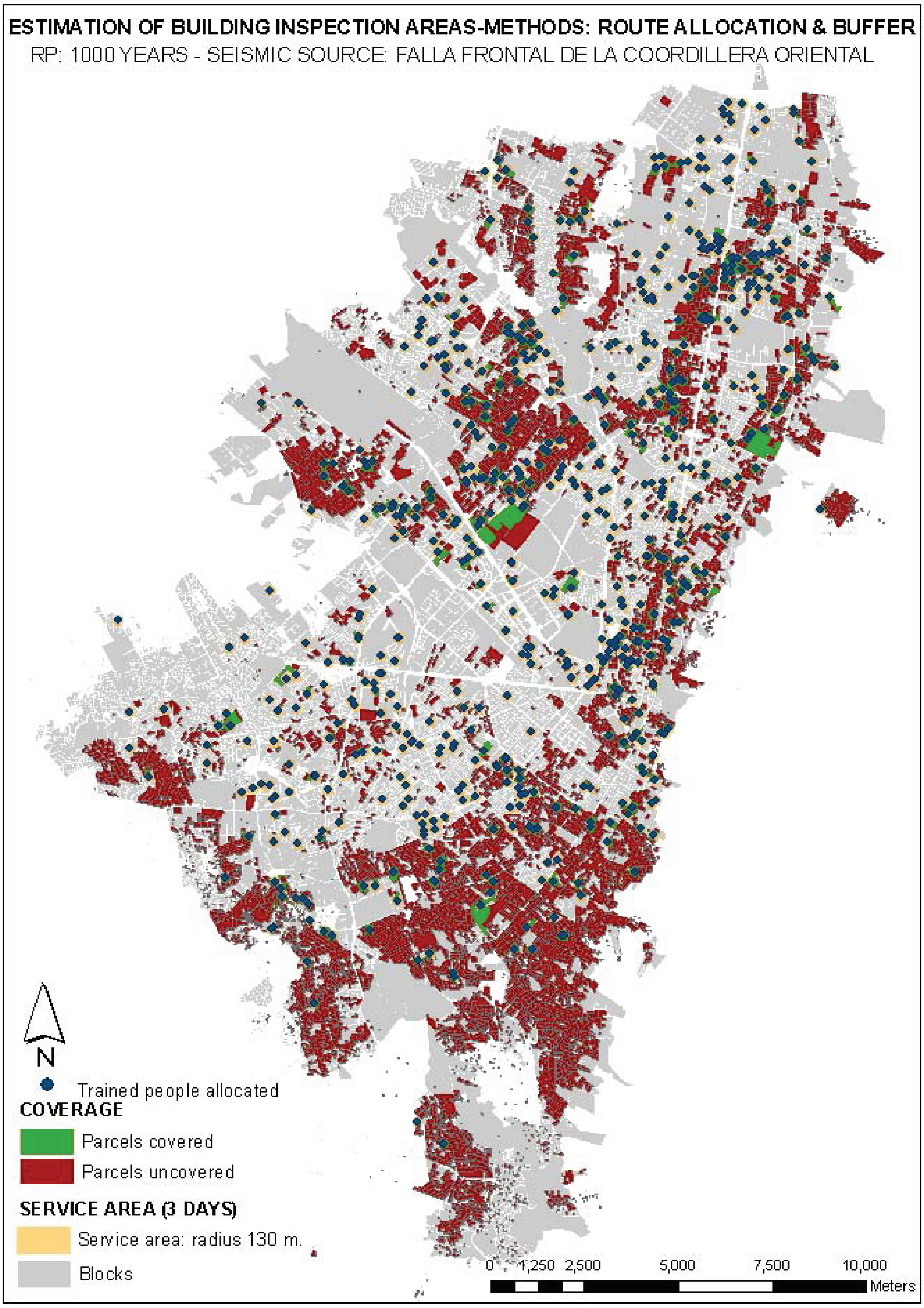


Figure 4-15 Estimation of service areas based on the combination of *route allocation* and *buffer analysis* method in the RP 1000 years

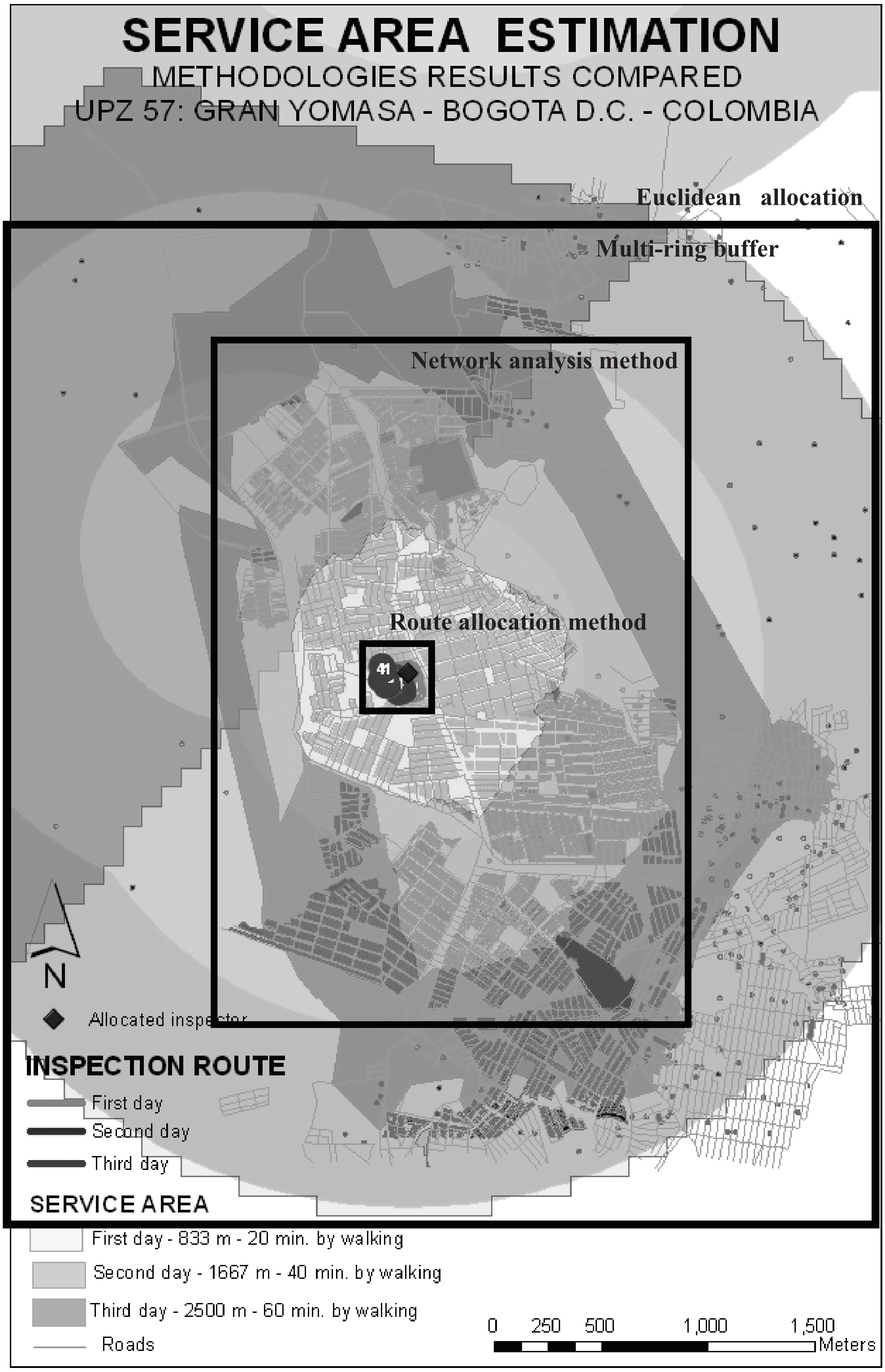


Figure 4-16 Comparison of the results applying different methodologies (*Euclidean distance, multiple ring buffer, network analysis, route allocation*)

On the one hand, the methods of *Euclidean allocation, multi-ring buffer and network analysis* (service area) show a high deficit of coverage in the South- East. On the other hand, the route allocation method combined with the buffer method show a deficit of coverage in all the city (between 90% and 93%), which is worrying.

Due to the last, it is necessary to develop priority attention scenarios. Priority attention scenarios allow the emergency response planners to know where the people must be trained and to the decision-makers, the scenarios show, where the people must be sent at first.

To develop the scenarios, it is necessary to follow the fourth step in the second model about display the different priority scenarios. The suitability layers in the research are: In the first analysis the whole city (table 4-10), and in the second analysis, the uncovered zones (table 4-11). The other layers or factors considered were population density, as way to know how many people could be affected; degree of damage, as an indicator of the number of buildings, that can collapse; built-up area, as an indicator of the areas where more buildings might be affected; industrial areas and areas with hazard by landslides as a way to estimate where may have fires or landslides as a secondary effects after the earthquake; and the last one, is related to trained people available without service area allocated, to know from where and to where is easy to relocate people.

A weight is given to factors: Population density, degree of damage, built-up density, areas prone to landslides or fires (industrial areas and zones with) and areas where there are people with any service area allocated. These factors are weighted in order to decide where the free inspectors must be sent.

The scenarios displayed are called: Equal weight, population, landslides and available. Every priority scenario is explained below:

- *Equal weight* (Figure 4-17 a): in this priority scenario all the priority factors have the same score.
- *Population – Damage degree/Built-up density* (Figure 4-17 b): population density always will have the highest weight, due to the main objective of the rapid building damage survey is to save lives; therefore, high density populated areas are priority areas to be inspected. Degree of damage and built-up density has the second score because both of them, not only are the raw material of the inspection task but also they determine their development. Degree of damage and built-up density have the same score because it could assumed that where there are more buildings, likely will be more damage. The third and the fourth score is given to the secondary effects: Landslides and fires, with more score to the landslides due to large area prone to landslides that Bogotá D.C. has. The location of the inspectors with any service area allocation has the lowest score, because the coverage of the city, at least under the concept of the walking distance is acceptable.
- *Population –Landslides* (Figure 4-17 c): this factor is usually a secondary effect after an earthquake. As it was already described, Bogotá D.C. has a large area frequently affected by landslides; therefore it was created an scenario, in which this factor has the second high score. The third one is for fires, also as a secondary effect that could take place due to the industry is spread out over the city, not all of them, follow safety regulations and the smallest ones are even located into residential areas. The fourth score is for damage degree and built-up density; the lowest is again the location of the inspectors with any service area allocation.

- *Population –Location of inspectors available* (Figure 4-17 d): this scenario is created taking into account people not allocated to any service area according to the walking distance. This scenario was created because if there is no any information after the event about the mentioned factors before, the building inspection task might take up in the areas, where trained people is reported available. The second score is given to the degree of damage and built-up density, and the lowest to the secondary effects: Landslides and fires.

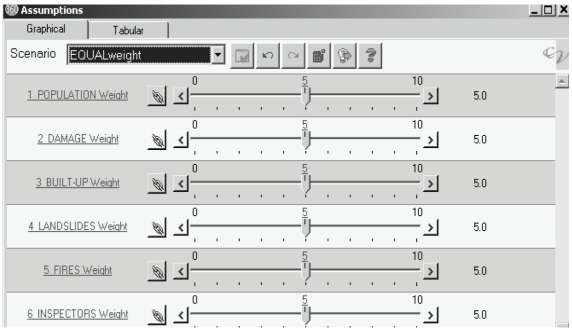
ANALYSIS 1	**PRIORITY AREAS TO BE INSPECTED**	**CALCULATION METHOD**
SUITABILITY LAYER (Dynamic layer)	Residential area in Bogotá D.C.	
LAYERS (Priority factors)	Population density	AVERAGE VALUE OF UNDERLYING GRID **HIGHER SCORES** result from **HIGHER GRID VALUES**
	Damage degree – Seismic scenario (RP) 1000 years	
	Builp-up area density	
	Landslides area (not in the present analysis)	
	Industrial area	AVERAGE VALUE OF UNDERLYING GRID **LOW SCORES** result from **HIGHER GRID VALUES**
	Not allocated people	

Table 4-10 Factors displayed as layers to carry out the attention priority analysis in Bogotá D.C.

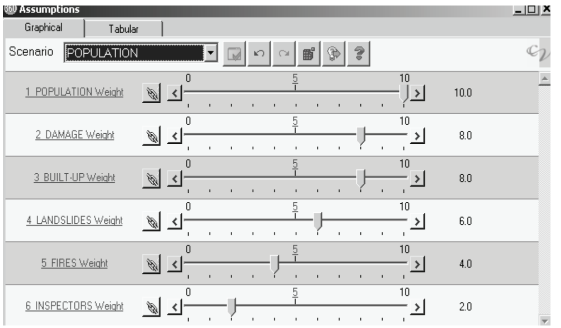
ANALYSIS 2	**PRIORITY AREAS TO BE INSPECTED**	**CALCULATION METHOD**
SUITABILITY LAYER (Dynamic layer)	Uncovered areas in the South-East of Bogotá D.C. (RP 1000 years).	
LAYERS (Priority factors)	Population density	AVERAGE VALUE OF UNDERLYING GRID **HIGHER SCORES** result from **HIGHER GRID VALUES**
	Damage degree – Seismic scenario (RP) 1000 years	
	Builp-up area density	
	Landslides area (not in the present analysis)	
	Industrial area	AVERAGE VALUE OF UNDERLYING GRID **LOW SCORES** result from **HIGHER GRID VALUES**
	Not allocated people	

Table 4-11 Factors displayed as layers to carry out the priority analysis in the not covered area located at the South-East.

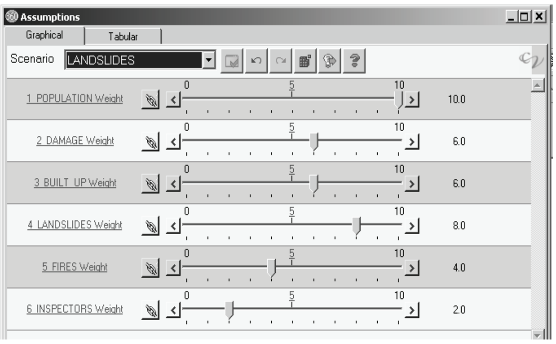
The weights given to carry out the analysis are displayed on figure 4-17, the results of the priority attention analysis 1, which is done for all the city are shown on figure 4-18; and the outcome of the analysis 2, applied in the uncovered areas in the South-East of Bogota D.C. is shown in figure 4-19.



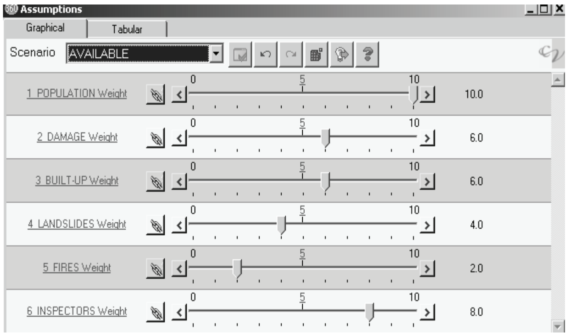
a. Equal weights.



b. Population – Damage degree/Built up density.



c. Population – Landslides.



d. Population – Trained people available.

Figure 4-17 Weights given to carry out the attention priority analysis.

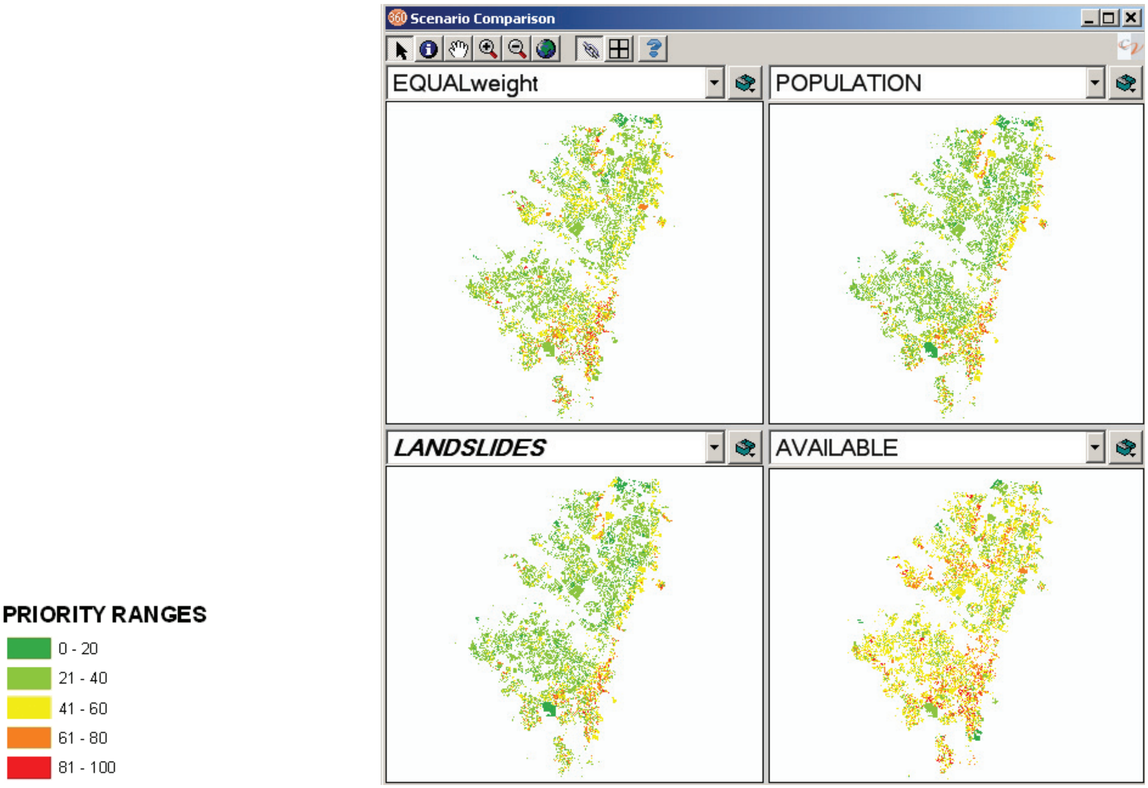


Figure 4-18 Attention priority scenarios for Bogotá D.C.

