Diana María Contreras Mojica
Phone: +43 - 662 – 80445275
Address: Centre for Geoinformatics, Z_GIS
Salzburg University
Schillerstrasse 30 (Bauteil 15, 3 stock)
5020 Salzburg
E-mail: dianamaria.contreras-mojica@sbg.ac.at

Designing a spatial planning support system for rapid building damage survey after an earthquake: The case of Bogota D.C., Colombia

ABSTRACT

Damage assessment determines the safe condition of houses and buildings that were affected in a disaster. These elements must be inspected to determine if they can be occupied by people. The objective of the present research is to design a model for the planning of a rapid building damage survey after an earthquake and manage the spatial information collected. The model is built on by three sub-models aiming to estimate the number of trained people required, their spatial allocation and the right information flow. The combination of cadastral data and organizational issues will be the input, to estimate the number of trained people required. To allocate the trained people, five methods were applied: *average number of parcels or blocks, euclidean allocation, multiple-ring-buffer, network analysis (service area), and route allocation*. All the data required to respond in an emergency must be collected, updated and shared in order to have informed decisions. The results show wide ranges of values that can be utilized in the preparedness or in the response phase; the allocation methods can be used according to the data that every city has, but the highest level of accuracy comes from the *route allocation* method. The data must be available, updated and accessible to all the entities involved in the emergency response task, due to these reasons the research recommends the implementation of a *Spatial Data Infrastructure (SDI)* to manage the information and to predefine the meeting points to compile the collected information by using methods as *mean center*.

1. INTRODUCTION

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

The present research is concentrated on the damage assessment of private houses and buildings, because building damage survey 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.

In Bogota, the District Office of Emergency Prevention and Management (DPAE), has been working on the project about strengthening the response capacity against a big earthquake, since 2003. Hence, the Colombian Association of Seismic Engineering (AIS) was hired to develop a methodology and also a manual which has guidelines, for inspecting buildings after an earthquake. DPAE has been training architects, engineers and student in these areas since 2002 until 2003 and again since 2007 until now. Nevertheless, it is important to say that in spite of the presence trained people for building inspection after an earthquake, the effectiveness of the methodology in a real operation has not been tested yet.

Additionally, DPAE contracted the Andes University (ULA) to undertake *The risk and loss study scenarios after an earthquake in Bogota D.C.* (CEDERI 2005), which aimed at estimating the number of affected houses in every return period[i] and consequently the likely number of trained people required. The study considered seven loss estimation scenarios but the present research considers the scenarios when the seismic source is the falla frontal de la Cordillera Oriental in the return periods (rp) of 250, 500 and 1000 years. Furthermore, not the total number of affected houses is taking into account to be inspected, only those which percentage of damage are between 15% and 65%.

Rapid building damage survey is a service that will be provided in an emergency state 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 the society (Pacione 2005), which is in this particular case, the safety of the individuals. This research is concentrated on the rapid survey, because it is oriented to save lives in short period, stoping people continue living in unsafe buildings. But this activity requires to be modelled in order to be effective and efficient, because according to Benini and Conley (2007) “rapid assessment is one of the standard informational tools in humanitarian response and is thought to contribute to rational decision-making”.

Rapid building damage survey is a service that must be allocated according to 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 immediately 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).

Research about decision support system for resource allocation in emergency response is invariably focussed on: search and rescue (SAR), stabilizing work (e.g. dam failures, fire, etc.) and immediate restoration of the transportation lifelines (Fiedrich, Gehbauer et al. 2000); schedule for the restoration of the transport lifelines (Yan and Shih 2007); traffic assignment and departure schedule decisions for multiple priority group (the elderly, hospital patients, etc.) (Chiu and Zheng 2007); demand, supplies and vehicle availability (Ozdamar, Ekinci et al. 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 to affected communities (Benini, Conley et al. 2008).

Nevertheless, few of them has tackle the problem of allocating resources for carrying out a building damage survey after an earthquake, in any of its modalities and in which there is a combination of two classes of resources: people and material. The resources must be ideally distributed with equity which is feasible in the case of the material resources, but not in the domain of people (human resources), because they are located according to the lifestyle and it is likely that they do not live in the most vulnerable areas. In this case, it is therefore necessary to address the problem between the logistics of moving personnel and the need of the situations.

2. LITERATURE REVIEW

The first step in a mitigation, preparedness or response planning process is to identify the hazards, which affects some areas. 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. The second step is to make the vulnerability evaluation, which is the process to estimate the susceptibility to a damage that the element at risk (e.g. population, built-up areas, infrastructure, etc.) have when a physical phenomenon struck them. 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.

The loss estimation is a technique to estimate the potential losses from earthquakes and key elements to be integrated in the management and development of megacities (Bendimerad 2001). The loss estimation scenarios mentioned in the introduction, are tools of the risk assessment, and authors as 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. This approach allow to 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 (Fuad Aleskerov 2005).

The rapid building damage 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.

Countries such as United States, Mexico, Japan, Colombia and Macedonia (Kiril and Metodij university, 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).

As it was observed in the introduction, the building damage survey after an earthquake is an activity that requires to be modelled; hence, the use of scenarios in the present research because they are a result of combination of: modelling and planning. Planning is a process, to reach decisions to achieve certain goals within the available resources, and one of the decision issues is how to allocate resources. There are several models aim to allocate resources for any emergency response, which authors as Batanovic, Petrovic and Petrovic (2009) classified as *general, approximate solutions and stochastic/fuzzy* and *anti-covering models*. While, other authors as Benini et al. (2008) have concentrated on developing statistical models to evaluate the effectiveness and efficiency of the resource allocation related to delivery of relief goods.

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 information plays an increasing significance in the mentioned effort (Wallace and Balogh 1985). Authors as Perry and Liddell (2003) assert that the effectiveness of emergency planning can be reduced by the wrong allocation of resources or an improper management of the information.

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

In the methodologies developed by the countries that have been dealing with the topic of the building damage survey after an earthquake, the information is collected by using paper forms. Nevertheless, the tendency in data capture in this kind of events have to be changed 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 has been considered the possibility to use mobile devices and software applications like *CyberTraker*, to capture a large quantity of geo-referenced data for field observation.

Mansourian 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 maker. 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 tools for the information management must “provide operational flexibility, require minimal operating and maintenance expertise, and finally, be readily deployable”(Patricelli, Beakley et al. 2009).

3. METHODOLOGY

The aim of this research is to design a process model for the planning of a rapid building damage survey after an earthquake, and to manage the spatial information collected. 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 the literature review section is illustrated in figure 3-1.