Figure 4-18 illustrated that in all the priority attention scenarios with the different weights, the South-East always appears with high priority. Due to the last, it is necessary to look for engineers or architects who use to live in, or near to the South–East to be trained; or at least an efficient way to transport trained people to those areas should be considered. Additionally, the inhabitants in those uncovered areas could to be trained to be able to recognize in some way damages in the structure, which could threat them, while trained people arrive to inspect their houses. This is because also one of the primary sources for the emergency stage is the self-help, besides of the emergency services and international relief agencies (Mitchell, 1996).

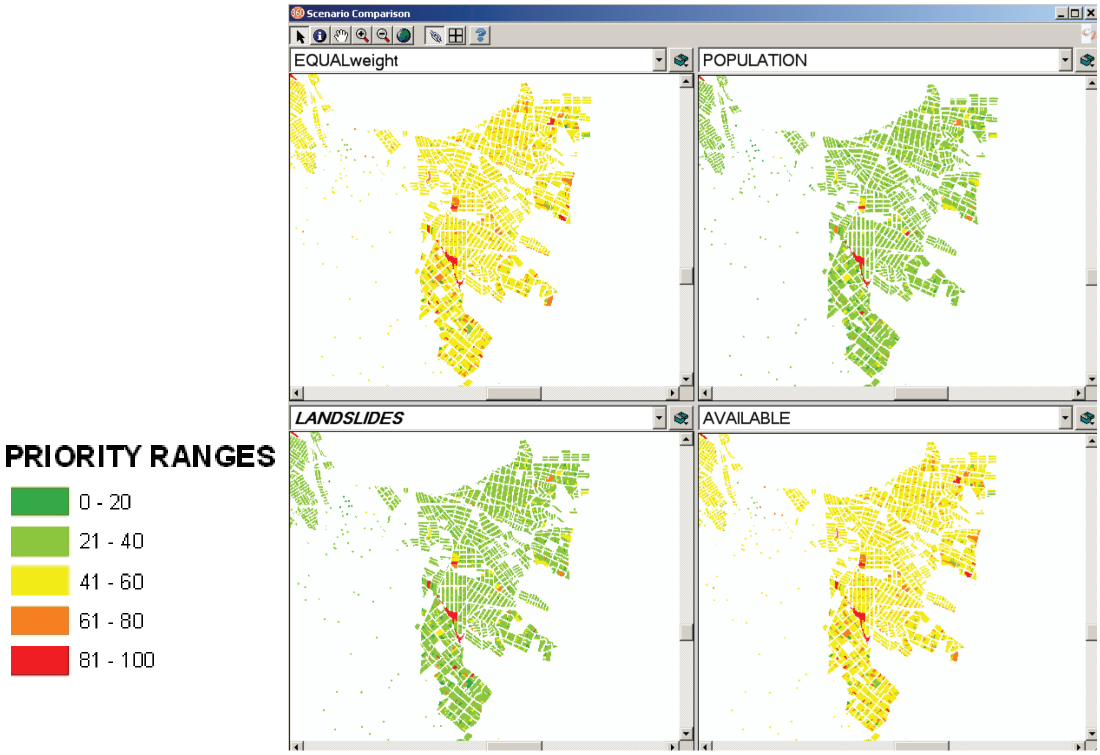


Figure 4-19 Attention priority scenarios for the uncovered area in the South-East of Bogotá D.C.

Figure 4-19 shows two different results with homogenous priority zones, where the area with a high range of priority is the same in all the scenarios; in this case, that area must be attended firstly by the building inspection teamd available.

The results of this sub objective are three: One is that the likely availability of the inspectors could be high in the real moment (99%); second, the best method to estimate and allocate service areas is the *route allocation* method based on the number of parcels calculated in model 1, that in fact are usually two or three blocks per team. The third and last result was the priority attention scenarios developed by the use of the GIS decision-making software, CommunityViz which allow to see the areas where the attention is required firstly according to different factors or criteria; and for the case study city shows that the South-East of Bogotá D.C. require priority attention in all the scenarios, which is worrying because after testing all the service area estimation methods, this areas always appears uncovered.

4.5. Sub-objective 3: Information management model

As it was mentioned in the methodology, the information must be a concern before, during and after the event. In the stage before the event, it is important the creation of a Spatial Data Infrastructure (SDI) which allows the entities access and integrate heterogeneous geospatial information.

For the time of the event, meeting points must be established to report the availability with a supervisor and receive the guidelines and the support material (e.g. meters, rulers, water, food, and flashlight, etc.) to carry out the inspection. In the present research, the parks have been considered as the proper meeting points due to are easy to be found and they are not built-up areas that could be destroyed by the earthquake.

The visualization of the spatial distribution of the parks compared with the walking-distance-service area using network analysis, it is shown in figure 4-20.

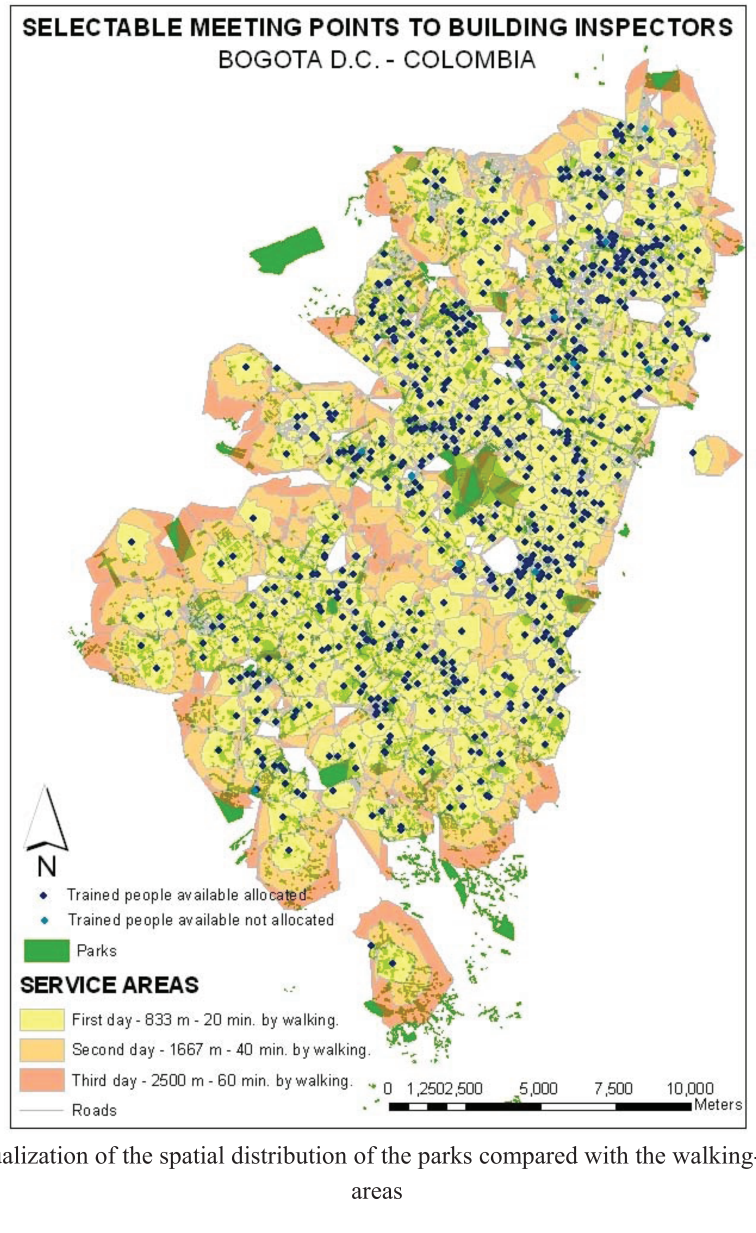


Figure 4-20 Visualization of the spatial distribution of the parks compared with the walking-distance-service areas

The districting criteria to allocate a meeting point in Bogotá D.C. is to take into account the Planning Unit Zone (UPZs), that as it was explained before, it is a group of neighborhoods with similar urban characteristics

The mentioned similarity will make easy the inspection task because the degree of damage will be similar and for that reason, it is helpful to group the inspection teams based on the UPZ location. The analysis starts selecting by location the parks, which intersect with every UPZ; for carrying out the analysis, it was selected UPZ number 75 as the UPZ case study. A pair of layers with the UPZ's parks and the location of the inspectors included in the UPZ were created. By using tools like central feature or mean center is selected the most equidistant park to the group of inspectors. The result of these analysis can be seen on figure 4-21.

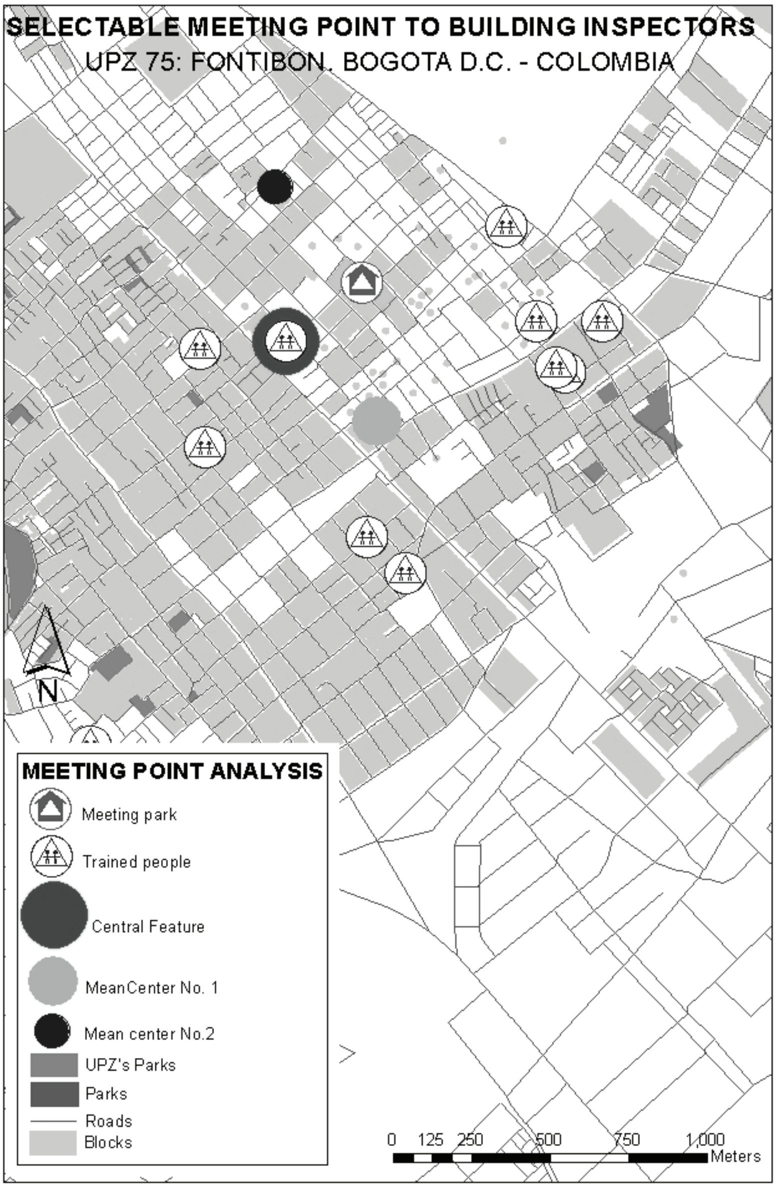


Figure 4-21 Example of meeting point allocation

The information flow model shows a sort of process in a frame of media to capture data, time, and people in charge and place to carry out every process.

The flow chart show in the left two alternatives to capture data: paper forms and mobile devices. In the upper part, the period of time to carry out every process is indicated with the person who is in charge of the process, as well. In the lower part, it is pointed up the place where every process must be done.

The process started since the building inspectors go to every house to inspect them, then they meet their supervisor to download the data or to give him the filled out paper forms. Next, supervisors after making a quality control of the information collected; they have to go to the coordinator of the area to give him the information or the paper forms collected and this person have to sent the information to the Emergency Operation Center - EOC or he must have to organize the process to digitize the information to be sent to the EOC.

In the EOC, a person or unit in the operation section receive the information, make the GIS analysis and compare with the information received by calls and remote sensing source, if they are available. The same unit in the operation section produces the indicators to the operation section chief and incident commander or decision makers. They look at the analysis, and the data and using a software application, or just based in their expert opinion, they prioritize areas to be attended according to some criteria and to allocate the resources according to them. The extended process can be seen on figure 4-21.

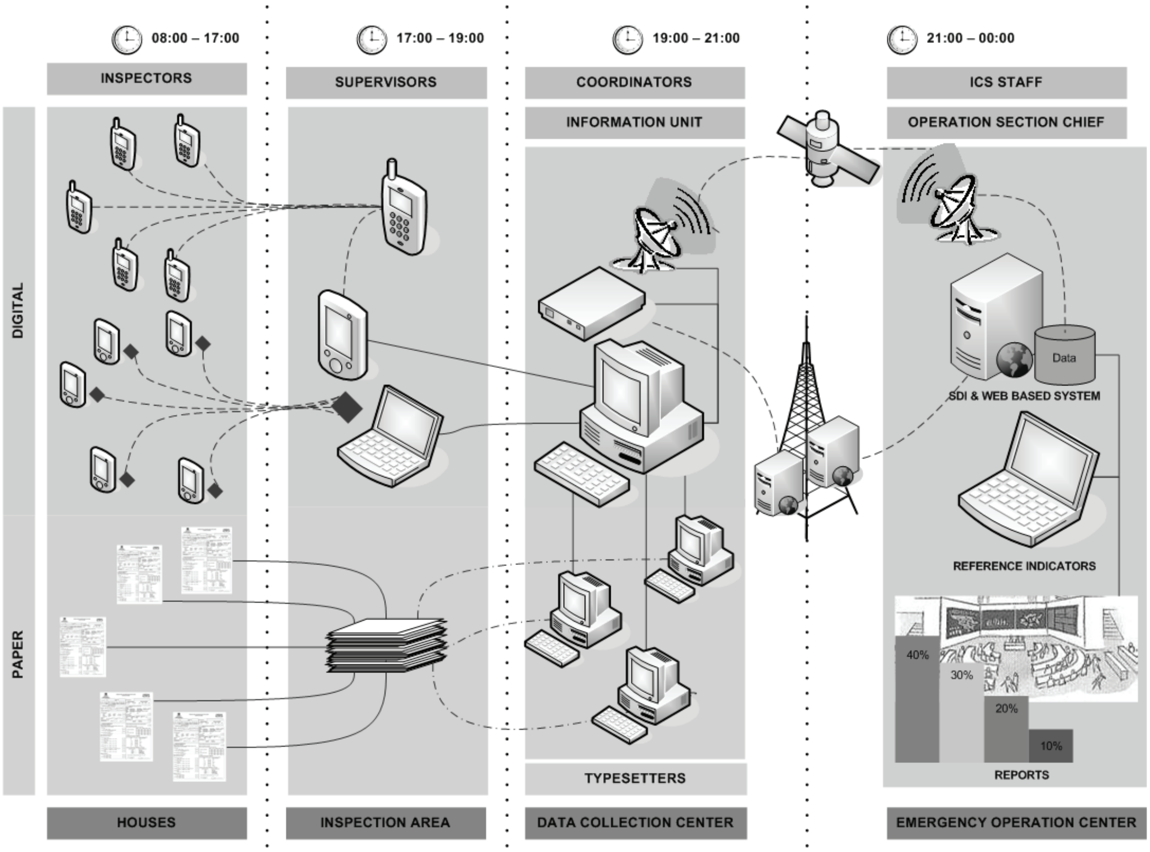


Figure 4-22 Flow information model

5. Discussion, Conclusions & Recommendations

This chapter draws the observations which come from the application of the methodology and its results. It contains discussion, conclusions and recommendations following the order of the research objectives which also are the models as well, which made the spatial planning support system for rapid building damage survey.

5.1. Fieldwork

In a next survey, the question asking about availability must be split to differentiate between desirability and capability, because trained people some years ago may want to collaborate with the inspection task; but nowadays maybe, they may not remember the procedure, nor the criteria assessment to establish the habitability of a building.

In real time, expressed availability and effective presence must be items to be measured, and later they must be used to calibrate the model in the part related to the estimation of the likely availability; this is done in order to know the percentage of trained people who having expressed their availability before the event, actually make presence to carry out the inspection.

5.2. Sub-objective 1: Estimation of the number of trained people required

The research firstly makes use of secondary data collected by the ULA to carry out *“The risk and loss scenarios study after an earthquake in Bogota D.C.” (2005)*. In the present research the inspection area is defined based on the degree of damage already estimated in the loss scenarios developed by ULA, but in the real time the inspection area must be defined by the information from the aerial photography, the reports made by phone-calls from people and the information from field.

It is necessary to join the insurance companies in the process of a rapid building damage survey, in order that they start the building inspection task in the period of response time and not several days after the event, to reduce the workload of the voluntary trained people.

Space-parameters and *time-parameters* are the main inputs to estimate the number of required trained people. A range of values are considered based on the different control range under different operational times. In real time, the control range will depend on the number of trained people available after the event, while the operational time will vary during the three days.

The methodology developed by DPAE fixed a unique control range of 7 units per supervisor o per coordinator, while the research model consider a range between 5 to 9, in order to present different options to the decision-makers according to the availability of the inspectors in the real time. The estimation already made by DPAE is presented in appendix H.

The combination of the time, space and control ranges generate different values that should be used by the emergency planners before the disaster to demand resources such as money for training programs, to buy elements to inspect (flashlights, meters, identification, palms, handheld computer, helmet, etc) and to know how many people must be trained in the short, medium and long term. The output of this model can be used in the re-planing activity in real time, after the earthquake; re-planning is a concept mentioned by Ozdamar et al. (2004) as an essential issue in dynamic logistic situations like disasters, when the requirements change all the time. The values could be calibrated according to the number of resources available and looking at the table (appendix L), it can be possible to know according to the people available, how many teams must be grouped, and how many inspectors and coordinators are possible to have. Finally, after the disaster, the results could be used to validate the model and further to improve the model.

When the model proposed to estimate the number of trained people required is compared with the model proposed by DPAE, the only common ground is related to the time needed to carry out the rapid survey (three days). The methodology developed by DPAE aiming at inspecting all the parcels in the city, but the Spatial Planning Support System – SPSS in this research, is oriented to inspect just the residential area; this is because these are the spaces where people use to live and spend the night and they must be safe in the case of an aftershockIt is not necessary to take into account institutional buildings because it decreases the accuracy in the estimation and in the real time, it reduces the effectiveness and the efficiency of the survey

DPAE considers according to their estimation methodology that it is necessary to train 2.926 people and the model presented consider a range between 1.111 and 18.750 people with an average of 7.059 taking into account the different seismic scenarios, control ranges, inspection and operational times. But the drawbacks in DPAE's methodology is that it does not consider the number of supervisor and coordinators in the estimation of the people to be trained.

In its methodology, DPAE just considers as *time-parameter* the total inspection time, but in the model developed by this research the calculation of the inspection time could be done in different ways depending on the data: parcel area, built-up area, floors number, damage degree or in the case that data is not available it can be done just fixing an inspection time per parcel. The use of a fixed time will give a low level of accuracy; nevertheless to compensate the accuracy level, the analysis use as input several inspection times instead of just one, to have a range of values. Additionally, the idea to use a range of inspection times is, that in the real time according to the resources available (building inspectors in this specific case), the operation section chief or the person in charge in the emergency management staff, determines the maximum inspection time per parcel, to cover the required inspection area in three days.

The maps with the inspection times on figures 4-14 according to the damage degree display a view of where the problems with high range times could appear, but these problems can be seen as well in a map with inspection times according to the built-up area of the parcels, if the data according to the degree of damage is not available.

The inspection times predicted by the model must be calibrated in every city where the model will be applied through simulation exercises; these kind of exercises give trained people the chance to gain experience, through visiting houses and measuring the time to look at the structure elements, fill in the inspection form, and assess the safety conditions of the building. This activity allows not only to calibrate the *time-parameters* but also test the performance of the trained people. However, even if an earthquake ocurred, the calibration of the model will still have uncertainty due to the different characteristics that are involved in an earthquake (source, magnitude, peak ground acceleration, depth and distance epicentral average) and also the vulnerability conditions, which always are dynamic.

The accuracy of the results not only depends on the right assumptions in the analysis, they depend on the accuracy, completeness and update level of the data. Aiming to reduce the uncertainty in the loss estimation and make the right preparedness, it is important to invest money in seismic hazard research and monitoring, updated census, cadastral data and vulnerability analysis in the most disaggregate possible way.

The important in the present research is not the numbers of parcels to be inspected, nor the estimated inspection times, neither the number of people to be trained, because that numbers belongs to a specific area and they just can be used there. The really important issue is the proposed algorithm to estimate these variables.

5.3. Sub-objective 2: Allocation of trained people to service areas

According to Baber et al. (Lau et al., 2008), in the proposed model three discrete levels of autonomy are applied: “command driven” between the range from the Incident commander, till the supervisors level, because they have to obey orders; but between the supervisors and building inspection teams there is a “consensus” because in the field, the agents have to share decision according to the situation and every team is “locally autonomous” when they assess the damage of a building because they take the assessment alone.

The data and the preparedness level of the city will define the method to allocate the service areas to the inspectors. The compulsory inputs in the analysis are the location of the trained people and the parcels data, but the data about roads will increase the accuracy in the service area allocation.

DPAE’s methodology as a practical approach allocate 100 parcels per day, without taking into account the size of the buildings to inspect; while the methodology developed here estimates a range between 16 and 72 parcels per day with an average of 35 between all the values taking into account the different seismic scenarios, control ranges, inspection and operational times. The service areas designed by DPAE are quite logical because it is based on the Urban Planning Zones – UPZ. The design of the service areas using the UPZ will make easy the inspection and the decision task because the degree of damage might be similar in the allocated area.

If the level of the service area estimation through route allocation is achieved it will increase the effectiveness of the inspection task because owners can met before the inspector who will be in charge to check their houses after the earthquake, avoiding security problems. Not only people in uncovered areas must be trained in recognizing serious damage in the houses structure, but also in the areas where the coverage is more likely because it increases the effectiveness of the rapid building damage survey. Cities with seismic hazard interested in developing and implementing this kind of model have to do their best to reach this stage.

The scenarios must show the needs, desires, motives and values to the users in a direct way. The scenarios must interact with the users effectively and safely (Wei-Ning & Keith, 2003) so that they identify or assess decision options, keeping in mind possible major changes and exchange information; even, the presentation of the scenario must be designed according to the preference of the stakeholders involved (Wollenberg et al., 2000). Biases such as using extreme outcomes, not the predictable; creating disruption of historic trends, selecting just the positive and negative scenario without any gradient, and starting the construction of the scenario from an imagined future, instead of current trends must be avoided (Wollenberg et al., 2000). The idea with the scenarios generation and the priorities is to avoid bureaucratic rationality that distracts agencies from the needs of the people who need their assistance; it is in order to fulfill other interest from the institutional framework (Waters, 2001;Benini et al., 2008).

Authors have different opinions about the right number of scenarios, Wei-Ning & Keith (2003) suggest a range between two to seven, but also mention that many consider that three are advantageous; instead, of just have the paired two-scenario approach (optimistic versus pessimistic). Some authors suggest three to nine ((Wack, 1985b; Deshler, 1987; Steward and Scott, 1995;Wollenberg et al., 2000) . Wollenberg (2000) asserts that the number of scenarios depend on the kind of analysis; one, is enough in the case of learning exercises ,and more than one is necessary, when the aim is to test the "robustness against a large number of uncertainties" (Bunn and Salo, 1993;Wollenberg et al., 2000). The authors also mention that according to Steward and Scott (1995), cognitive research demonstrate that people are only capable of comparing from five to nine scenarios at one time.

Since CommunityViz is one of the more complete PSS application (Batty, 2007), it is possible to test its use not only in the land use planning process, but also as a tool in the emergency planning process. The effectiveness of the CommunityViz utilization to establish priority areas depends on the availability and update conditions of the data used as priority factors. The priority attention criteria must decided in the preparedness phase by the entities involved in the emergency response task. The use of a PSS as CommunityViz to prioritize the attention areas must leave the feeling between the stakeholder in the emergency management that their opinion must be taken seriously. The user-interface of the PSS application should take into account the characteristics, the information required and the purpose that their users will have or will want and finally the application must be transparent, utilizable by all the stakeholders and replicable. (Geertman & Stillwell, 2004).

The priority areas in all the scenarios are located in the South-East, which match with the landslide hazard zone in Bogotá D.C.Small variations are observed between the scenarios and the differences in priorities are more noticeable in a big scale. The priority attention analysis in the uncovered areas shows that the areas with highest priority are in the most of the cases the same, but difference is middle priorities are observed in the scenario where priority factors have the same weight and the scenario where the second important priority is the availability of the not allocated trained people, with population priority and population-landslides priority.

The priority scenarios were estimated as it was done in the research carry out by Benini et al., 2008 using proxy indicators. The uses of decision factors will be dynamic according to the organizational learning in the entity in charge of emergency response, not only in the response but also in the preparedness phases. Their research considers that the use of proxy indicators, linked to formalized models are one of the future research fields in theory-building and hypothesis-testing in terms of humanitarian action.

Glasziou and Longbottom (1999) cited by Hoard et al. (2005) remark that computer simulation might be used to build the capacity of the individuals and organization to use the evidence in order to improve their practice and to support research, policy development, planning, and training (Gunning-Schepers, 1999;Hoard et al., 2005). The main idea of carrying out a simulation process is to understand and evaluate a system in a virtual world with "low-cost and risk-free settings"; and in order to have accurate results it is necessary to have logical assumptions under all scenarios(Hoard et al., 2005).

The experience of planning based on PSS is still limited and sometime their application do not allow to have robust conclusions and recommendations. The performance of the algorithms presented on the literature review chapter use to expend a lot of time and this constraint, limit their application in real time and in large scale problems (Batanovic et al., 2009).Each planning process have limitations like time and policy context which influence the potential or restrictions on the use of the technology (Geertman & Stillwell, 2004). Fiedrich et al. (2000) maintains that computer-based decision-support systems are suitable tools to achieve the efficiency in the relief measures and they criticize GIS-based system like HAZUS and database systems as SUMA, as they are just information systems but they "do not give active decision support". Nowadays, there are spatial information systems as IISIS (Interactive, Intelligent, Spatial Information System), which is an "information technology-based emergency management decision support system developed by the University of Pittsburg" (Comfort, 2008). The advantages of this application are that it integrates planning support system and decision support system and it focus on emergency response.

The discussion about the difference between spatial planning support system and spatial decision support system is beyond of the scope of the present research but both of them are required in the field of disaster management and if there is a tool that integrates both of them, it must be used.

Concluding, although the results presented in the present research have a high degree of uncertainty, they are useful to design a preparedness program on building damage survey and the model can be replicated in cities interested on being prepared for an earthquake; because at it was stated before, the contribution of the present research is the methodology to obtain the results, rather than the results themselves.

The suitable data input to estimate an inspection time will be known until the model can be validated, but it is not necessary to wait for an earthquake to at least calibrate the model. The calibration could be carried out through simulation exercises. The importance of the simulation exercises is that they test the plans under the different scenarios (Kirschenbaum, 2002;Hoard et al., 2005). Evidence-based research is required to make visible challenges related to disaster preparedness (NRC, 2002; IOM, 2002; Kirschenbaum, 2002;Hoard et al., 2005); it is necessary to enlighten emergency response planners with the accurate data and suitable methodologies to figure out the most efficient decision (Hoard et al., 2005). Ozdamar et al (2004) implemented their model and methodology on a scenario based on the Izmit earthquake's (1999) in Turquia and it allows the authors to test how much time took to have a feasible solution and the quality of this solution.

Policy options are able to come out after a model calibration, which is done through an iterative process of model refinement (Homer, 1996; Sterman, 2000;Hoard et al., 2005). Modeling and simulation are essential in the disaster preparedness process (Hoard et al., 2005). The sensitivity/scenario analysis could be done based on the total number of work teams, the time required to finish the specific task(Yan & Shih, 2007), the size of the districts (atom), the location of the bases (Iannoni et al., 2009); but in the present research is possible using the control ranges, the operational times, the inspection times, the seimic scenarios, etc.

Iannoni et al., (2009) suggest as a topic for future research the use of methods as hypercube approximation algorithms to support configuration decisions: The location of service bases and response segments. While, Chiu and Zheng (2007) mention that future research must focus on improving the capability of modeling the problem of "complex evacuation logistics mobilization problem"; also they consider that it is required an efficient algorithm which deal with large-scale network implementation, although a decomposition scheme development is ongoing to not only improve the computational efficiency, but also to reduce computational resources. "A real-time implementation, a cyclic rolling horizon based updating and a re-optimization framework" is necessary to improve accuracy and robustness of the model in the highly unpredictable evacuation environment (Chiu & Zheng, 2007).

As Novaes et al. (2009) asserts, the optimization of the allocation process depends on the users requirement and behavioral, operational and geographical constraints like continuity and compactness. The average between the inspection times estimated in the analysis, and the inspection time measured in a simulation exercise might be used to adjust the service area and also as a kind of sensitivity analysis, until validation can be done.

This graphs presented in the models of Lau et al. (2008) and Benini and Conley (2007) are similar to the graphs that must be produced every day to represent the performance of the building inspection groups comparing time and number of houses inspected and people available to carry out the inspection.

5.4. Sub-objective 3: Development of Information management model

The government must encourage the creation of Spatial Data Infrastructure (SDI) as a framework for the development of total web-based system; although its design is beyond the scope of the present research, it is mentioned due to the importance that all the entities involved in the emergency response task have a framework to collect, store, access, update and most importantly, share information before, during and after any disaster.

Perry and Liddell (2003) asserts that the effectiveness of emergency planning can be reduced by the wrong allocation of resources or an improper manage of the information. The implementation of an SDI as WEB-BASED system to make easy share the information using a common language, eliminate the bureaucracy that can be an obstacle to respond in a efficient way, so that as Waters (2001) argues, bureaucratic rationality will not distract "agencies from the needs of the people they are supposed to assist, in favor of other values that their institutional frameworks dictate" (Benini et al., 2008).

Nowadays, in case of an earthquake the case study city will carry out the survey in paper forms. Nevertheless, DPAE begins to be quite conscious about the importance to capture data in a digital way to avoid delays in the information process but the matter is how to select the right device?, what can be done with the technology while this is no needed? How to avoid robberies? Which could be the suitable software application?

It is necessary to consider that the data must be captured through the use of mobile devices, supported with the paper forms, as the second alternative. The suggestion on having paper forms is just in case the device is out of order, or when the survey must be done in areas where the terrain do not make easy to transmit the data, or even areas where the security does not allow the use of the device because they may be stolen.

Regarding to the software, it is important to use applications like Cyber tracker or similar, that let the surveyors geocode every parcel inspected; and also, that the application could have images that support the decision of the inspector related to the habitability of the houses.

According to the distribution of the meeting points, it will be possible to decide how to transmit data. To have information in a real time is the most ideal situation, but it depends of the characteristics of the machine; nevertheless, it must not be a concern, because the first information will come from the remote sensing sources (over flight, satellite images, etc.) and after that, there will be enough time to compile more accurate data from the survey in the field.

Combining the control range and spatial criteria, some service areas are allocated to a meeting point. The concept of the meeting points is similar to the concept of work station presented by Yan and Shih (2007) and mentioned in the literature review chapter. The solutions developed by Batanovic et al., (2009) could be also considered.

To allocate the meeting points, two methods were tested: *central feature* and *mean center*, but eventually, it is observed that it is more suitable to use the mean center of the inspector's location, due to there can be another parks included in the UPZ but not in the inspection area, which make change the output to a park in a not suitable distance. This concept is similar to the concept of measure of belief "that one facility site is the best with respect to the node coverage (Batanovic et al., 2009)".

Aldo Benini and Charles Conley (2007), in the analysis of the Iraq case they consider that the rapid assessment after the war generated information in a dense way and it was observed that speed was the priority instead of qualities as reliability, validity, precision and completeness; also the selection of the survey areas where influence by the conditions of the security or access. Even, the authors state that the most rapidly is not necessary the best survey and a well done survey is nor the cheapest one. They observed that surveyors show a variably rational behavior under conditions of insecurity and the results
were errors in the sampling and low quality data. Finally, the authors suggest four criteria to be taken into account by the organizers of rapid assessments: information cost versus benefits to decision-makers, use of pre-existing information; respect for policies that translate assessment goals and dynamic adaptation during fieldwork. The study tests the assessment behavior and found cast doubt on the requirement of full-census approach or a sample survey and if the surveyors have the right incentives to produce information in effective and efficient way. Beyond, the survey task itself, the data collector must have security, personal comfort and incentives and usually, this conditions are not noted by the emergency response planners (Benini & Conley, 2007).

The information management must be not only about the data collected but also about the performance of the survey itself, it could be done using tabs included in the software application to control the efficiency of the building inspectors; the objective is collect the data to calibrate the model to calculate the number of trained people required and to know when stop the data collection (Benini & Conley, 2007). The contribution of Benini et al. (2008) research study to the present research is that it demonstrates the importance of keeping data of the survey operation itself in order to analyze the performance of the operations, validate models and provide feedbacks data to improve the next emergency response operation and finally gain a better understanding of the issues involved in the emergency response.

Glossary

- **Accuracy level:** the degree of uncertainty that the number of parcels grouped in a service area by the application of this model, they will be similar to the number of parcels that can be inspected in the reality.

- **Control range:** is the number of teams or people who can be coordinated or supervised just by one person.

- **Operational-time:** 8, 10 and 12 hours. The operational time is the number of hours in the day to carry out the building inspection.

- **Process model:** it is the kind of model which describes the functional and structural relationships between the elements of the planning environment, in order to analysis the state of the system aim to identify problems and opportunities. It is useful to support resource analysis (Sharifi, 2004).

- **Response-time:** 1 day. This is the time that is take for every inspector to be ready to start the building inspection task. In this period, the trained people about building damage survey have to check the condition of their family and their properties; the non-affected inspectors should go to the meeting points.

- **Resource:** anything which is considered by those making decisions to be of potential use in achieving a particular objective Sharify (2004).

- **Schematic model:** it is a representation of the reality by using qualitative diagrams or flowcharts, which also utilize lines, points or arrows to show the relationships between the elements contained in this (Flacke, 2008).

- **Service areas:** Inspection areas made up by a certain number of parcels assigned to every inspector in the period of the rapid survey.

- **Space-parameters:** spatial fixed conditions of the area where the model is applied.

- **Time-parameters:** periods of times in the subsequent stages of the rapid building damage survey.

References

AIS. (2002). *Estudio para el diseño de la guía de evaluación post-sismo de edificaciones en Bogotá. Informe No. 1: Revisión de las principales metodologías existentes a nivel nacional e internacional.* Retrieved. from.

Aldo Benini, C. C. (2007). Rapid humanitarian assessments and rationality: a value-of-information study from Iraq, 2003-04. *Disasters, 31*(1), 29-48.

Aldo Benini, C. C. B. D. Z. W. (2008). Survivor needs or logistical convenience? Factors shaping decisions to deliver relief to earthquake-affected communities, Pakistan 2005–06. *Disasters, 9999*(9999).

Batanovic, V., Petrovic, D., & Petrovic, R. (2009). Fuzzy logic based algorithms for maximum covering location problems. *Information Sciences, 179*(1-2), 120-129.

Batty, M. (2007). *Planning Support Systems: Progress, Predictions, and Speculations on the shape of things to come*. Paper presented at the Planning Support Systems for Urban and Regional Analysis.