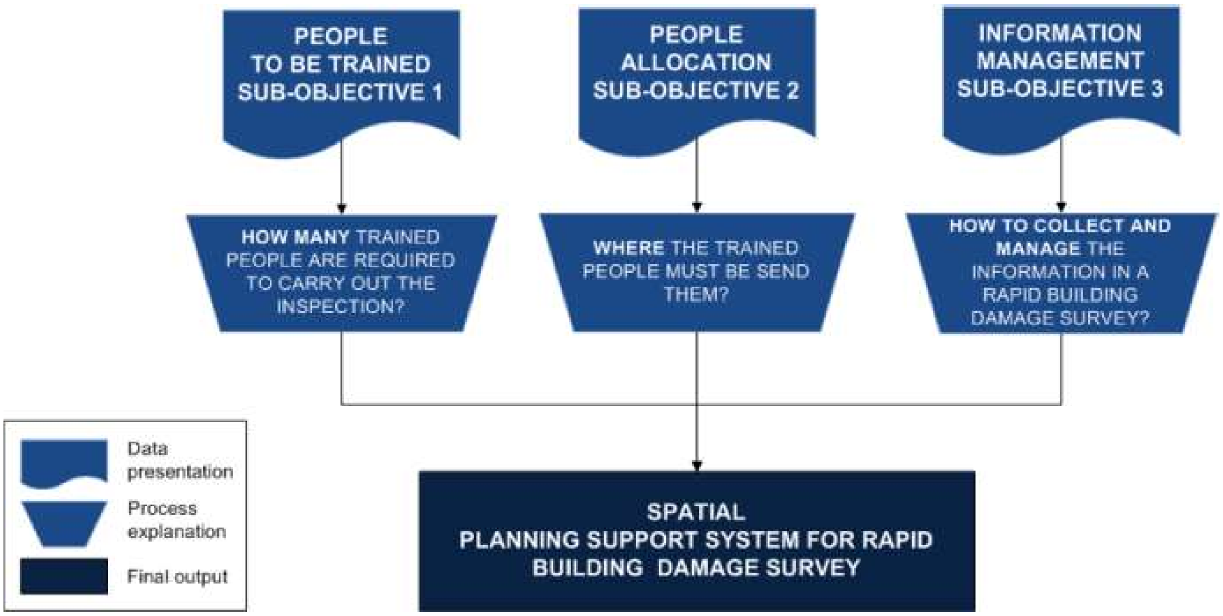


Figure 3-1 Basic model

Following sections, the input data, the parameters included in the models and the analysis process is explained.

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

In the presented 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 was divided in three stages: in the first stage, the *space-parameters* are defined, in the second stage *time-parameters* are determined; and in the third and final stage, the parameters and the variable of control range is combined to calculate the number of people required according to the different inspection times, operational times and control ranges as it can be seen in figure 3-2.

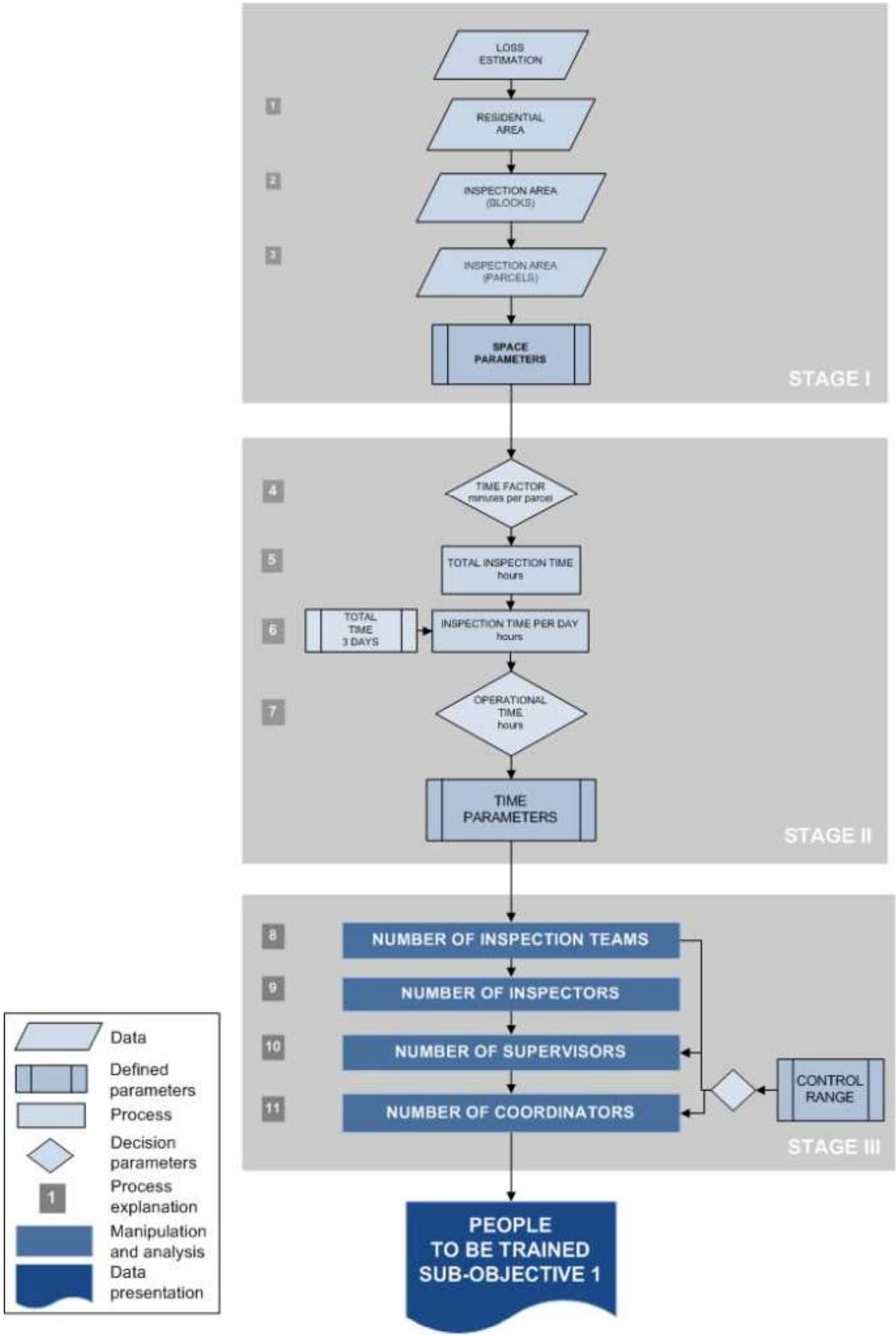


Figure 3-2 Sub-objective 1: Model to estimate the number of trained people required.

Defining *space-parameters*: Stage I. *Space-parameters* are the spatially fixed conditions for the area where the model is applied. The partial model can be appreciated on figure 3-3.

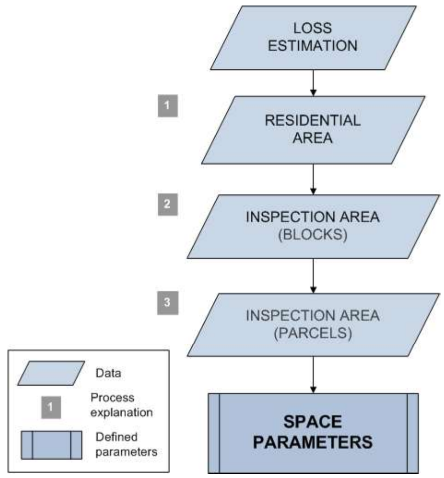


Figure 3-3 Sub-model – *Space-parameters* (Stage I)

The procedure first selects the residential areas; second, delimitates the inspection area in the city according to a selected range of degree of damage; and third, disaggregates the degree of damage to the parcel level.