Bendimerad, F. (2001). Loss estimation: a powerful tool for risk assessment and mitigation. *Soil Dynamics and Earthquake Engineering, 21*(5), 467-472.

Benini, A., & Conley, C. (2007). Rapid humanitarian assessments and rationality: a value-of-information study from Iraq, 2003-04. *Disasters, 31*(1), 29-48.

Benini, A., Conley, C., Dittemore, B., & Waksman, Z. (2008). Survivor needs or logistical convenience? Factors shaping decisions to deliver relief to earthquake-affected communities, Pakistan 2005–06. *Disasters, 9999*(9999).

CEDERI, U. (2005). *Informe Final, Escenarios de Riesgo y Perdidas por Terremoto para Bogotá D.C.* Retrieved. from.

Chiu, Y.-C., & Zheng, H. (2007). Real-time mobilization decisions for multi-priority emergency response resources and evacuation groups: Model formulation and solution. *Transportation Research Part E: Logistics and Transportation Review, 43*(6), 710-736.

Comfort, L. K. An Interactive, Intelligent, Spatial Information System: A Community Model. Retrieved February 3, 2009, from https://www.riskinstitute.org/peri/component/option,com_bookmarks/Itemid,44/catid,26/navstart,0/task,detail/mode,0/id,151/search,*/

Comfort, L. K. (2008). An Interactive, Intelligent, Spatial Information System: A Community Model. Retrieved 21-March-2008, 2008, from https://www.riskinstitute.org/peri/component/option,com_bookmarks/Itemid,44/catid,26/navstart,0/task,detail/mode,0/id,151/search,*/

Contreras, D. (2002). *Estrategia Metodológica para la conformación de grupos inspectores de edificaciones después de un sismo en Bogotá D.C.*, Universidad de Los Andes, Bogota D.C.

CyberTracker. (2008). CyberTracker. Retrieved November 23, 2008, 2008, from http://www.cybertracker.org/index.html

Debarati Guha-Sapir, M. F. L. (1986). Information systems and needs assessment in natural disasters: An approach for better disaster relief management. *Disasters, 10*(3), 232-237.

FEMA. (2001). *Understanding your risks. Identifying hazards and estimating losses*.

Fiedrich, F., Gehbauer, F., & Rickers, U. (2000). Optimized resource allocation for emergency response after earthquake disasters. *Safety Science, 35*(1-3), 41-57.

Fiedrich F, G. F., Rickers U (2000). Optimized resource allocation for emergency response after earthquake disasters. *Safety Science, 35* (1-3), 41-57

Flacke, J. (2008). Introduction to modeling and scenario development. Enschede.

Frédéric Patricelli, J. E. B. A. C. M. T. D. K. J. E. v. L. (2008). Disaster management and mitigation: the telecommunications infrastructure. *Disasters, 9999*(9999).

Fuad Aleskerov, A. I. S. A. T. H. L. A. G. A. (2005). A cluster-based decision support system for estimating earthquake damage and casualties. *Disasters, 29*(3), 255-276.

Geertman, S., & Stillwell, J. (2004). Planning support systems: an inventory of current practice. *Computers, Environment and Urban Systems, 28*(4), 291-310.

Hoard, M., Homer, J., Manley, W., Furbee, P., Haque, A., & Helmkamp, J. (2005). Systems modeling in support of evidence-based disaster planning for rural areas. *International Journal of Hygiene and Environmental Health, 208*(1-2), 117-125.

Iannoni, A. P., Morabito, R., & Saydam, C. (2009). An optimization approach for ambulance location and the districting of the response segments on highways. *European Journal of Operational Research, 195*(2), 528-542.

Kerle, N., & Widartono, B. (2007). Geoinformation-Based Response to the 27 May Indonesia Earthquake - an Initial Assessment. 13.

Lau, H. C., Agussurja, L., & Thangarajoo, R. (2008). Real-time supply chain control via multi-agent adjustable autonomy. *Computers & Operations Research, 35*(11), 3452-3464.

Lee, J. Y. (2007). A three-dimensional navigable data model to support emergency response in microspatial built-environments. *ANNALS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS, 97*(3), 512-529.

Mansourian, A., Rajabifard, A., Valadan Zoej, M. J., & Williamson, I. (2006). Using SDI and web-based system to facilitate disaster management. *Computers & Geosciences, 32*(3), 303-315.

Melanie, G. (2004). Where to Go? Strategic Modelling of Access to Emergency Shelters in Mozambique. *Disaster, 28*(1), 82-97.

Mitchell, J. K. (1996). The long road to recovery: Community responses to industrial disaster. In T. U. N. University (Eds.), Available from http://www.unu.edu/unupress/unupbooks/uu21le/uu21le00.htm#Contents

Novaes, A. G. N., Souza de Cursi, J. E., da Silva, A. C. L., & Souza, J. C. (2009). Solving continuous location-districting problems with Voronoi diagrams. *Computers & Operations Research, 36*(1), 40-59.

Ozdamar, L., Ekinci, E., & Kucukyazici, B. (2004). Emergency logistics planning in natural disasters. *Annals of Operations Research, 129*(1-4), 217-245.

Pacione, M. (2005). *Urban geography : a global perspective* (Second edition ed.). London etc.: Routledge.

Patricelli, F., Beakley, J. E., Carnevale, A., Tarabochia, M., & Lubitz, D. K. J. E. v. (2009). Disaster management and mitigation: the telecommunications infrastructure. *Disasters, 33*(1), 23-37.

Perry, R. W., & Lindell, M. K. (2003). Preparedness for Emergency Response: Guidelines for the Emergency Planning Process. *Disasters, 27*(4), 336-350.

Sharifi, A. (2004). *Reader on Introduction to Planning and Scenario Development*. Enschede, The Netherlands.

Sharifi, A. (2008). Scenario development and analysis. 53.

Sharify, A., & Flacke, J. (2008). Introduction to planning support systems, scenario development and analysis advanced module 12, 2008. [Lecture]. 16.

Unidad de Prevención y Atención de Emergencias - UPES, I. C. d. M. y. G.-I., Universidad de Los Andes. (1997). *Estudio de Microzonificacion Sismica de Santafe de Bogotá D.C.* Retrieved. from.

W. Randolph Daley, A. K. M. S. (2001). Needs Assessment of the Displaced Population Following the August 1999 Earthquake in Turkey. *Disasters, 25*(1), 67-75.

Wallace, W. A., & Balogh, F. D. (1985). Decision Support Systems for Disaster Management. *Public Administration Review, 45*, 134-146.

Waugh, W. L. (2000). *Living with hazards, dealing with disasters : an introduction to emergency management*. Armonk etc.: M.E. Sharpe.

Wei-Ning, X., & Keith, C. C. (2003). The use of scenarios in land-use planning. *Environment and Planning B: Planning and Design, 30*(6), 885-909.

Wollenberg, E., Edmunds, D., & Buck, L. (2000). Using scenarios to make decisions about the future: anticipatory learning for the adaptive co-management of community forests. *Landscape and Urban Planning, 47*(1-2), 65-77.

Yan, S., & Shih, Y.-L. (2007). A time-space network model for work team scheduling after a major disaster. *Journal of the chinese institute of engineers, 30* (1), 63-75

Zlatanova, S., van Oosterom, P., & Verbree, E. (2006). Geo-information support in management of urban disasters. *Open House International, 31*(1), 62-69.

Appendices

Appendix A. ATC-20 Rapid evaluation safety assessment form (American methodology).
Appendix B. Rapid building damage survey form in Mexican methodology.
Appendix C. Rapid building damage survey form in Japanese methodology.
Appendix D. Alternatives considered by DANE to send the data captured in the surveys for the census 2005
Appendix E. Questionnaire to test availability to carry out the building damage survey in people trained from 2002 to 2003.
Appendix F. Survey results.
Appendix G. Remarks about the interview with the preparedness manager group manager in DPAE.
Appendix H. Remarks about the interview with the Emergency manager group manager in DPAE.
Appendix I. Remarks about the interview with the technical manager of the project about digitalization of cadastral cartography in IGAC.
Appendix J. Remarks about interview with a public servant who worked in the Census and demography department in DANE.
Appendix K. Fieldwork requirements and information collected.
Appendix I. Remarks about the interview with the technical manager of the project about digitalization of cadastral cartography in IGAC.
Appendix M. Number of trained people according to the inspection time based on the degree of damage for every seismic scenario (RP).
Appendix N. Comparison of scenarios about damage degree, collapsed areas, injured and casualties.
Appendix O. Comparison of the application of allocation methods in every scenario.

Appendix A. ATC-20 Rapid evaluation safety assessment form (American methodology)
Source: AIS, 2002.

ATC-20 Rapid Evaluation Safety Assessment Form

Inspection

Inspector ID: ______ Inspection date and time: ______ ☐ AM ☐ PM

Affiliation: ______ Areas inspected: ☐ Exterior only ☐ Exterior and interior

Building Description

Building name: ______

Address: ______

Building contact/phone: ______

Number of stories above ground: ______ below ground: ______

Approx. "Footprint area" (square feet): ______

Number of residential units: ______

Number of residential units not habitable: ______

Type of Construction

☐ Wood frame ☐ Concrete shear wall
☐ Steel frame ☐ Unreinforced masonry
☐ Tilt-up concrete ☐ Reinforced masonry
☐ Concrete frame ☐ Other: ______

Primary Occupancy

☐ Dwelling ☐ Commercial ☐ Government
☐ Other residential ☐ Offices ☐ Historic
☐ Public assembly ☐ Industrial ☐ School
☐ Emergency services ☐ Other: ______

Evaluation

Investigate the building for the conditions below and check the appropriate column.

Observed Conditions:	Minor/None	Moderate	Severe	Estimated Building Damage (excluding contents)
				☐ None
Collapse, partial collapse, or building off foundation	☐	☐	☐	☐ 0–1%
Building or story leaning	☐	☐	☐	☐ 1–10%
Racking damage to walls, other structural damage	☐	☐	☐	☐ 10–30%
Chimney, parapet, or other falling hazard	☐	☐	☐	☐ 30–60%
Ground slope movement or cracking	☐	☐	☐	☐ 60–100%
Other (specify) ______	☐	☐	☐	☐ 100%

Comments: ______

Posting

Choose a posting based on the evaluation and team judgment. *Severe* conditions endangering the overall building are grounds for an Unsafe posting. Localized *Severe* and overall *Moderate* conditions may allow a Restricted Use posting. Post INSPECTED placard at main entrance. Post RESTRICTED USE and UNSAFE placards at all entrances.

☐ **INSPECTED** (Green placard) ☐ **RESTRICTED USE** (Yellow placard) ☐ **UNSAFE** (Red placard)

Record any use and entry restrictions exactly as written on placard: ______

Further Actions

Check the boxes below only if further actions are needed.

☐ Barricades needed in the following areas: ______

☐ Detailed Evaluation recommended: ☐ Structural ☐ Geotechnical ☐ Other: ______

☐ Other recommendations: ______

Comments: ______

Appendix B. Rapid building damage survey form in Mexican methodology

Source: AIS, 2002.

Forma para inspección postsísmica. Evaluación rápida.

Identificación del edificio

Zonificación propuesta de la ciudad para efectuar la evaluación ____________

Dirección: ____________

Colonia: ____________

Número de niveles sobre el terreno (incluyendo azoteas y mezanines) ________

Sótanos Si O No O Núm _____ Desconocido O

Uso Casa habitación O Departamentos O Comercios O Oficinas públicas O

Oficinas privadas O Industrias O Estacionamientos O Bodegas O

Educación O Recreativo O Otro: ____________

Información adicional ____________

Instrucciones

Revisar la edificación para las condiciones señaladas abajo. Con un *Si* a cualesquiera de las preguntas 1,2,3,4,5, marcar la edificación como *Insegura*. Con un *Si* a las preguntas 6 o 7 marcar *Área Insegura* y colocar barreras alrededor de la zona en peligro. Si en esta evaluación existen dudas se debe marcar *Seguridad en duda*.

Estado de la edificación

	Si	No	Existen dudas
1.- Derrumbe total o parcial, edificación separada de su cimentación o falla de ésta. Hundimiento.	O	O	O
2.- Inclinación notoria de la edificación o de algún entrepiso	O	O	O
3.- Daño en miembros estructurales (columnas, vigas, muros, etc.)	O	O	O
4.- Daño severo en muros no estructurales, escaleras, etc.	O	O	O
5.- Grietas, movimiento del suelo o deslizamiento de talud	O	O	O
6.- Pretiles, balcones ú otros elementos en peligro de caer	O	O	O
7.- Otros peligros (derrames tóxicos, líneas rotas, etc.)	O	O	O

Clasificación global

Habitable O

Inspección exterior únicamente O

Inspección interior y exterior O

Seguridad en duda O

Insegura O

Inspectores (Indicar profesión)

1.- ____________

2.- ____________

3.- ____________

Fecha de inspección ____________

Recomendaciones

O**No se requiere revisión futura**

O**Es necesaria evaluación detallada** (señalar) Estructural O Geotécnica O Otra ________

O**Área insegura** (colocar barreras en las siguientes áreas) ____________

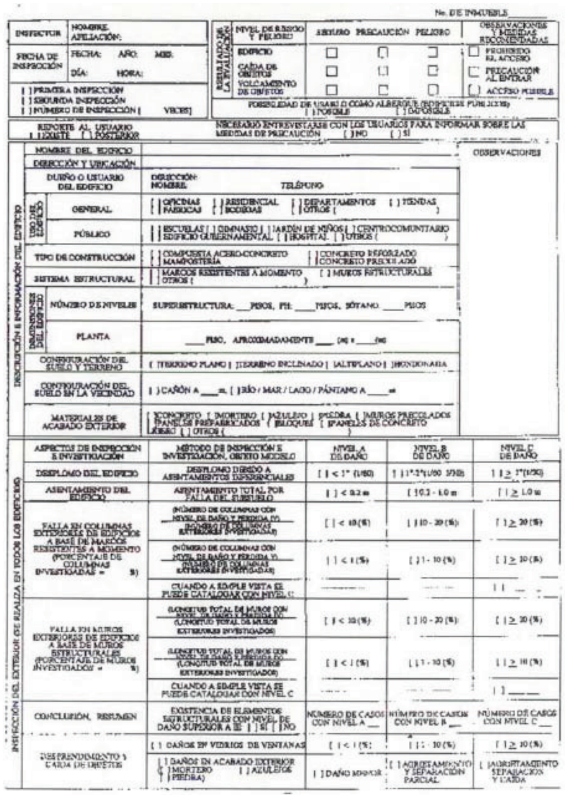
O**Otros** (remover elementos en peligro de caer, apuntalar, etc.) ____________

Comentarios

Explicar los motivos principales de la clasificación ____________

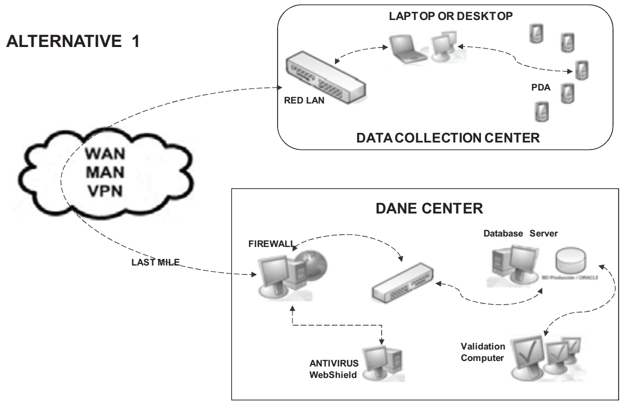
Appendix C. Rapid building damage survey form in Japanese methodology

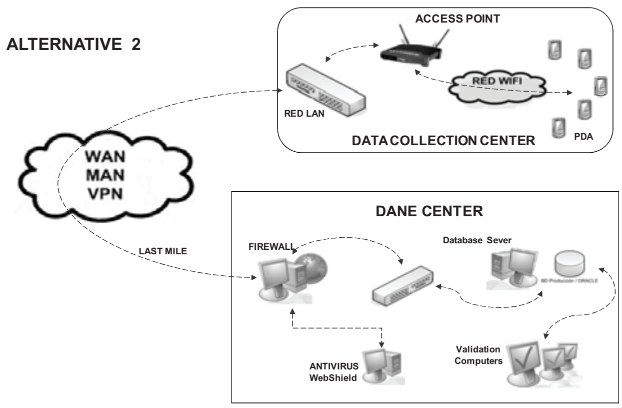
Source: AIS, 2002.

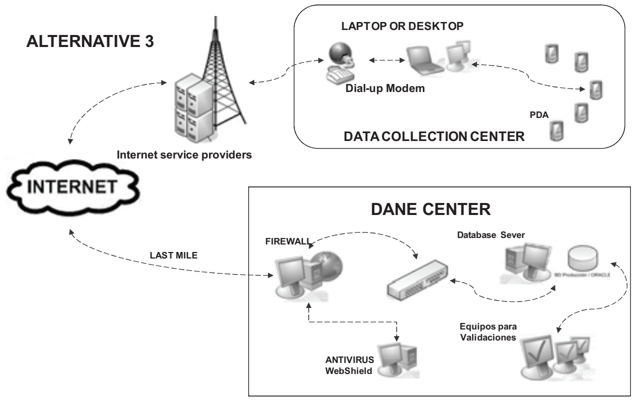


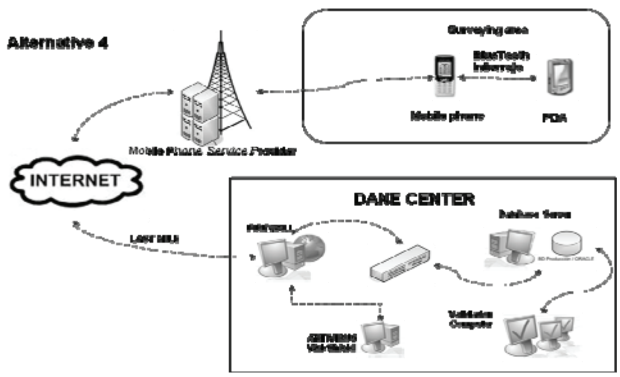
Appendix D. Alternatives considered by DANE to transmit the data captured in the surveys for the census 2005

Source: DANE.









Appendix E. Questionnaire to test availability to carry out the building damage survey in people trained in the periods 2002 - 2003 and 2007-2008

BUILDING INSPECTION GROUP AFTER AN EARTHQUAKE

Building damage survey after an earthquake in Bogota D.C. (Colombia). September – march, 2008. This survey has an academic purpose in the research project: Designing a spatial planning support system for rapid earthquake damage assessment: The case study of Bogota D.C.. The research project is part of the program: Urban Planning and Management in the International Institute for geo-information science and earth observation – ITC in Enschede, (The Netherlands).

Introduction

The purpose of this survey is to test the availability of trained people in the last years, about building damage survey after an earthquake. The methodology is to contact trained people and asks them if they would carry out the building damage survey, in case that an earthquake happens in the city; if their physical and psychological condition[1] allow them in that moment. People who answer in a positive way will be located in the city and with this information will be possible to estimate the coverage level in the city, what areas could be not covered by trained people?, what areas could be over-covered?, and finally to present a purpose to improve the training plan developed by the District Office of Emergency Prevention and Management – DPAE, through agreements with entities in charge of certifying the training. Thanks for your cooperation.

Dear alumni:

I would like to remain you that you have attended a training course about building damage survey after an earthquake, developed by the district office of emergency prevention and management (DPAE)[2]in the period 2002 – 2003. In this course, you received a brief introduction about how the district system of emergency prevention and management works, you watched a video about the earthquake in Mexico,1985 and finally, you attended a training to set out the habitability condition of the building (safety condition) according to the degree of damage in its structure.

Please, answer the next questions underlining the suggested options, which describe your condition:

1. Do you remember to have attended this awareness activity?
    - Yes
    - Not

    If your **ANSWER** is **NEGATIVE**, it is **NOT NECESSARY** that you **FOLLOW THE NEXT QUESTIONS**. I appreciate that you have paid attention to this message. **THANK YOU**.

2. Do you remember the topics discussed in the presentations?
    - Everything
    - Some parts
    - Nothing

3. Do you keep the material that you received during the training? (Technical booklet for building damage survey after an earthquake, operational booklet for the building inspection group and general building damage survey form.)
    - Everything
    - Part of the material
    - Nothing

[1] Not have been injured or been under stress because of the event itself or a family loss.

[2] Spanish Acronym of the district office of emergency prevention and management.

4. In case of an earthquake and you were called for carrying out the building damage survey, would you like to participate?
    - AVAILABLE
    - NOT AVAILABLE

    Remark: The positive answer to the last question **(AVAILABLE)** does not imply **ANY COMMITMENT FROM YOU,** this is just a survey with academic purpose. **PLEASE, REMIND THAT YOUR PARTICIPATION IS TOTALLY VOLUNTARY.**

5. **IF YOUR ANSWER IS POSITIVE,** please let us to update your personal data:
    - Family name:
    - First name:
    - Bachelor:
    - Specialization:
    - Work Experience (years):
    - Home telephone:
    - Bussiness telephone:
    - Mobile phone:
    - Home address (compulsory):
    - Neighborhood:
    - UPZ (Zonal units for planning – non compulsory):
    - District (no compulsory):

We appreciate the time spent on answering this survey because it allows me to continue developing methodologies to estimate the number of required people to inspect the buildings, to design models for allocating resources to respond to emergency and manage the information in the right way.

THIS QUESTIONARY DOES NOT REPRESENT ANY COMMITMENT FROM DPAE because as it is mentioned before, the purpose of this survey is mainly academic but the results will be sent to DPAE for its study.

Appendix F. Survey results

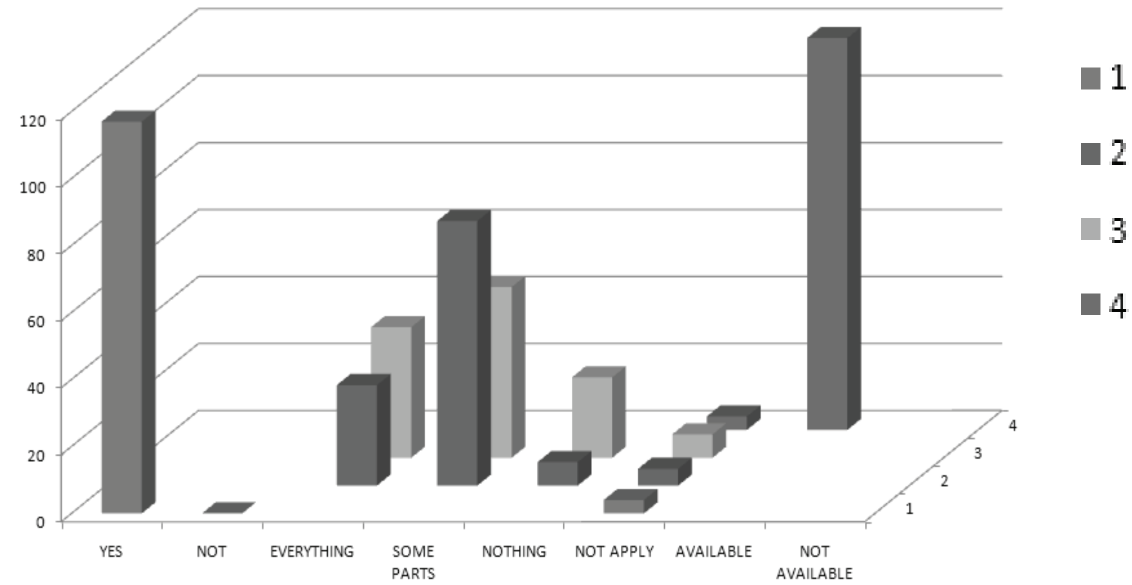
- E: Everything.
- P: Some parts.
- N: Nothing.
- N Ap: Not apply.
- A: Available.
- N Av: Not Available

QUESTION 1	**YES**	**NOT**	**N Ap**
Do you remember having attended this training course?	117	0	4
	97%	0%	3%

QUESTION 2	E	P	N	N Ap
Do you remember the topics discussed in the presentations?	**30**	**79**	**7**	**5**
	25%	**65%**	**6%**	**4%**

QUESTION 3	E	P	N	N Ap
Do you keep the material that you received during the training? (Technical booklet for building damage survey after an earthquake, operational booklet for the building inspection group and general building damage survey form.)	**39**	**51**	**24**	**7**
	32%	**42%**	**21%**	**4%**

QUESTION 4	**A**	**NA**	**N Ap**
In case of an earthquake and you were called for carrying out the building damage survey, would you like to participate?	117	0	4
	97%	0%	3%



Appendix G. Remarks on the interview with the Manager of the preparedness group in the emergency department of DPAE

The forms to carry out a damage assessment must be available all the time everywhere.
It is essential that people keep in mind their task into the organization scheme based on the Incident Command System-ICS, the Emergency Plan of Bogotá D.C.-PEB and the organization of the office.
The operational time have to be fixed up at the start of the day, in order that everyone has the same work conditions.
Everyone who works in the emergency response task have to report their availability as soon as possible, thus the emergency management staff is able to know the number of resources available and design the response strategy according to the priorities.
The form to carry out a damage assessment must be just one, and each person has to know how to fill in according to the same criterias.
The data must be shared in order to not duplicate efforts to collect it.
The information captured must be available all the time to answer the questions which come from the government and the people affected.
The information management must guarantee low margin of error in the data analysis.
The data capture must be in a digital way, otherwise the emergency management staff will have to look for people to type. Capture information in paper forms not only will delay the data analysis and the outputs, but also it will increase the number of resources required in the emergency response.
It is important to guarantee an acceptable supply of the building damage survey as a public service to the demand from the people.
The data capture task must be done using a mobile device with the survey form in the screen and it will desirable that it also have a printer as it is used in the devices who capture data from the credit card, to have printed information for the people.
The software application and the devices used must have the option to send information on real time. In the case that the communications will be out of order, there must be the possibility to download the information in the data collection centers set up by the emergency management staff or sending someone to pick up the information using also a mobile device to store the data.
The final goal of the information management have to have the data necessary to make plans draws on the right information and to take the right decisions.

Appendix H. Remarks on the Interview with the Manager of the emergency response group in the emergency department of DPAE

Comparison between DPAE's methodology and the methodology purposed in the present research.

	METHODOLOGY DPAE	METHODOLOGY PURPOSED
RAPID BUILDING DAMAGE SURVEY PERIOD	3 Days	3 Days
TARGET	All the parcels in the city 887.071 parcels	Focused in the damaged areas allocated by the study about Risk and loss scenarios because an earthquake for Bogotá D.C. 675.588 parcels
NUMBER OF PARCELS THAT A INSPECTION TEAM MUST BE ABLE TO EVALUATE PER DAY	100	Between 16 and 72
CONTROL RANGE	7	5 or 7 or 9
NUMBER OF INSPECTORS REQUIRED	2.926 (Not including supervisors and coordinators)	The range could be between 1.111 and to 34.905 people (Including supervisors and coordinators)
SERVICE AREAS	Based on Urban Planning Zones–UPZ, and each one is divided in six areas and allocated to a DPAE building inspector.	According to the walking distance (threshold: 5.000 meters around) and to the estimated inspection time.

Estimation of the number of trained people required according to the methodology designed by DPAE, which is based on the administrative (Districts) and urban planning zones – UPZ.

NUMBER OF DAYS	3
PARCELS EVALUATED PER DAY	100
PEOPLE PER TEAM	7

				NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					
DISTRICTS	PARCELS	TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	
1 USAQUÉN	39493	18.8	132	9446	4275	105	14	5	23.9%
2 CHAPINERO	16667	7.9	56	4455	3666	345	26	22	26.7%
3 SANTA FE	15172	7.2	51	7021	4099	1775	144	235	46.3%
4 SAN CRISTÓBAL	62603	29.8	209	15274	30661	1402	1121	242	24.4%
5 USME	76344	36.4	254	21632	14867	208	1345	368	28.3%
6 TUNJUELITO	20635	9.8	69	10328	3917	124	77	0	50.1%
7 BOSA	65874	31.4	220	15297	741	122	22	27	23.2%
8 KENNEDY	111294	53.0	371	9537	13812	1034	3235	706	8.6%
9 FONTIBÓN	15184	7.2	51	14339	1073	449	363	14	94.4%
10 ENGATIVÁ	94655	40.6	284	29790	4504	464	169	29	31.5%
11 SUBA	101429	48.3	338	25279	10021	288	241	2	24.9%
12 BARRIOS UNIDOS	27686	13.2	92	6084	1063	227	13	2	22.0%
13 TEUSAQUILLO	16842	8.0	56	6211	1829	72	32	12	36.9%
14 LOS MÁRTIRES	15032	7.2	50	7888	1897	1031	325	60	52.5%
15 ANTONIO NARIÑO	13259	6.3	44	7952	761	179	174	99	60.0%
16 PUENTE ARANDA	38947	18.5	130	8981	1216	789	365	53	23.1%
17 LA CANDELARIA	3556	1.7	12	429	808	896	4	429	12.1%
18 RAFAEL URIBE URIBE	53536	25.5	178	20009	22117	520	397	146	37.4%
19 CIUDAD BOLÍVAR	98863	47.1	330	30404	9783	3566	137	476	30.8%
	887071	**418.0**	**2926**	**250356**	**131110**	**13596**	**8204**	**2927**	**406193**