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 is shown in figure 3-4.

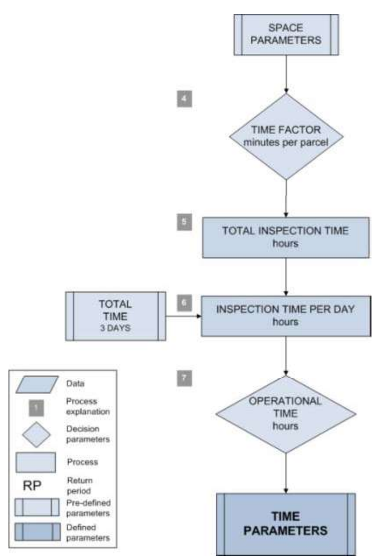


Figure 3-4 Sub-model – *Time – parameters* (Stage II)

The operational time is the number of working hours of the building inspectors, assumed here in three possible states 8, 10 or 12 hours and while maintaining the total time to carry out the inspection according to the international standards, 72 hours or three days from event of disaster.

The procedure continues with: fourth, where 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); fifth, the last result is obtained in minutes and it is necessary to convert it into hours; sixth, the total inspection time in hours is now divided in three (standard number of days to carry out a rapid building damage survey) and the output is the inspection time per day; seventh, the inspection time per day could be divided into different operational times that the emergency response planners or the decision makers consider suitable or necessary. 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: in this stage, it is necessary to start explaining that a team is a group made up by two trained people. Every team must have one supervisor, and also every supervisor must have one coordinator. Every supervisor has a limited number of teams and every coordinator has a limited number of coordinators under their control, as well; this number depends on the control range or the numbers of teams or people, who can be coordinated or supervised just by one person. The organizational chart can be appreciated on figure 3-5.

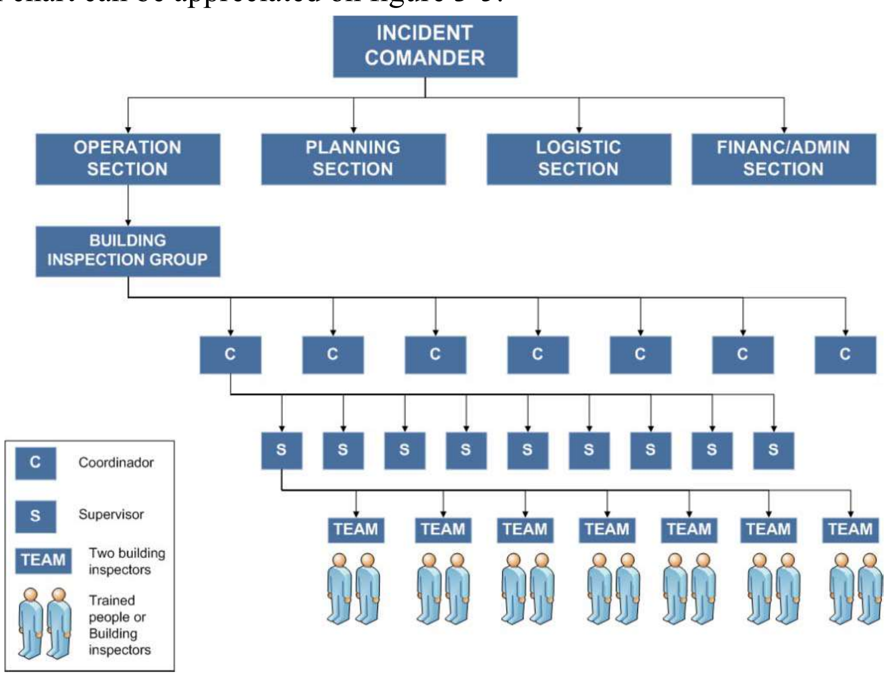


Figure 3-5 Building inspection group organizational chart

The process models finish in this way: eighth, the number of teams necessary to carry out the inspection comes from the combination between *space* and *time-parameters*; ninth, to calculate how many inspectors will be necessary to train, the number of team is multiplied by two; tenth, in this stage, the control ranges to manage the operation must be decided; and finally, eleventh, 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-parameters* are the main input of the *time-parameters* and according to this output the estimation of the number of people is done, as it is possible to see in annex A (Tables 1,2, and 3).

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 building damage 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.

It is assumed that inspectors will be at home for the time of an earthquake. The model is developed in the next steps: first, geocode trained people; second, estimate likely availability of the trained people after an earthquake by comparing their location with the areas with a high degree of damage or a high number of injuries and casualties, according to loss scenarios; and third, estimate service areas. According to the availability of the data and the accuracy level that decision makers or emergency response planners require, it is necessary to use different methods to estimate the service areas. 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. This second model is presented on figure 3-6.