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
1	1		-	-	-	-	-	340	0.2	1	6	0	0	0	0	340	1.8%	0.0%	0.0%	0.0%	0.0%	1.76%	GREEN
	9				-	-	-	9222	4.4	31	1213	429	0	2	0	9222	13.2%	4.7%	0.0%	0.0%	0.0%	17.83%	GREEN
	10			-	-	-	-	889	0.4	3	151	38	3	0	0	889	17.0%	4.3%	0.3%	0.0%	0.0%	21.60%	GREEN
	11			-	-	-	-	8381	4.0	28	2779	270	17	1	2	8381	33.2%	3.2%	0.2%	0.0%	0.0%	36.62%	YELLOW
	12				-	-	-	4856	2.3	16	1343	972	16	0	1	4856	27.7%	20.0%	0.3%	0.0%	0.0%	48.02%	YELLOW
	13							6525	3.1	22	1523	1130	6	2	1	6525	23.3%	17.3%	0.1%	0.0%	0.0%	40.80%	YELLOW
	14				-	-	-	3967	1.9	13	1392	744	24	2	1	3967	35.1%	18.8%	0.6%	0.1%	0.0%	54.52%	ORANGE
	15			-	-	-	-	899	0.4	3	117	78	10	0	0	899	13.0%	8.7%	1.1%	0.0%	0.0%	22.80%	GREEN
	16						-	4414	2.1	15	922	614	29	7	0	4414	20.9%	13.9%	0.7%	0.2%	0.0%	35.61%	YELLOW
								39493	18.8	132	9446	4275	105	14	5								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
2	88						-	2322	1.1	8	775	447	6	0	1	2322	33.4%	19.3%	0.3%	0.0%	0.0%	52.93%	ORANGE
	89		-	-	-	-	-	2737	1.3	9	187	683	87	0	0	2737	6.8%	25.0%	3.2%	0.0%	0.0%	34.97%	YELLOW
	90					-	-	4131	2.0	14	890	672	111	0	0	4131	21.5%	16.3%	2.7%	0.0%	0.0%	40.50%	YELLOW
	97							4931	2.3	16	1962	848	69	18	6	4931	39.8%	17.2%	1.4%	0.4%	0.1%	58.87%	ORANGE
	99				-	-	-	2546	1.2	8	641	1016	72	8	15	2546	25.2%	39.9%	2.8%	0.3%	0.6%	68.81%	ORANGE
								16667	7.9	56	4455	3666	345	26	22								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
3	91	-	-	-	-	-	-	901	0.4	3	192	163	158	5	6	901	21.3%	18.1%	17.5%	0.6%	0.7%	58.16%	ORANGE
	92	-	-	-	-	-	-	2174	1.0	7	176	983	351	0	3	2174	8.1%	45.2%	16.1%	0.0%	0.1%	69.60%	ORANGE
	93	-	-	-	-	-	-	2990	1.4	10	979	429	121	17	41	2990	32.7%	14.3%	4.0%	0.6%	1.4%	53.08%	ORANGE
	95	-	-	-	-	-					1438	581	840	37	185	0						0.00%	GREEN
	96	-	-	-	-	-	-	9107	4.3	30	4236	1943	305	85	0	9107	46.5%	21.3%	3.3%	0.9%	0.0%	72.13%	ORANGE
								15172	7.2	51	7021	4099	1775	144	235								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
4	32	-	-	-	-	-	-	13283	6.3	44	3849	4721	4	461	1	13283	29.0%	35.5%	0.0%	3.5%	0.0%	68.03%	ORANGE
	33	-	-	-	-	-	-	4846	2.3	16	2497	342	1079	21	225	4846	51.5%	7.1%	22.3%	0.4%	4.6%	85.93%	ROJO
	34	-	-	-	-	-	-	14071	6.7	47	3044	9097	304	64	16	14071	21.6%	64.7%	2.2%	0.5%	0.1%	89.01%	ROJO
	50	-	-	-	-	-	-	15570	7.4	52	3178	9759	13	201	0	15570	20.4%	62.7%	0.1%	1.3%	0.0%	84.46%	ROJO
	51	-	-	-	-	-	-	14833	7.1	49	2706	6742	2	374	0	14833	18.2%	45.5%	0.0%	2.5%	0.0%	66.23%	ORANGE
								62603	29.8	209	15274	30661	1402	1121	242								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
5	52	-	-	-	-	-	-	11073	5.3	37	1575	640	0	93	368	11073	14.2%	5.8%	0.0%	0.8%	3.3%	24.17%	GREEN
	56	-	-	-	-	-	-	12736	6.1	42	1701	272	11	576	0	12736	13.4%	2.1%	0.1%	4.5%	0.0%	20.10%	GREEN
	57	-	-	-	-	-	-	21377	10.2	71	7018	7864	37	310	0	21377	32.8%	36.8%	0.2%	1.5%	0.0%	71.24%	ORANGE
	58	-	-	-	-	-	-	17658	8.4	59	6149	5376	147	357	0	17658	34.8%	30.4%	0.8%	2.0%	0.0%	68.12%	ORANGE
	59	-	-	-	-	-	-	11214	5.3	37	4932	415	2	4	0	11214	44.0%	3.7%	0.0%	0.0%	0.0%	47.73%	YELLOW
	60	-	-	-	-	-	-	1068	0.5	4	25	12	0	5	0	1068	2.3%	1.1%	0.0%	0.5%	0.0%	3.93%	GREEN
	61	-	-	-	-	-	-	1218	0.6	4	232	288	11	0	0	1218	19.0%	23.6%	0.9%	0.0%	0.0%	43.60%	YELLOW
								76344	36.4	254	21632	14867	208	1345	368								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
6	42	-	-	-	-	-	-	13832	6.6	46	7454	1103	60	21	0	13832	53.9%	8.0%	0.4%	0.2%	0.0%	62.45%	ORANGE
	62	-	-	-	-	-	-	6803	3.2	23	2874	2814	64	56	0	6803	42.2%	41.4%	0.9%	0.8%	0.0%	85.37%	ROJO
								20635	9.8	69	10328	3917	124	77	0								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
7	49	-	-	-	-	-	-	5905	2.8	20	1522	47	9	4	2	5905	25.8%	0.8%	0.2%	0.1%	0.0%	26.82%	YELLOW
	84	-	-	-	-	-	-	20759	9.9	69	2149	49	6	5	0	20759	10.4%	0.2%	0.0%	0.0%	0.0%	10.64%	GREEN
	85	-	-	-	-	-	-	32070	15.3	107	11626	645	107	13	25	32070	36.3%	2.0%	0.3%	0.0%	0.1%	38.72%	YELLOW
	86	-	-	-	-	-	-	5579	2.7	19	0	0	0	0	0	5579	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	GREEN
	87	-	-	-	-	-	-	1561	0.7	5	0	0	0	0	0	1561	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	GREEN
								65874	31.4	220	15297	741	122	22	27								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
8	44	-	-	-	-	-	-	9909	4.7	33	747	105	26	210	0	9909	7.5%	1.1%	0.3%	2.1%	0.0%	10.98%	GREEN
	45	-	-	-	-	-	-	13518	6.4	45	487	1541	8	24	0	13518	3.6%	11.4%	0.1%	0.2%	0.0%	15.24%	GREEN
	46	-	-	-	-	-	-	10692	5.1	36	968	575	1	2754	24	10692	9.1%	5.4%	0.0%	25.8%	0.2%	40.42%	YELLOW
	47	-	-	-	-	-	-	12339	5.9	41	305	3729	68	144	0	12339	2.5%	30.2%	0.6%	1.2%	0.0%	34.41%	YELLOW
	48	-	-	-	-	-	-	19329	9.2	64	4958	73	15	33	0	19329	25.7%	0.4%	0.1%	0.2%	0.0%	26.28%	YELLOW
	78	-	-	-	-	-	-	0	0.0	0	32	1627	208	30	37	0						0.00%	GREEN
	79	-	-	-	-	-	-	1643	0.8	5	6	0	0	0	0	1643	0.4%	0.0%	0.0%	0.0%	0.0%	0.37%	GREEN
	80	-	-	-	-	-	-	9407	4.5	31	340	318	27	5	0	9407	3.6%	3.4%	0.3%	0.1%	0.0%	7.33%	GREEN
	81	-	-	-	-	-	-	12166	5.8	41	1261	5821	33	6	642	12166	10.4%	47.8%	0.3%	0.0%	5.3%	63.81%	ORANGE
	82	-	-	-	-	-	-	19818	9.4	66	305	7	83	25	0	19818	1.5%	0.0%	0.4%	0.1%	0.0%	2.12%	GREEN
	83	-	-	-	-	-	-	25	0.0	0	0	0	0	0	0	25	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	GREEN
	113	-	-	-	-	-	-	2448	1.2	8	128	16	565	4	3	2448	5.2%	0.7%	23.1%	0.2%	0.1%	29.25%	YELLOW
								111294	53.0	371	9537	13812	1034	3235	706								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
9	75	-	-	-	-	-	-	1555	0.7	5	8972	699	122	60	1	1555	577.0%	45.0%	7.8%	3.9%	0.1%	633.70%	ROJO
	76	-	-	-	-	-	-	4451	2.1	15	1847	63	78	21	0	4451	41.5%	1.4%	1.8%	0.5%	0.0%	45.14%	YELLOW
	77	-	-	-	-	-	-	748	0.4	2	219	39	30	20	7	748	29.3%	5.2%	4.0%	2.7%	0.9%	42.11%	YELLOW
	110	-	-	-	-	-	-	364	0.2	1	32	26	1	0	0	364	8.8%	7.1%	0.3%	0.0%	0.0%	16.21%	GREEN
	112	-	-	-	-	-	-	1484	0.7	5	88	102	164	227	6	1484	5.9%	6.9%	11.1%	15.3%	0.4%	39.56%	YELLOW
	114	-	-	-	-	-	-	5139	2.4	17	2545	68	2	0	0	5139	49.5%	1.3%	0.0%	0.0%	0.0%	50.89%	ORANGE
	115	-	-	-	-	-	-	1420	0.7	5	621	72	49	32	0	1420	43.7%	5.1%	3.5%	2.3%	0.0%	54.51%	ORANGE
	117	-	-	-	-	-	-	23	0.0	0	15	4	3	3	0	23	65.2%	17.4%	13.0%	13.0%	0.0%	108.70%	ROJO
								15184	7.2	51	14339	1073	449	363	14								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
10	26	-	-	-	-	-	-	14268	6.8	48	4778	2388	178	92	22	14268	33.5%	16.7%	1.2%	0.6%	0.2%	52.27%	ORANGE
	29	-	-	-	-	-	-	14284	6.8	48	3521	1061	40	4		14284	24.6%	7.4%	0.3%	0.0%	0.0%	32.39%	YELLOW
	30	-	-	-	-	-	-	16015	7.6	53	10588	604	114	52	4	16015	66.1%	3.8%	0.7%	0.3%	0.0%	70.95%	ORANGE
	31	-	-	-	-	-	-	9319		0	3420	140	13	3		9319	36.7%	1.5%	0.1%	0.0%	0.0%	38.37%	YELLOW
	72	-	-	-	-	-	-	1721	0.8	6	77	55	5	0		1721	4.5%	3.2%	0.3%	0.0%	0.0%	7.96%	GREEN
	73	-	-	-	-	-	-	20349	9.7	68	3958	153	18	3		20349	19.5%	0.8%	0.1%	0.0%	0.0%	20.31%	GREEN
	74	-	-	-	-	-	-	17266	8.2	58	3448	102	96	15		17266	20.0%	0.6%	0.6%	0.1%	0.0%	21.20%	GREEN
	105	-	-	-	-	-	-	17	0.0	0	0	1	0	0		17	0.0%	5.9%	0.0%	0.0%	0.0%	5.88%	GREEN
	116	-	-	-	-	-	-	1416	0.7	5	0	0	0	0	3	1416	0.0%	0.0%	0.0%	0.0%	0.2%	0.21%	GREEN
								94655	40.6	284	29790	4504	464	169	29								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
11	2		-	-	-	-	-	376	0.2	1	72	0	0	0	0	376	19.1%	0.0%	0.0%	0.0%	0.0%	19.15%	GREEN
	3		-	-	-	-	-	730	0.3	2	8	0	0	0	0	730	1.1%	0.0%	0.0%	0.0%	0.0%	1.10%	GREEN
	17				-	-	-	3769	1.8	13	80	5	0	0	0	3769	2.1%	0.1%	0.0%	0.0%	0.0%	2.26%	GREEN
	18				-	-	-	2840	1.4	9	646	1	0	0	0	2840	22.7%	0.0%	0.0%	0.0%	0.0%	22.78%	GREEN
	19					-	-	6361	3.0	21	1887	1343	84	13	0	6361	29.7%	21.1%	1.3%	0.2%	0.0%	52.30%	ORANGE
	20					-	-	4110	2.0	14	1834	967	2	0	0	4110	44.6%	23.5%	0.0%	0.0%	0.0%	68.20%	ORANGE
	23				-	-	-	996	0.5	3	105	375	11	1	0	996	10.5%	37.7%	1.1%	0.1%	0.0%	49.40%	YELLOW
	24						-	6846	3.3	23	459	113	2	0	0	6846	6.7%	1.7%	0.0%	0.0%	0.0%	8.38%	GREEN
	25				-	-	-	4287	2.0	14	924	819	38	205	2	4287	21.6%	19.1%	0.9%	4.8%	0.0%	46.37%	YELLOW
	27						-	9347	4.5	31	1785	1280	51	2	0	9347	19.1%	13.7%	0.5%	0.0%	0.0%	33.36%	YELLOW
	28							34636	16.5	115	10307	4875	78	11	0	34636	29.8%	14.1%	0.2%	0.0%	0.0%	44.09%	YELLOW
	71						-	27131	12.9	90	7172	243	22	9	0	27131	26.4%	0.9%	0.1%	0.0%	0.0%	27.44%	YELLOW
								101429	48.3	338	25279	10021	288	241	2								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
12	21	-	-	-	-	-	-	4825	2.3	16	1616	114	35	2	0	4825	33.5%	2.4%	0.7%	0.0%	0.0%	36.62%	YELLOW
	22	-	-	-	-	-	-	9594	4.6	32	1453	235	1	0	0	9594	15.1%	2.4%	0.0%	0.0%	0.0%	17.60%	GREEN
	98	-	-	-	-	-	-	12842	6.1	43	2975	702	191	11	2	12842	23.2%	5.5%	1.5%	0.1%	0.0%	30.22%	YELLOW
	103	-	-	-	-	-	-	425	0.2	1	40	12	0	0	0	425	9.4%	2.8%	0.0%	0.0%	0.0%	12.24%	GREEN
								27686	13.2	92	6084	1063	227	13	2								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
13	100	-	-	-	-	-	-	5646	2.7	19	2288	485	35	15	6	5646	40.5%	8.6%	0.6%	0.3%	0.1%	50.11%	ORANGE
	101	-	-	-	-	-	-	5056	2.4	17	1765	924	30	15	6	5056	34.9%	18.3%	0.6%	0.3%	0.1%	54.19%	ORANGE
	104	-	-	-	-	-	-	480	0.2	2	187	42	0	0	0	480	39.0%	8.8%	0.0%	0.0%	0.0%	47.71%	YELLOW
	106	-	-	-	-	-	-	2767	1.3	9	845	328	1	0	0	2767	30.5%	11.9%	0.0%	0.0%	0.0%	42.43%	YELLOW
	107	-	-	-	-	-	-	2665	1.3	9	1097	42	5	2	0	2665	41.2%	1.6%	0.2%	0.1%	0.0%	43.00%	YELLOW
	109	-	-	-	-	-	-	228	0.1	1	29	8	1	0	0	228	12.7%	3.5%	0.4%	0.0%	0.0%	16.67%	GREEN
								16842	8.0	56	6211	1829	72	32	12								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
14	37	-	-	-	-	-	-	6441	3.1	21	3264	416	177	75	12	6441	50.7%	6.5%	2.7%	1.2%	0.2%	61.23%	ORANGE
	102	-	-	-	-	-	-	8591	4.1	29	4624	1481	854	250	48	8591	53.8%	17.2%	9.9%	2.9%	0.6%	84.47%	ROJO
								15032	7.2		7888	1897	1031	325	60								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
15	35	-	-	-	-	-	-	3557	1.7	12	1134	115	23	8	0	3557	31.9%	3.2%	0.6%	0.2%	0.0%	35.99%	YELLOW
	38	-	-	-	-	-	-	9702	4.6	32	6818	646	156	166	99	9702	70.3%	6.7%	1.6%	1.7%	1.0%	81.27%	ROJO
								13259	6.3	44	7952	761	179	174	99								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
16	40	##	##	-	-	-	-	13336	6.4	44	3455	85	265	12	23	13336	25.9%	0.6%	2.0%	0.1%	0.2%	28.79%	YELLOW
	41	##	##	-	-	-	-	9640	4.6	32	2589	363	2	1	0	9640	26.9%	3.8%	0.0%	0.0%	0.0%	30.65%	YELLOW
	43	##	-	-	-	-	-	10826	5.2	36	1667	112	34	217	0	10826	15.4%	1.0%	0.3%	2.0%	0.0%	18.75%	GREEN
	108	##	-	-	-	-	-	2809	1.3	9	943	621	40	132	29	2809	33.6%	22.1%	1.4%	4.7%	1.0%	62.83%	ORANGE
	111	##	-	-	-	-	-	2336	1.1	8	327	35	448	3	1	2336	14.0%	1.5%	19.2%	0.1%	0.0%	34.85%	YELLOW
								38947	18.5	130	8981	1216	789	365	53								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
17	94	-	-	-	-	-	-	3556	1.7	12	429	808	896	4	429	3556	12.1%	22.7%	25.2%	0.1%	12.1%	72.16%	ORANGE
								3556	1.7	12	429	808	896	4	429								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
18	36	-	-	-	-	-	-	6352	3.0	21	3620	1357	32	7	8	6352	57.0%	21.4%	0.5%	0.1%	0.1%	79.09%	ROJO
	39	-	-	-	-	-	-	14125	6.7	47	8554	3402	116	90	0	14125	60.6%	24.1%	0.8%	0.6%	0.0%	86.10%	ROJO
	53	-	-	-	-	-	-	8421	4.0	28	1213	6383	84	51	16	8421	14.4%	75.8%	1.0%	0.6%	0.2%	92.00%	ROJO
	54	-	-	-	-	-	-	13384	6.4	45	4135	5990	113	6	27	13384	30.9%	44.8%	0.8%	0.0%	0.2%	76.74%	ROJO
	55	-	-	-	-	-	-	11254	5.4	38	2487	4985	175	243	95	11254	22.1%	44.3%	1.6%	2.2%	0.8%	70.95%	ORANGE
								53536	25.5	178	20009	22117	520	397	146								

		PARCELS PER DIVISION IN EVERY UPZ									NUMBER OF PARCELS ACCORDING TO PERCENTAGE OF DAMAGE					Total	Porcentaje de predios con daño					Porcentaje Total	Categoria de Daño
DISTRICT	UPZ	A	B	C	D	E	F	PARCELS	UPZ TEAMS	INSPECTORS	0-10	10.-20	20-30	30-40	>45	Predios	0-10	10.-20	20-30	30-40	>45	Daño	
19	63	-	-	-	-	-	-	117	0.1	0	6	18	2	0	4	117	5.1%	15.4%	1.7%	0.0%	3.4%	25.64%	YELLOW
	64	-	-	-	-	-	-	1028	0.5	3	105	19	0	1	0	1028	10.2%	1.8%	0.0%	0.1%	0.0%	12.16%	GREEN
	65	-	-	-	-	-	-	8192	3.9	27	2116	87	8	10	6	8192	25.8%	1.1%	0.1%	0.1%	0.1%	27.19%	YELLOW
	66	-	-	-	-	-	-	10197	4.9	34	4315	3206	105	8	123	10197	42.3%	31.4%	1.0%	0.1%	1.2%	76.07%	ROJO
	67	-	-	-	-	-	-	27379	13.0	91	7820	2883	756	7	289	27379	28.6%	10.5%	2.8%	0.0%	1.1%	42.93%	YELLOW
	68	-	-	-	-	-	-	10124	4.8	34	2946	461	623	5	14	10124	29.1%	4.6%	6.2%	0.0%	0.1%	39.99%	YELLOW
	69	-	-	-	-	-	-	26302	12.5	88	6614	1623	1667	106	30	26302	25.1%	6.2%	6.3%	0.4%	0.1%	38.17%	YELLOW
	70	-	-	-	-	-	-	15524	7.4	52	6482	1486	405	0	10	15524	41.8%	9.6%	2.6%	0.0%	0.1%	54.00%	ORANGE
								98863	47.1	330	30404	9783	3566	137	476								

Appendix I. Remarks on the Interview with the technical Manager of the project about digitalization of cadastral cartography in IGAC

- Which kind of data IGAC prepared to carry out the census 2005? IGAC up-dated the cartographic database that DANE already had, by using the aerial photography and the vector data which was used to design the POT (Land Use plan) in Bogotá D.C.
- The cartography is in the block level, it is geocoded and it also receives radiometric and geometric corrections.
- And to the places where the information was not available, a team was sent to get information; in this way the information was completed.

- How is the information shared between IGAC and DANE? The information is given in digital format mainly but also in paper.

- How the cadastral data was incorporated in the mobile devices used in the census? DANE contracted a company to upload the shape files follow some rules as the files always have to have an ID, a good topology and every file had to had the same attribute order.

- How the geocodification of the data took place in the survey? In the screen of the mobile devices appears the blocks; it was not reliable to have the data per parcels, because not every surveyor has the concept of the parcel in their minds. Due to the last, people make a dot in the block to show every household surveyed. The technical specifications and the surveyors profile were a little bit different between the urban and the rural area, because in the rural area the batteries of the mobile devices must have more duration, and also they had to had a GPS, integrated.

- How much time did it take place to prepare the information? It started in January 2005 (the census began on may 2005, four months later) and during the year the information was given according to the areas were the census was on-going. The census 2005 was done carried out in four months.

- What is it the suggested up date level of the information used in this kind of events? The most updated possible.

- In the case of Bogotá D.C., do you prepare the information or was the DACD (District Department of Cadastral Administration)? The DACD gave a cartographic database to DANE and this department also passes it to IGAC. In this particular case, because there were recent aerial photography, their were just geocoded.

Appendix J. Remarks on the interview with a public servant who worked in the Census and demography department in DANE

- The cartography started to be prepared three years earlier, through an agreement between DANE and IGAC; in order than the cartography will be prepared as the DANE needed for the census purpose.
- There were several entities involved in the census: DANE as the manager, FONADE (National Fund for the Developmen) as the entity to manage all the financial matters related to buy the mobile devices; ALMAMATER, like the company in charge of the logistic to distribute and pick up the mobiles devices over the country; INTEGRA as the company to supply the mobile devices, the software application and the helpdesk; FESA, to print and capture data from the forms using a scanner; and finally, TELECOM was the support company to transmit and store the information.
- The use of mobile devices to pick up the information must be supported by forms in paper, because there are some areas such as the jungle where there is no way to recharge a battery and there is also places where the security conditions do not make feasible the use of them.
- There must be an agreement with the manufacturer company, when large quantities of mobile devices are required because these kinds of quantities are not usually in stock. All the devices must be covered by insurance and it is desirable that they will be also useful to other kind of surveys.
- Personnel department in DANE made an agreement with some universities in the country, to select and hire the suitable surveyors, supervisors and coordinators according to a specific profile already designed by DANE.
- The surveyor capture the data in a mobile device and at the end of the workday, every surveyor synchronized their SD with the Supervisor's SD. The operational time was eight hours and the control range was five surveyors per supervisor. After that, every supervisor used to go to a data collection center to download the data in a PC. Then, the information in the PC was sent to the main data collection center in DANE. A report was generated with the specific information about the census and another one with information about census management.
- The census management report included the information from the controller time in the mobile devices to know how much time a surveyor took to carry out the survey. There was a verification of the sampling to create internal reports to know is everything is on-going in the right way.
- When the inspection area was in the areas where the access was difficult, the inspection route must be planned ahead to contract facilities, such a local guide or the suitable transportation modes like horses or boats.
- The feedback showed that the software application must be improved and also the technical specifications in the mobile devices. It would desirable to sent the information from the mobile device to the data collection center through a FTP protocol. The idea about to send the information on-line will have to wait until the technical specifications of the devices and the media to transmit the information will be improved.

Appendix K. Fieldwork requirements and information collected

		FORMAT
FACILITIES	E-mail account	
	Telephone account	
	Geocode people	DIGITAL
INFORMATION	Layer of loss estimation scenarios	DIGITAL
	Layer of roads	DIGITAL
	Layer of parks	DIGITAL
	Layer of important buildings.	DIGITAL
	Database of people trained from2002 to 2003 and from 2007 to 2008.	DIGITAL
DOCUMENTS	The study to design the technical guidebook to building damage survey after anearthquake in Bogotá D.C.- Field work manual . (2002)	DIGITAL PRINTED
	The risk and loss study scenarios after an earthquake in Bogota D.C	DIGITAL PRINTED
	Study about the urban vulnerability in case of a disaster in Bogotá D.C. (1999)	DIGITAL PRINTED
	Emergency Plan of Bogotá D.C.- PEB (2008)	DIGITAL PRINTED
	Guidebook to design the protocol and procedures manual- ICS manual. (2004)	PRINTED
	Guide to developing effective standard operating procedures for fire and EMS departments.	PRINTED

Appendix L. Number of people to be trained according to Sub-objective 1

												CONTROL RANGE - 5 UNITS								
SPACE PARAMETERS		TIME PARAMETERS				7 - OPERATIONAL TIME (HOURS)														
PARCELS TO INSPECT		4 -TIME FACTOR	MINUTES	5- HOURS	6 - HOURS PER DAY	8	10	12	8	10	12	8	10	12	8	10	12	8	10	12
		min per parcel		min/60	Hours/3	8 - TEAMS NUMBER			9 - INSPECTORS NUMBER			10 - SUPERVISORS NUMBER			11 - COORDNATORS NUMBER			NUMBER OF PEOPLE TO TRAIN		
RP 250	106,838	10	1,068,380	17,806	5,935	742	594	495	1,484	1,187	989	297	237	198	59	47	40	1,840	1,472	**1,227**
		15	1,602,570	26,710	8,903	1,113	890	742	2,226	1,781	1,484	445	356	297	89	71	59	2,760	2,208	1,840
		20	2,136,760	35,613	11,871	1,484	1,187	989	2,968	2,374	1,978	594	475	396	119	95	79	3,680	2,944	2,453
		25	2,670,950	44,516	14,839	1,855	1,484	1,237	3,710	2,968	2,473	742	594	495	148	119	99	4,600	3,680	3,067
		30	3,205,140	53,419	17,806	2,226	1,781	1,484	4,452	3,561	2,968	890	712	594	178	142	119	5,520	4,416	3,680
RP 500	318,945	10	3,189,450	53,158	17,719	2,215	1,772	1,477	4,430	3,544	2,953	886	709	591	177	142	118	5,493	4,394	3,662
		15	4,784,175	79,736	26,579	3,322	2,658	2,215	6,645	5,316	4,430	1,329	1,063	886	266	213	177	8,239	6,592	5,493
		20	6,378,900	106,315	35,438	4,430	3,544	2,953	8,860	7,088	5,906	1,772	1,418	1,181	354	284	236	10,986	8,789	7,324
		25	7,973,625	132,894	44,298	5,537	4,430	3,691	11,074	8,860	7,383	2,215	1,772	1,477	443	354	295	13,732	10,986	9,155
		30	9,568,350	159,473	53,158	6,645	5,316	4,430	13,289	10,632	8,860	2,658	2,126	1,772	532	425	354	16,479	13,183	10,986
RP 1000	362,898	10	3,628,980	60,483	20,161	2,520	2,016	1,680	5,040	4,032	3,360	1,008	806	672	202	161	134	6,250	5,000	4,167
		15	5,443,470	90,725	30,242	3,780	3,024	2,520	7,560	6,048	5,040	1,512	1,210	1,008	302	242	202	9,375	7,500	6,250
		20	7,257,960	120,966	40,322	5,040	4,032	3,360	10,081	8,064	6,720	2,016	1,613	1,344	403	323	269	12,500	10,000	8,333
		25	9,072,450	151,208	50,403	6,300	5,040	4,200	12,601	10,081	8,400	2,520	2,016	1,680	504	403	336	15,625	12,500	10,417
		30	10,886,940	181,449	60,483	7,560	6,048	5,040	15,121	12,097	10,081	3,024	2,419	2,016	605	484	403	**18,750**	15,000	12,500
		AVERAGE	**5,257,873**	**87,631**	**29,210**	**3,651**	**2,921**	**2,434**	**7,303**	**5,842**	**4,868**	**1,461**	**1,168**	**974**	**292**	**234**	**195**	**9,055**	**7,244**	**6,037**

Table 1 – Control range: 5 units per person.

												CONTROL RANGE - 7 UNITS								
SPACE PARAMETERS		TIME PARAMETERS				7 - OPERATIONAL TIME (HOURS)														
PARCELS TO INSPECT		4 -TIME FACTOR	MINUTES	5- HOURS	6 - HOURS PER DAY	8	10	12	8	10	12	8	10	12	8	10	12	8	10	12
		min per parcel		min/60	Hours/3	8 - TEAMS NUMBER			9 - INSPECTORS NUMBER			10 - SUPERVISORS NUMBER			11 - COORDNATORS NUMBER			NUMBER OF PEOPLE TO TRAIN		
RP 250	106,838	10	1,068,380	17,806	5,935	742	594	495	1,484	1,187	989	212	170	141	30	24	20	1,726	1,381	**1,151**
		15	1,602,570	26,710	8,903	1,113	890	742	2,226	1,781	1,484	318	254	212	45	36	30	2,589	2,071	1,726
		20	2,136,760	35,613	11,871	1,484	1,187	989	2,968	2,374	1,978	424	339	283	61	48	40	3,452	2,762	2,301
		25	2,670,950	44,516	14,839	1,855	1,484	1,237	3,710	2,968	2,473	530	424	353	76	61	50	4,315	3,452	2,877
		30	3,205,140	53,419	17,806	2,226	1,781	1,484	4,452	3,561	2,968	636	509	424	91	73	61	5,178	4,143	3,452
RP 500	318,945	10	3,189,450	53,158	17,719	2,215	1,772	1,477	4,430	3,544	2,953	633	506	422	90	72	60	5,153	4,122	3,435
		15	4,784,175	79,736	26,579	3,322	2,658	2,215	6,645	5,316	4,430	949	759	633	136	108	90	7,730	6,184	5,153
		20	6,378,900	106,315	35,438	4,430	3,544	2,953	8,860	7,088	5,906	1,266	1,013	844	181	145	121	10,306	8,245	6,871
		25	7,973,625	132,894	44,298	5,537	4,430	3,691	11,074	8,860	7,383	1,582	1,266	1,055	226	181	151	12,883	10,306	8,588
		30	9,568,350	159,473	53,158	6,645	5,316	4,430	13,289	10,632	8,860	1,898	1,519	1,266	271	217	181	15,459	12,367	10,306
RP 1000	362,898	10	3,628,980	60,483	20,161	2,520	2,016	1,680	5,040	4,032	3,360	720	576	480	103	82	69	5,863	4,691	3,909
		15	5,443,470	90,725	30,242	3,780	3,024	2,520	7,560	6,048	5,040	1,080	864	720	154	123	103	8,795	7,036	5,863
		20	7,257,960	120,966	40,322	5,040	4,032	3,360	10,081	8,064	6,720	1,440	1,152	960	206	165	137	11,726	9,381	7,818
		25	9,072,450	151,208	50,403	6,300	5,040	4,200	12,601	10,081	8,400	1,800	1,440	1,200	257	206	171	14,658	11,726	9,772
		30	10,886,940	181,449	60,483	7,560	6,048	5,040	15,121	12,097	10,081	2,160	1,728	1,440	309	247	206	17,589	14,072	11,726
		AVERAGE	**5,257,873**	**87,631**	**29,210**	**3,651**	**2,921**	**2,434**	**7,303**	**5,842**	**4,868**	**1,043**	**835**	**695**	**149**	**119**	**99**	**8,495**	**6,796**	**5,663**

Table 2 – Control range: 7 units per person.

												CONTROL RANGE - 9 UNITS								
SPACE PARAMETERS		TIME PARAMETERS				7 - OPERATIONAL TIME (HOURS)														
PARCELS TO INSPECT		4 -TIME FACTOR	MINUTES	5- HOURS	6 - HOURS PER DAY	8	10	12	8	10	12	8	10	12	8	10	12	8	10	12
		min per parcel		min/60	Hours/3	8 - TEAMS NUMBER			9 - INSPECTORS NUMBER			10 - SUPERVISORS NUMBER			11 - COORDNATORS NUMBER			NUMBER OF PEOPLE TO TRAIN		
RP 250	106,838	10	1,068,380	17,806	5,935	742	594	495	1,484	1,187	989	165	132	110	18	15	12	1,667	1,334	**1,111**
		15	1,602,570	26,710	8,903	1,113	890	742	2,226	1,781	1,484	247	198	165	27	22	18	2,501	2,000	1,667
		20	2,136,760	35,613	11,871	1,484	1,187	989	2,968	2,374	1,978	330	264	220	37	29	24	3,334	2,667	2,223
		25	2,670,950	44,516	14,839	1,855	1,484	1,237	3,710	2,968	2,473	412	330	275	46	37	31	4,168	3,334	2,778
		30	3,205,140	53,419	17,806	2,226	1,781	1,484	4,452	3,561	2,968	495	396	330	55	44	37	5,001	4,001	3,334
RP 500	318,945	10	3,189,450	53,158	17,719	2,215	1,772	1,477	4,430	3,544	2,953	492	394	328	55	44	36	4,977	3,981	3,318
		15	4,784,175	79,736	26,579	3,322	2,658	2,215	6,645	5,316	4,430	738	591	492	82	66	55	7,465	5,972	4,977
		20	6,378,900	106,315	35,438	4,430	3,544	2,953	8,860	7,088	5,906	984	788	656	109	88	73	9,953	7,963	6,636
		25	7,973,625	132,894	44,298	5,537	4,430	3,691	11,074	8,860	7,383	1,230	984	820	137	109	91	12,442	9,953	8,294
		30	9,568,350	159,473	53,158	6,645	5,316	4,430	13,289	10,632	8,860	1,477	1,181	984	164	131	109	14,930	11,944	9,953
RP 1000	362,898	10	3,628,980	60,483	20,161	2,520	2,016	1,680	5,040	4,032	3,360	560	448	373	62	50	41	5,663	4,530	3,775
		15	5,443,470	90,725	30,242	3,780	3,024	2,520	7,560	6,048	5,040	840	672	560	93	75	62	8,494	6,795	5,663
		20	7,257,960	120,966	40,322	5,040	4,032	3,360	10,081	8,064	6,720	1,120	896	747	124	100	83	11,325	9,060	7,550
		25	9,072,450	151,208	50,403	6,300	5,040	4,200	12,601	10,081	8,400	1,400	1,120	933	156	124	104	14,156	11,325	9,438
		30	10,886,940	181,449	60,483	7,560	6,048	5,040	15,121	12,097	10,081	1,680	1,344	1,120	187	149	124	**16,988**	13,590	11,325
		AVERAGE	**5,257,873**	**87,631**	**29,210**	**3,651**	**2,921**	**2,434**	**7,303**	**5,842**	**4,868**	**811**	**649**	**541**	**90**	**72**	**60**	**8,204**	**6,563**	**5,469**

Table 3 – Control range: 9 units per person.

SPACE PARAMETERS			TIME PARAMETERS			7 - OPERATIONAL TIME								
PARCELS TO INSPECT		PARCELS TO INSPECT PER DAY	4 -TIME FACTOR		5 - HOURS	8	10	12	8	10	12	8	10	12
		Parcels/3	min per parcel	Total minutes	min/60	8 - TEAMS NUMBER			PARCELS TO INSPECT PER TEAM IN ONE DAY			BLOCKS TO INSPECT PER TEAM IN ONE DAY		
RP 250	106,838	35,613	10	356,127	5,935	742	594	495	48	60	72	3	4	5
			15	534,190	8,903	1,113	890	742	32	40	48	2	3	3
			20	712,253	11,871	1,484	1,187	989	24	30	36	2	2	2
			25	890,317	14,839	1,855	1,484	1,237	19	24	29	1	2	2
			30	1,068,380	17,806	2,226	1,781	1,484	16	20	24	1	1	2
RP 500	318,945	106,315	10	1,063,150	17,719	2,215	1,772	1,477	48	60	72	3	4	5
			15	1,594,725	26,579	3,322	2,658	2,215	32	40	48	2	3	3
			20	2,126,300	35,438	4,430	3,544	2,953	24	30	36	2	2	2
			25	2,657,875	44,298	5,537	4,430	3,691	19	24	29	1	2	2
			30	3,189,450	53,158	6,645	5,316	4,430	16	20	24	1	1	2
RP 1000	362,898	120,966	10	1,209,660	20,161	2,520	2,016	1,680	48	60	72	3	4	5
			15	1,814,490	30,242	3,780	3,024	2,520	32	40	48	2	3	3
			20	2,419,320	40,322	5,040	4,032	3,360	24	30	36	2	2	2
			25	3,024,150	50,403	6,300	5,040	4,200	19	24	29	1	2	2
			30	3,628,980	60,483	7,560	6,048	5,040	16	20	24	1	1	2
		AVERAGE	**20**	**1752624**	**29210**	**3651**	**365**	**30**	**28**	**35**	**42**	**2**	**2**	**3**

Table 4 – Parcels and blocks to inspect per day.

Appendix M. Number of trained people according to the inspection time based on the degree of damage for every seismic scenario (RP). Control range: 9 units per person.

RP 250 YEARS			7 -TIME FACTOR
INSPECTION TIME minutes	INSPECTION TIME minutes	5 - PARCELS TO INSPECT	MINUTES PER PARCEL
10	10	102200	1,022,000
15	15	3678	55,170
20	20	743	14,860
25	25	172	4,300
30	30	45	1,350
		106838	**1,097,680**

8-HOURS	9-HOURS PER DAY	CONTROL RANGE - 9 UNITS / 10 - OPERATIONAL TIME (HOURS)														
		8	10	12	8	10	12	8	10	12	8	10	12	8	10	12
min/60	Hours/3	11 - TEAMS NUMBER			12 - INSPECTORS NUMBER			13 - SUPERVISORS NUMBER			14 - COORDINATORS NUMBER			15 - NUMBER OF PEOPLE TO TRAIN		
18,295	6,098	762	610	508	1,525	1,220	1,016	85	68	56	9	8	6	1,619	1,295	1,079
		SERVICE AREAS														

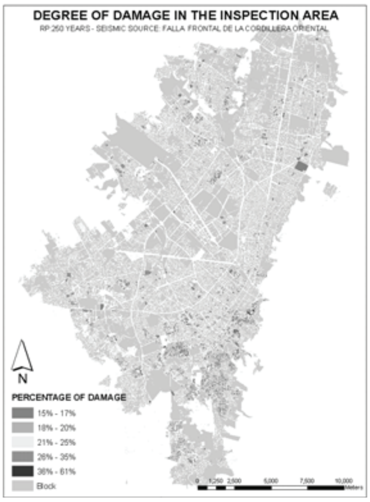
RP 500 YEARS			7 -TIME FACTOR
INSPECTION TIME minutes	INSPECTION TIME minutes	5 - PARCELS TO INSPECT	MINUTES PER PARCEL
10	10	189920	1,899,200
15	15	47717	715,755
20	20	62670	1,253,400
25	25	16361	409,025
30	30	2277	68,310
		318945	**4,345,690**

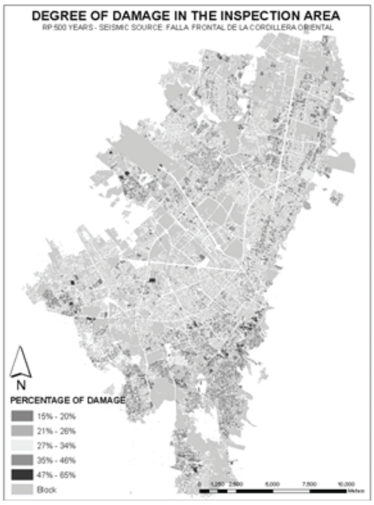
8-HOURS	9-HOURS PER DAY	CONTROL RANGE - 9 UNITS / 10 - OPERATIONAL TIME (HOURS)														
		8	10	12	8	10	12	8	10	12	8	10	12	8	10	12
min/60	Hours/3	11 - TEAMS NUMBER			12 - INSPECTORS NUMBER			13 - SUPERVISORS NUMBER			14 - COORDINATORS NUMBER			15 - NUMBER OF PEOPLE TO TRAIN		
72,428	24,143	3,018	2,414	2,012	6,036	4,829	4,024	335	268	224	37	30	25	6,408	5,127	4,272
		SERVICE AREAS														

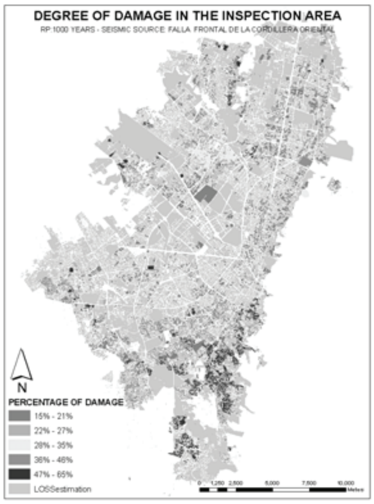
RP 1000 YEARS			7 -TIME FACTOR
INSPECTION TIME minutes	INSPECTION TIME minutes	5 - PARCELS TO INSPECT	MINUTES PER PARCEL
10	10	167946	1,679,460
15	15	87888	1,318,320
20	20	31901	638,020
25	25	56380	1,409,500
30	30	18783	563,490
		362898	**5,608,790**