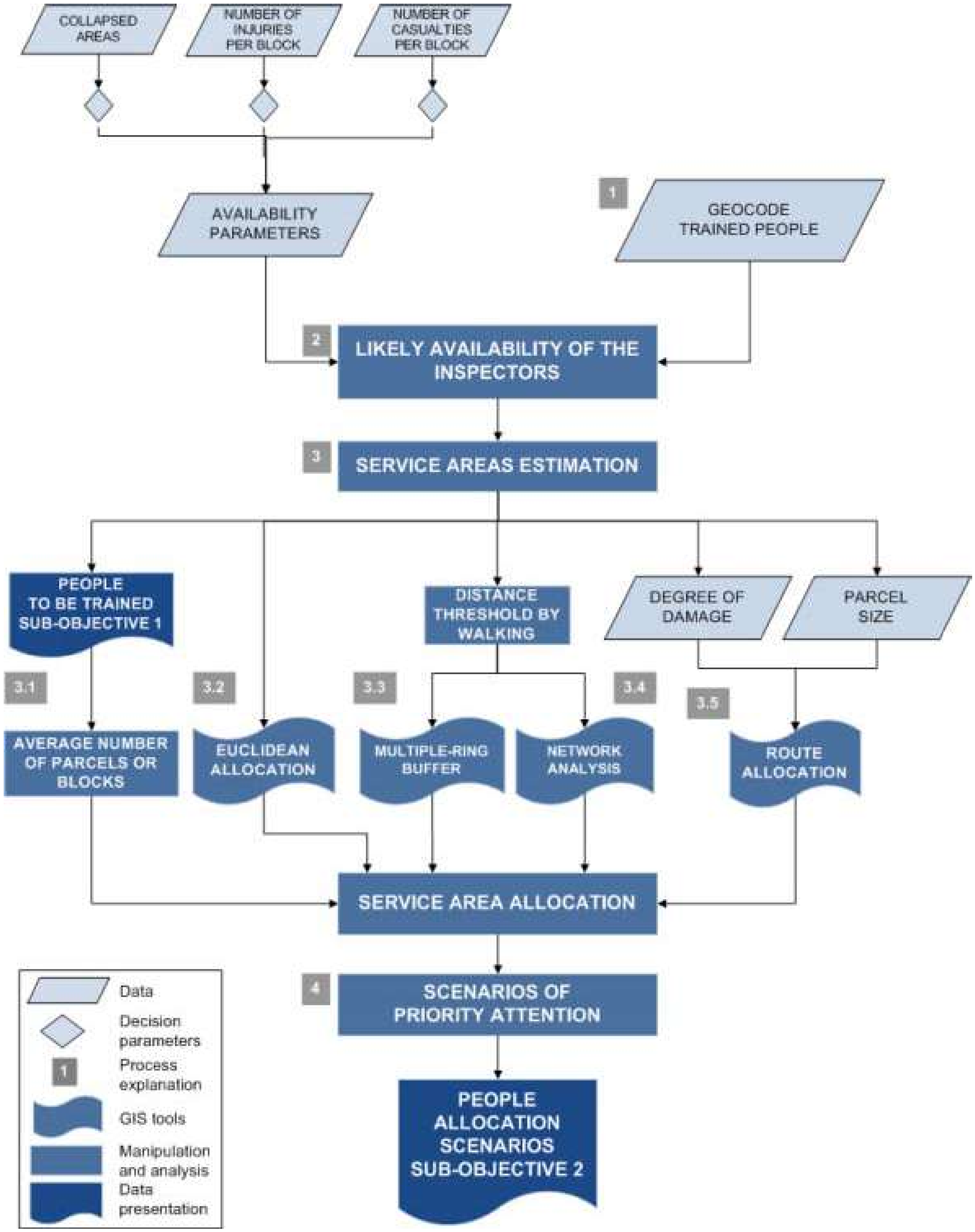


Figure 3-6 Sub-objective 2: Model to allocate trained people.

***Average number of parcels or blocks to inspect*:** the total number of parcels to inspect in every return period is divided in three (the standard time to carry out the rapid building damage survey), to know how many parcels must be inspected each 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 results can be observed in annex A (table 4).

***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.

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, Petrovic 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, Petrovic et al. 2009); 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. Under this concept, two methods were 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

***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, which shows the covered areas; and then, it is possible to switch the selection to have a view of the uncovered areas.

***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 per day it is important in the polygon generation tab check *Not overlapping* option.

Route allocation**:** the route allocation is the route of every inspector. The route is designed according to the estimated inspection time that every house may require according to the degree of damage estimated, as it can be observed in table 3-2.

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

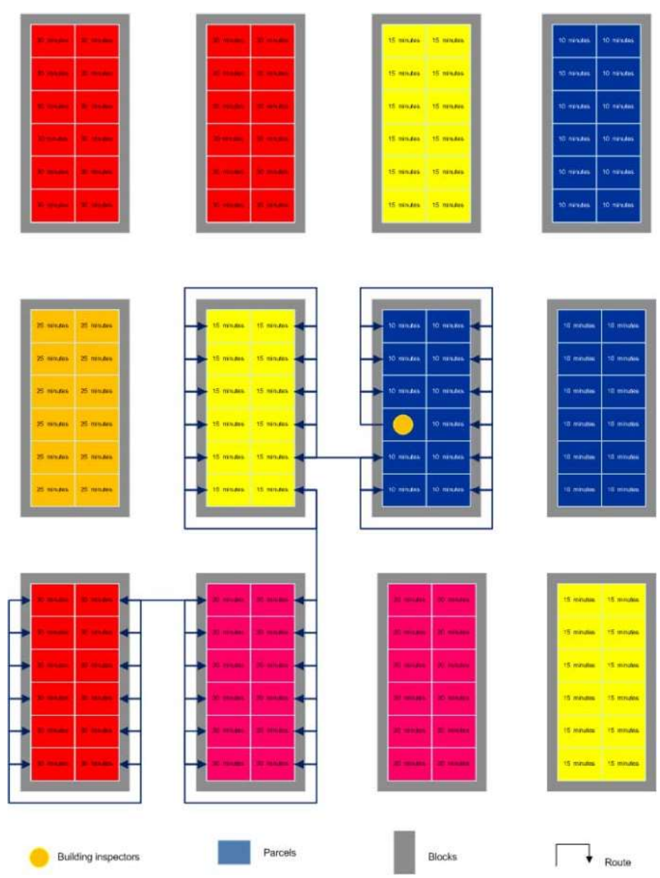


Figure 3-7 Schematic allocation route according to the inspection time (operational time: 12 hours)

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. The path starts at the inspector's house and when they head off their own house, they will continue in a clock wise direction during the operational time, e.g.: 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)*; the program calculates the route and symbolizes the stops, which are centroids with the attribute of the inspection time; 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. A schematic example of a route allocation to one inspector , when the operational time is a period of 12 hours is illustrated on figure 3-7.

The last step is the fourth, display the different priority scenarios. In a rapid building damage survey after an earthquake, some areas in the city must be inspected first. The tool of suitability wizard in *Community Viz* is applied to make priority attention analysis, over the areas in the city. 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. The *other layers* are 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 availability parameters developed in the model are determined according to the location of the inspectors compared with the collapsed areas and the blocks with a high numbers of casualties or injuries.

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

The information must be a concern before and after the event to ensure that updated data, tools to capture information, and the logistic to transmit and communicate the information collected will be available.