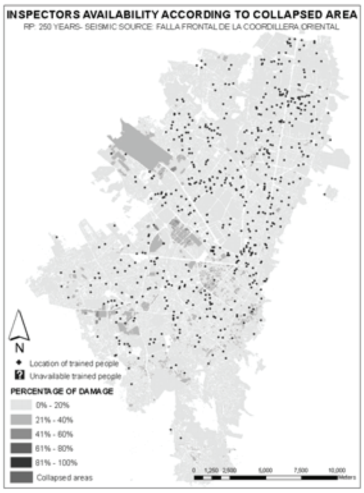
8-HOURS	9-HOURS PER DAY	CONTROL RANGE - 9 UNITS / 10 - OPERATIONAL TIME (HOURS)														
		8	10	12	8	10	12	8	10	12	8	10	12	8	10	12
min/60	Hours/3	11 - TEAMS NUMBER			12 - INSPECTORS NUMBER			13 - SUPERVISORS NUMBER			14 - COORDINATORS NUMBER			15 - NUMBER OF PEOPLE TO TRAIN		
93,480	31,160	3,895	3,116	2,597	7,790	6,232	5,193	433	346	289	48	38	32	8,271	6,617	5,514
		SERVICE AREAS														

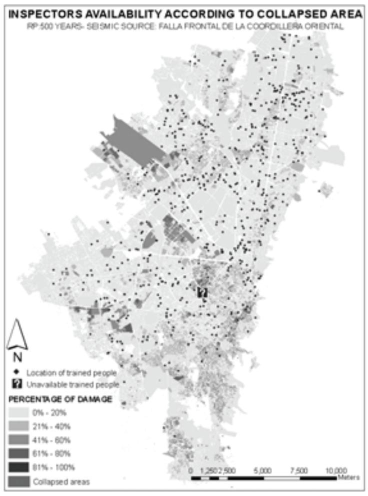
Appendix N. Comparison of scenarios about damage degree, collapsed areas, injured and casualties

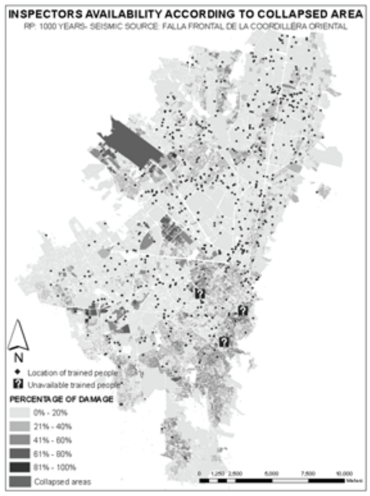


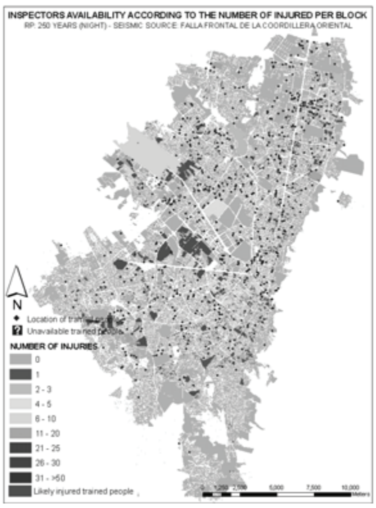


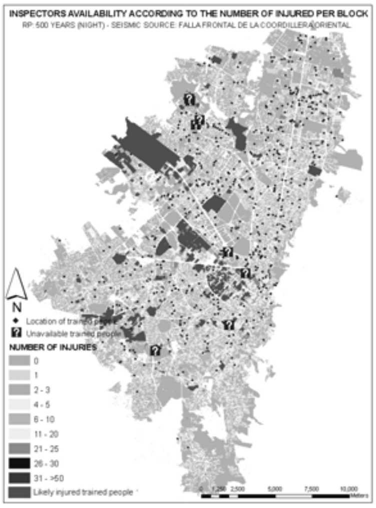


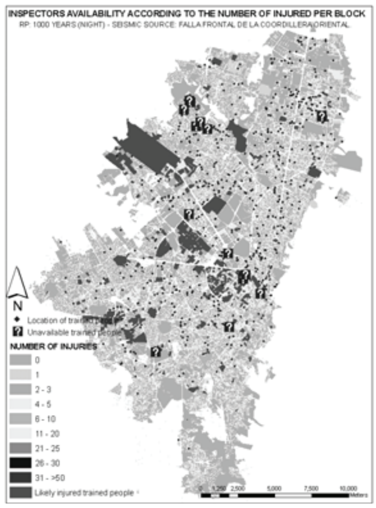


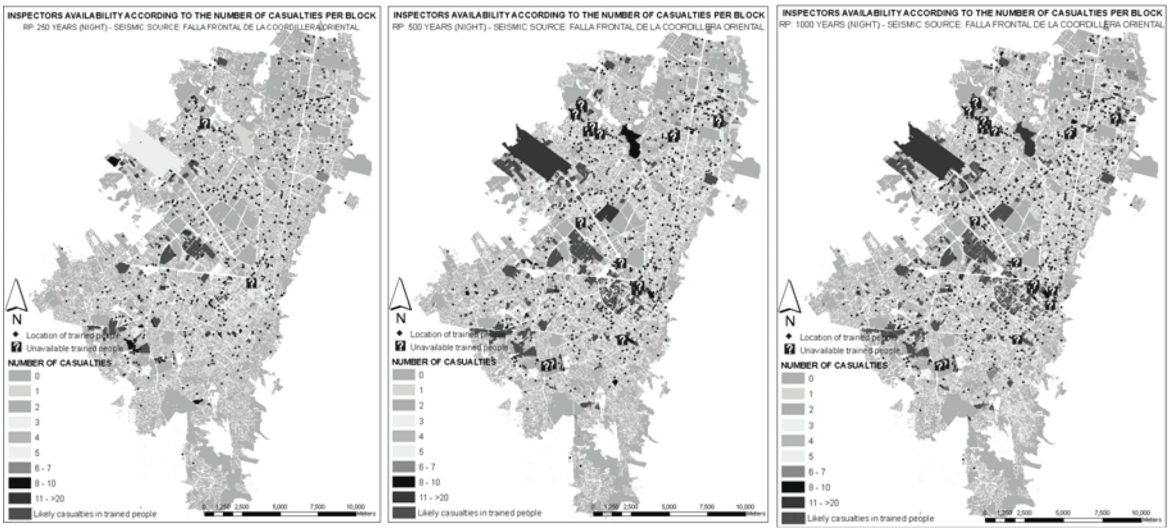




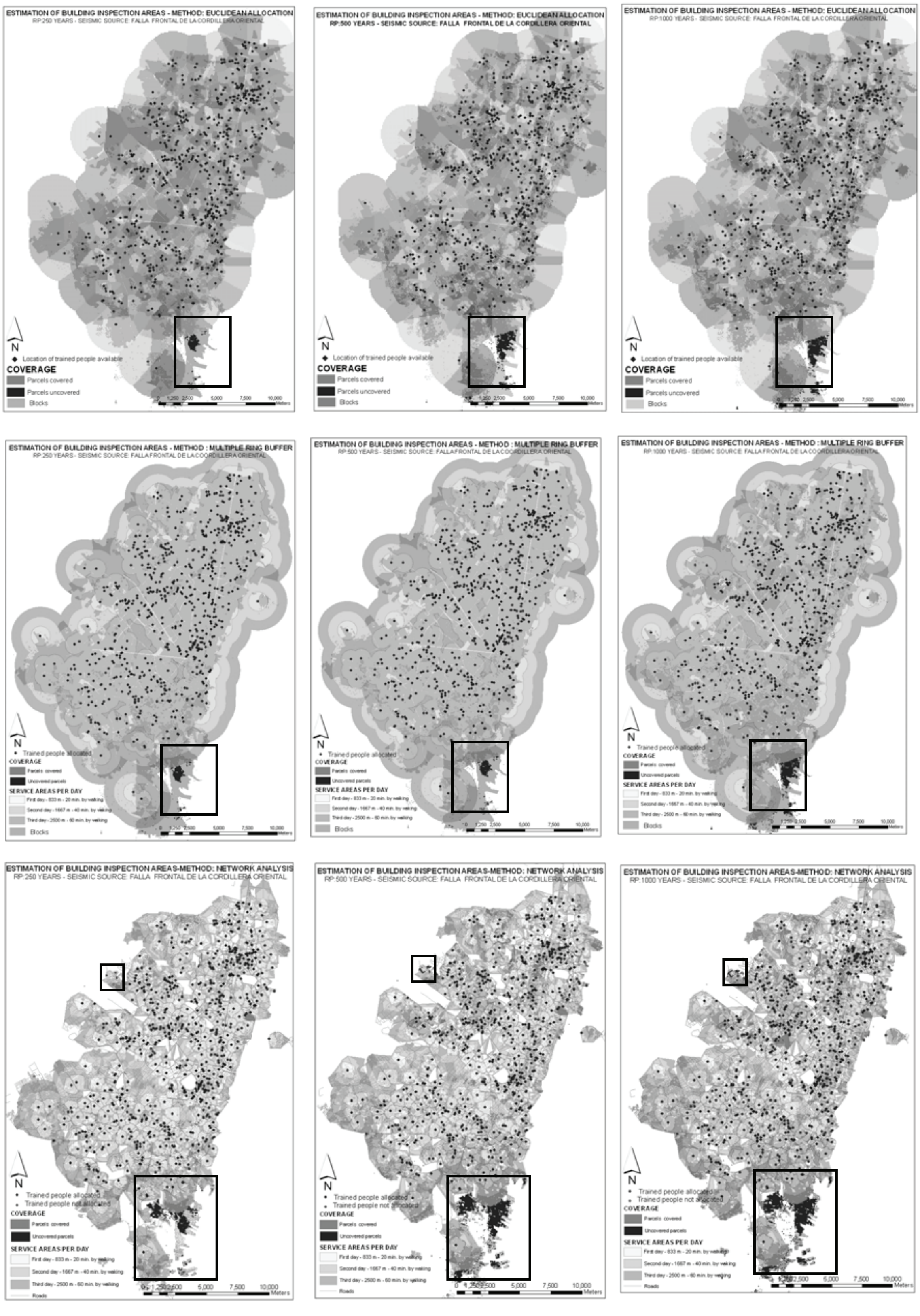


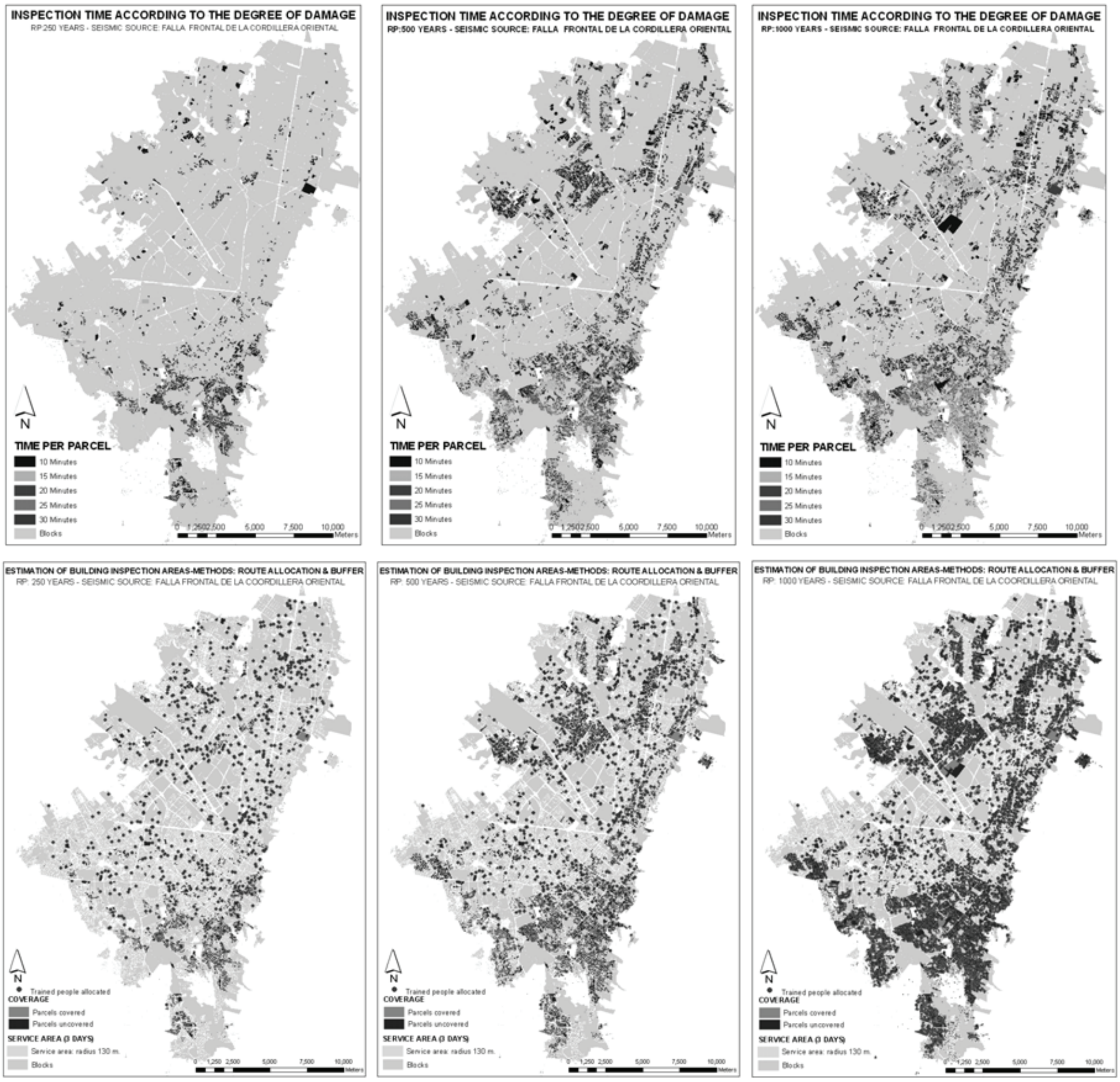





INSPECTORS AVAILABILITY ACCORDING TO THE NUMBER OF CASUALTIES PER BLOCK
RP: 250 YEARS (NIGHT) - SEISMIC SOURCE: FALLA FRONTAL DE LA COORDILLERA ORIENTAL
N
Location of trained people
Unavailable trained people
NUMBER OF CASUALTIES
0
1
2
3
4
5
6 - 7
8 - 10
11 - >20
Likely casualties in trained people
0 1,250 2,500 5,000 7,500 10,000
Meters
INSPECTORS AVAILABILITY ACCORDING TO THE NUMBER OF CASUALTIES PER BLOCK
RP: 500 YEARS (NIGHT) - SEISMIC SOURCE: FALLA FRONTAL DE LA COORDILLERA ORIENTAL
N
Location of trained people
Unavailable trained people
NUMBER OF CASUALTIES
0
1
2
3
4
5
6 - 7
8 - 10
11 - >20
Likely casualties in trained people
0 1,250 2,500 5,000 7,500 10,000
Meters
INSPECTORS AVAILABILITY ACCORDING TO THE NUMBER OF CASUALTIES PER BLOCK
RP: 1000 YEARS (NIGHT) - SEISMIC SOURCE: FALLA FRONTAL DE LA COORDILLERA ORIENTAL
N
Location of trained people
Unavailable trained people
NUMBER OF CASUALTIES
0
1
2
3
4
5
6 - 7
8 - 10
11 - >20
Likely casualties in trained people
0 1,250 2,500 5,000 7,500 10,000
Meters

Appendix O. Comparison of the application of allocation methods in every scenario




INSPECTION TIME ACCORDING TO THE DEGREE OF DAMAGE
RP:250 YEARS - SEISMIC SOURCE: FALLA FRONTAL DE LA CORDILLERA ORIENTAL
N
TIME PER PARCEL
10 Minutes
15 Minutes
20 Minutes
25 Minutes
30 Minutes
Blocks
0 1,250 2,500 5,000 7,500 10,000 Meters
INSPECTION TIME ACCORDING TO THE DEGREE OF DAMAGE
RP:500 YEARS - SEISMIC SOURCE: FALLA FRONTAL DE LA CORDILLERA ORIENTAL
N
TIME PER PARCEL
10 Minutes
15 Minutes
20 Minutes
25 Minutes
30 Minutes
Blocks
0 1,250 2,500 5,000 7,500 10,000 Meters
INSPECTION TIME ACCORDING TO THE DEGREE OF DAMAGE
RP:1000 YEARS - SEISMIC SOURCE: FALLA FRONTAL DE LA CORDILLERA ORIENTAL
N
TIME PER PARCEL
10 Minutes
15 Minutes
20 Minutes
25 Minutes
30 Minutes
Blocks
0 1,250 2,500 5,000 7,500 10,000 Meters
ESTIMATION OF BUILDING INSPECTION AREAS-METHODS: ROUTE ALLOCATION & BUFFER
RP: 250 YEARS - SEISMIC SOURCE: FALLA FRONTAL DE LA COORDILLERA ORIENTAL
N
Trained people allocated
COVERAGE
Parcels covered
Parcels uncovered
SERVICE AREA (3 DAYS)
Service area: radius 130 m.
Blocks
0 1,250 2,500 5,000 7,500 10,000 Meters
ESTIMATION OF BUILDING INSPECTION AREAS-METHODS: ROUTE ALLOCATION & BUFFER
RP: 500 YEARS - SEISMIC SOURCE: FALLA FRONTAL DE LA COORDILLERA ORIENTAL
N
Trained people allocated
COVERAGE
Parcels covered
Parcels uncovered
SERVICE AREA (3 DAYS)
Service area: radius 130 m.
Blocks
0 1,250 2,500 5,000 7,500 10,000 Meters
ESTIMATION OF BUILDING INSPECTION AREAS-METHODS: ROUTE ALLOCATION & BUFFER
RP: 1000 YEARS - SEISMIC SOURCE: FALLA FRONTAL DE LA COORDILLERA ORIENTAL
N
Trained people allocated
COVERAGE
Parcels covered
Parcels uncovered
SERVICE AREA (3 DAYS)
Service area: radius 130 m.
Blocks
0 1,250 2,500 5,000 7,500 10,000 Meters