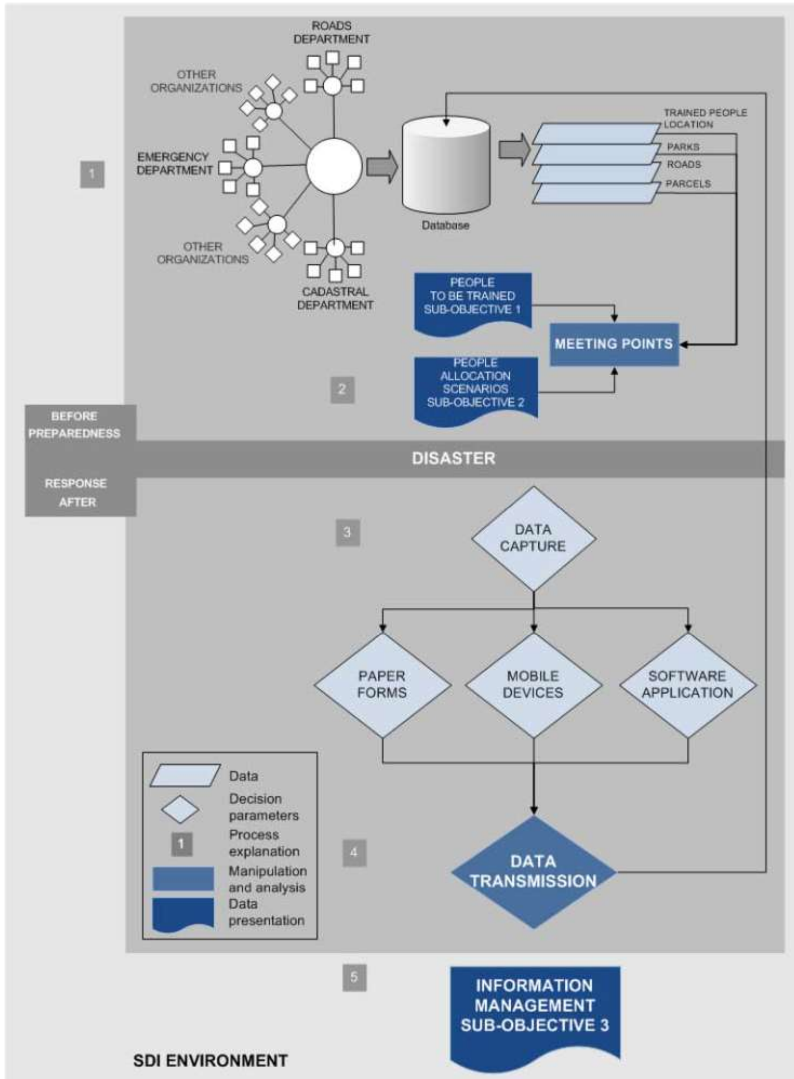


Figure 3-8 Sub-model 3: Information management

The present conceptual model is made up of five parts and it is illustrated on figure 3-8. The model is described through different sections: first, the model is based on a *Spatial Data Infrastructure (SDI),* as a concept of partnership in "data production, sharing and exchange"(Mansourian, Rajabifard et al. 2006); second, the spatial dataset of trained people, service areas and parks must be combined to define meeting points (parks), which could be located by using two GIS methods: *Central feature* and *Mean Center*; third, the data could be collected in paper forms, mobile devices or using a software application that could run on or be compatible with different platforms; fourth, the conditions to select the efficient way to transmit data depend on the media to collect it and the conditions on field; and fifth, the tools used to capture and transmit data must be combined with the organization of the building inspection group to design the information flow.

4. RESULTS:

The study area was Bogotá D.C., the capital city of Colombia. The city was selected as a case study because its seismic condition and the work that the district administration through DPAE has done to prepare the city for facing an earthquake.

The work on field consisted on three main activities: one, is a survey between people trained to estimate the availability (desirability) to carry out the building inspection in case of an earthquake in the city. At first, the result was 121 available, but later it was incorporated the number of trained people who did not reply to the survey to have a final result of 735 trained people geocoded.

The second activity was focused on interviews with experts to analysis methodologies for estimating the number of trained people required and to manage the information.

And third activity was the selection of secondary data related to: loss estimation scenarios, roads, parks, cadastral data, land use, landslides hazard areas and administrative divisions of the city. This fieldwork is starting point of the results presented in the next sections.

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

The inspection area contains 675.588 residential parcels. Nevertheless, only the affected parcels with a percentage of damage between 15% and 65% were considered to be inspected. According to this assumption, the number of parcels to be inspected is made up of 106.838 (16%) in the rp of 250 years, 318.945 (47%) in the rp of 500 years and 362.898 (54%) in the rp of 1000 years, as it can be appreciated on figure 4-1.

The time range changes according to the different inspection times per parcel in each seismic scenario and therefore the number of people to be trained is in a range which also varies from 1.111 to 18.750 people.

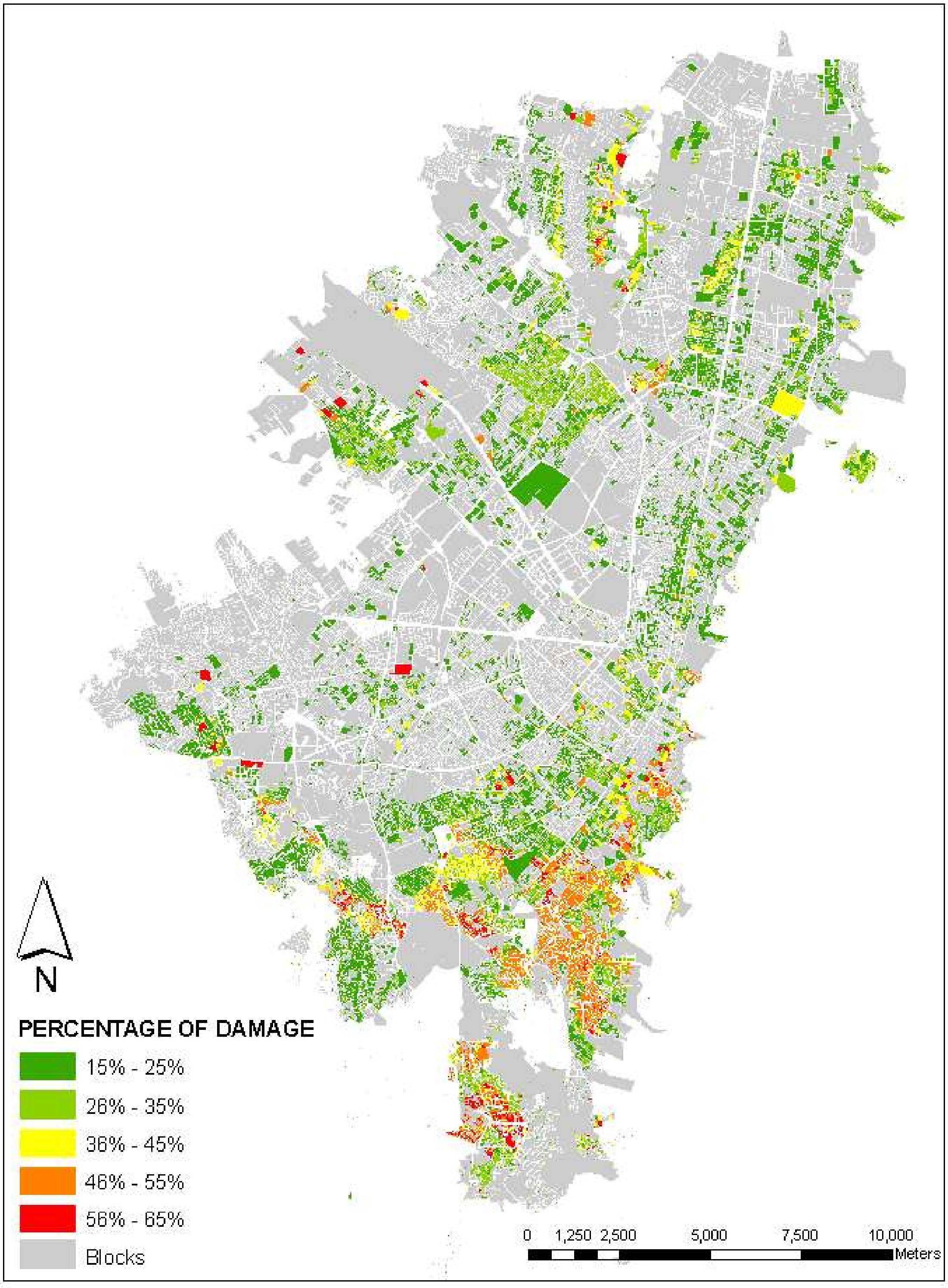


Figure 4-1 Degree of damage in the inspection area for the seismic scenario (RP) 1000 years, when the seismic source is the falla frontal de la cordillera oriental in Bogota D.C., Colombia.

4.2. Sub – objective 2: Allocation of trained people to service areas

Firstly, trained people were geocoded; and then, it was estimated their availability according to the parameters described in the methodology. The result was 712 (97%) trained people likely available, as the lowest value in the worst case. Trained people are spread out over the city with a light concentration in the North – Est as it is illustrated in figure 4-2.

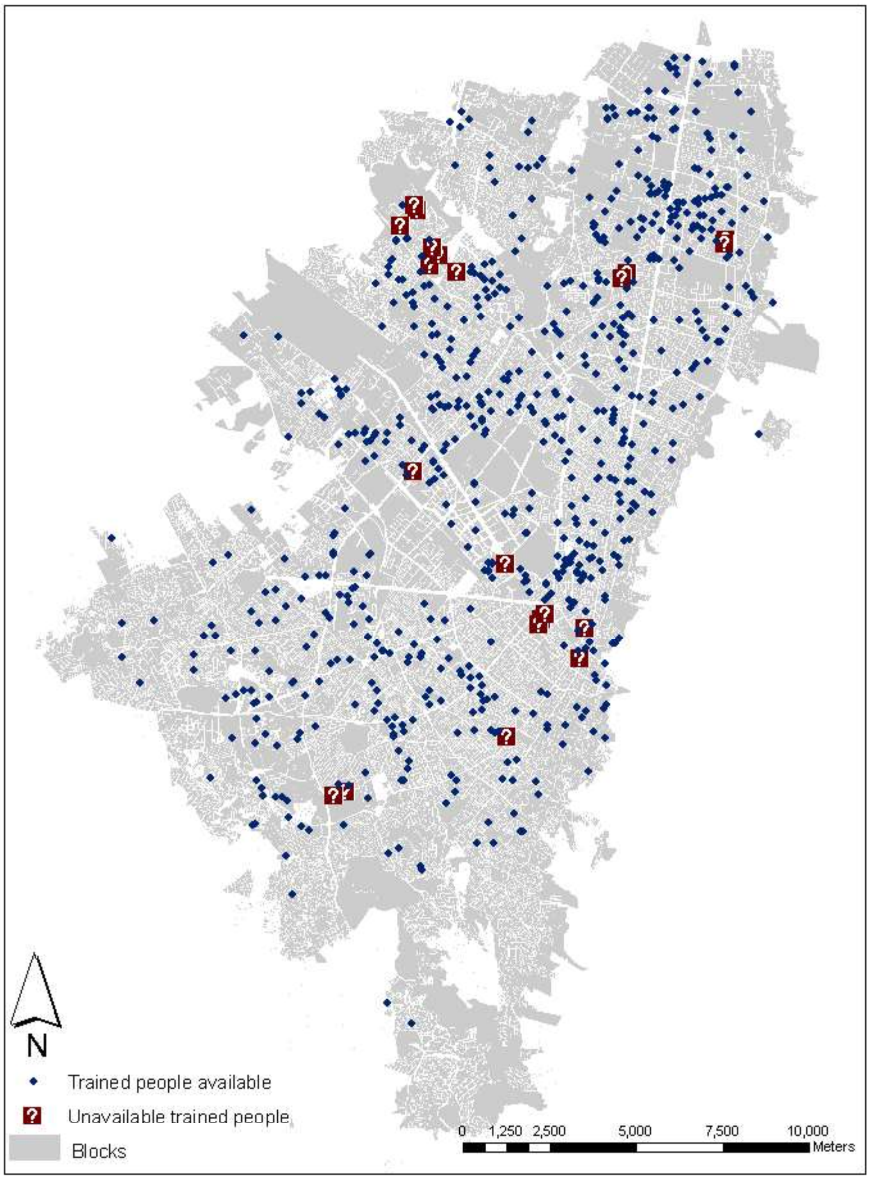


Figure 4-2 Location of trained people available to carry out the building damage survey

According to the methodology, the next step is to estimate the service areas for the available people and to have a view of the likely coverage. By using the methods detailed in the methodology, different results were observed.

The *average number of parcels or blocks to be inspected for a team in one day* is obtained by using the output of the estimation of the number of teams and inspectors required, as it can be seen on table 4-1. 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 4-1 Estimation of average number of parcels or blocks to be inspected for a team in one day.

The use of the *euclidean allocation* method has 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 coverage estimation presents for all the return periods an average of 95% of parcels that could be inspected. The result of the application of this method can be seen on figure 4-3.

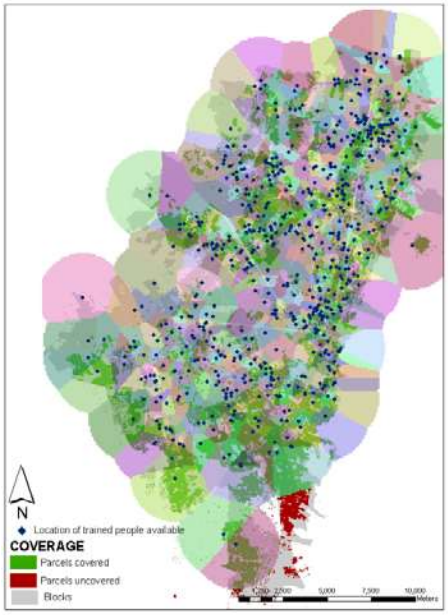
Multi-ring buffer method also allocate service areas to the 100% of the trained people and it is the first approach to estimate the coverage based on the maximum threshold *distance-to-walk* per day; nevertheless, the disadvantage of this method is that the most of the times boundaries between the service areas are not clear, even using any of the two dissolve options (*all* or *none*); the problem with the merge and overlap 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 level of coverage in the city under this method presents an average of 95% of the parcels that could be inspected in the three days. The result of allocation and coverage after using this method can be observed on figure 4-4.

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 based 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. 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 coverage by using this method put forward a likely average coverage of 89% of parcels inspected in the city. The result of allocation and coverage after using this method can be observed on figure 4-5.

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. The *route allocation* could be designed estimating the inspection time based on the degree of damage, 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, its estimations can be calibrated in both cases through a simulation exercises. There is no estimation of the coverage for the whole city, as the procedure requires long computation time that are beyond of the scope of this research. An example of the implementation of this method can be appreciated on figure 4-6.

Nevertheless, because of the level of the detail in this last method, it could offer more realistic results in terms of likely coverage. Therefore, to extrapolate this methodology to the rest of the city, it has to be combined with the *buffer analysis* method, due to it simulate in a proper way the probable size of the inspection area. This time, the results show a significant decrease related to the coverage with an average of just 9% of parcels than could be inspected in all the return periods. The result can be appreciated on figure 4-7.



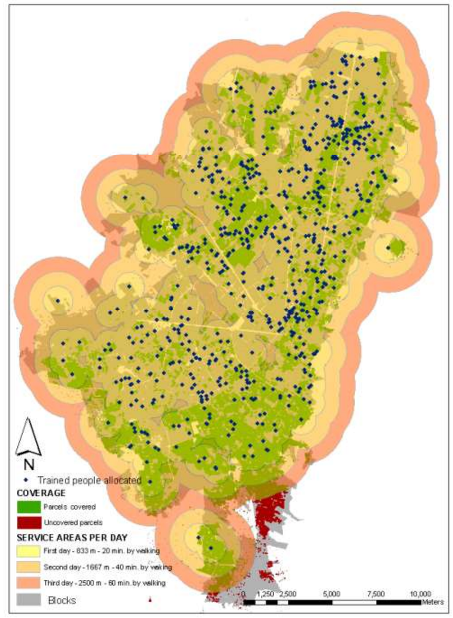


Figure 4-3 Estimation of service areas based on euclidean allocation method in the rp 1000 years. Seismic source: falla frontal de la cordillera oriental.

Figure 4-4 Estimation of service areas based on multiple ring buffer in the rp 1000 years. Seismic source: falla frontal de la cordillera oriental.

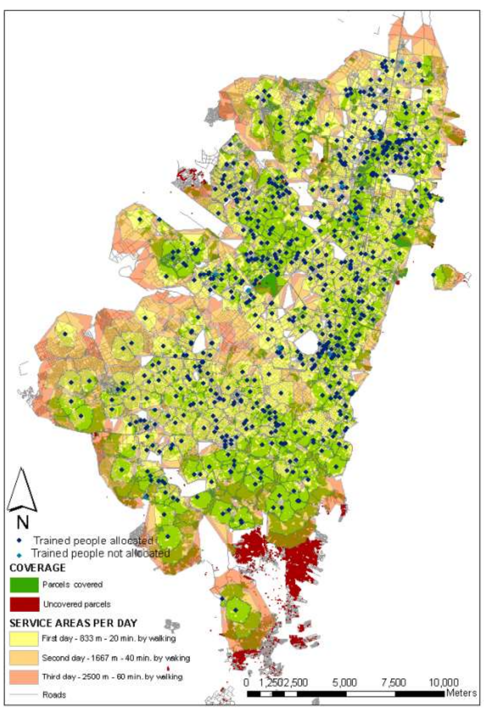


Figure 4-5 Estimation of service areas based on network analysis in the rp 1000 years. Seismic source: falla frontal de la cordillera oriental.

Figure 4-6 Estimation of one service area per day according to the inspection time. Seismic source: falla frontal de la cordillera oriental.

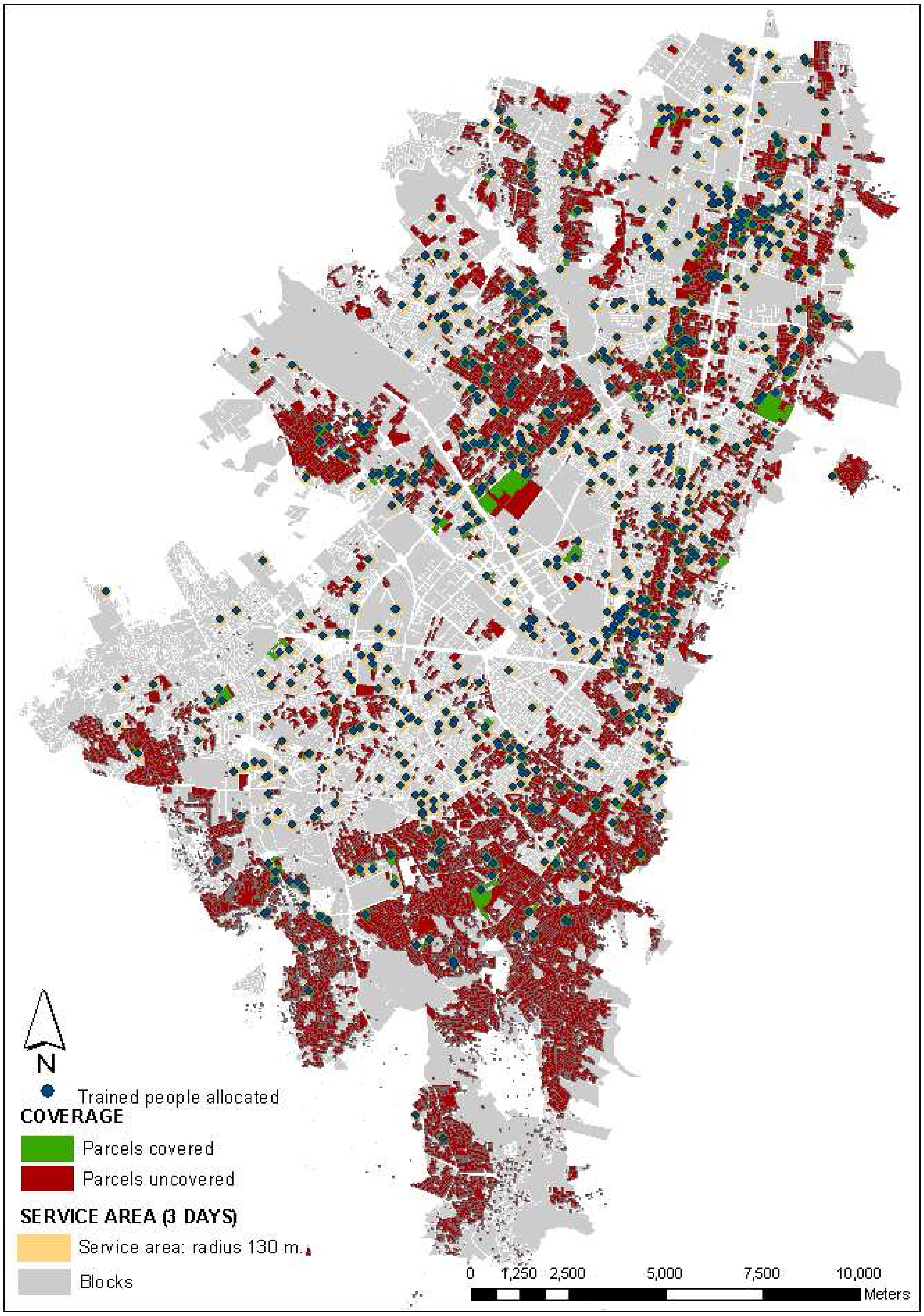


Figure 4-7 Estimation of service areas based on the combination of *route allocation* and *buffer analysis* method in the RP 1000 years. Seismic source: falla frontal de la cordillera oriental.

Due to the last results, it is necessary to develop priority attention scenarios in order to make a efficient use of the resources. Priority attention scenarios allow the emergency response planners to know where the people must be trained and to the decision-makers, 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 layer* in the present research is the whole city and the *other layers* or factors considered were population density, degree of damage, built-up area, industrial areas and areas with hazard by landslides, due to the possibility of secondary effects after the earthquake e.g. fires and landslides and finally the location of trained people. These factors are weighted in order to decide where the free inspectors must be sent.

Four scenarios with different scores for all the factors were developed in the entire research. However, in the present document just the scenario where population density and landslides have the highest scores is presented, mainly because Bogotá D.C. is a city prone to landslides and also because the spatial results do not change in a considerable way, in the other scenarios. The weights given are shown in figures 4-8 and the spatial result is displayed on figure 4-9.

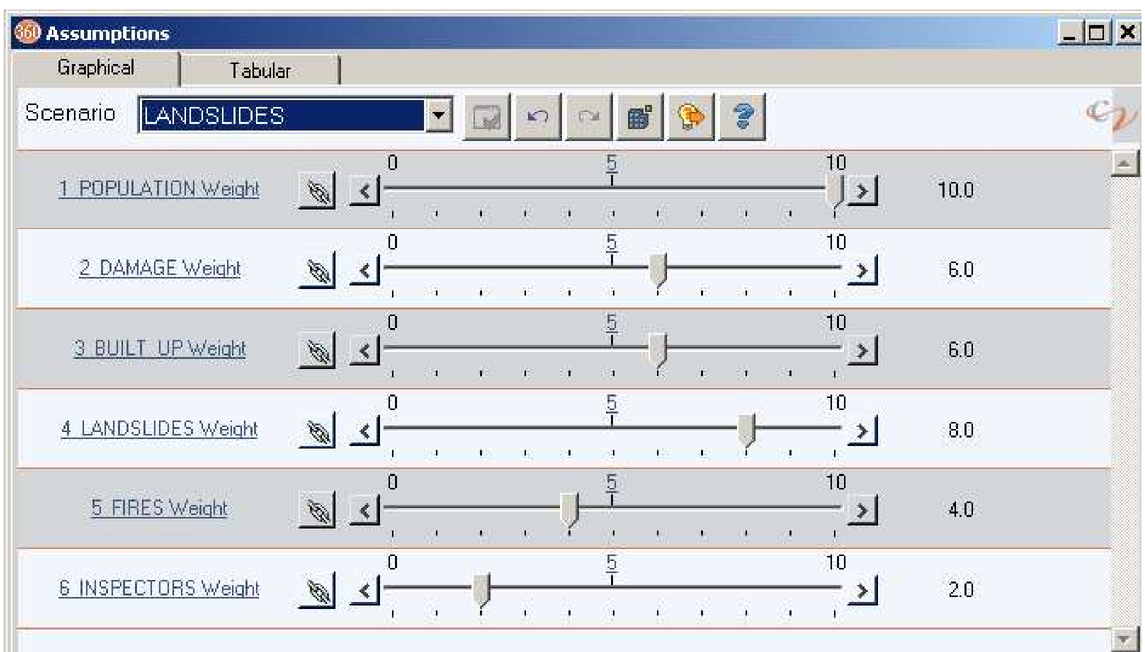


Figure 4-8 Weights given to carry out the attention priority analysis

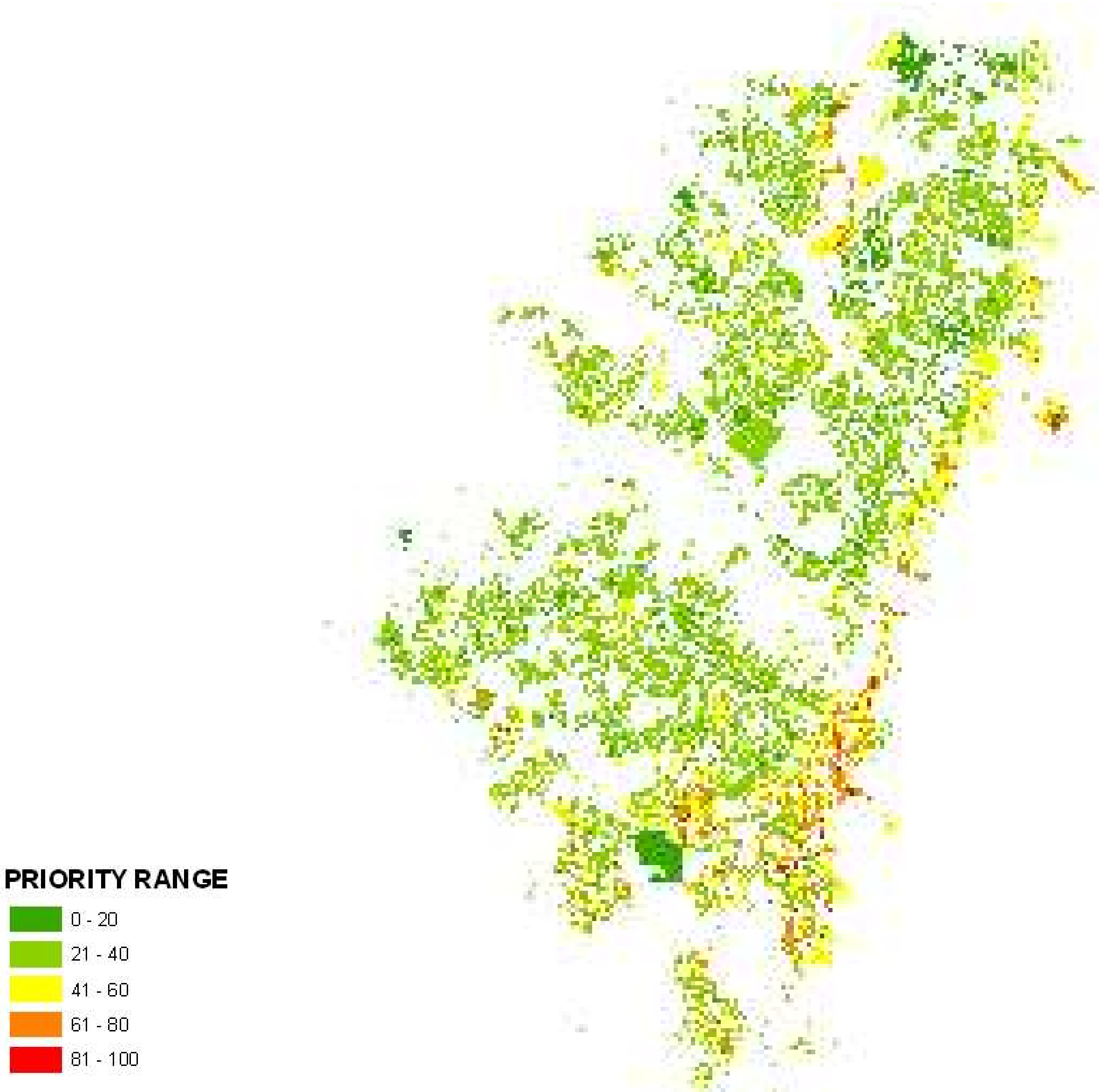


Figure 4-9 Attention priority scenarios for Bogotá D.C.

It is possible to observe that the South East of Bogotá D.C. shows the highest scores in the priority range, under the different priority attention scenarios.

4.3 Sub-objective 3: Information management model

For the time of the event, meeting points must be established to report the availability of personnel with a supervisor and receive the guidelines and the support material like metres, 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, as they 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* is shown in figure 4-10.

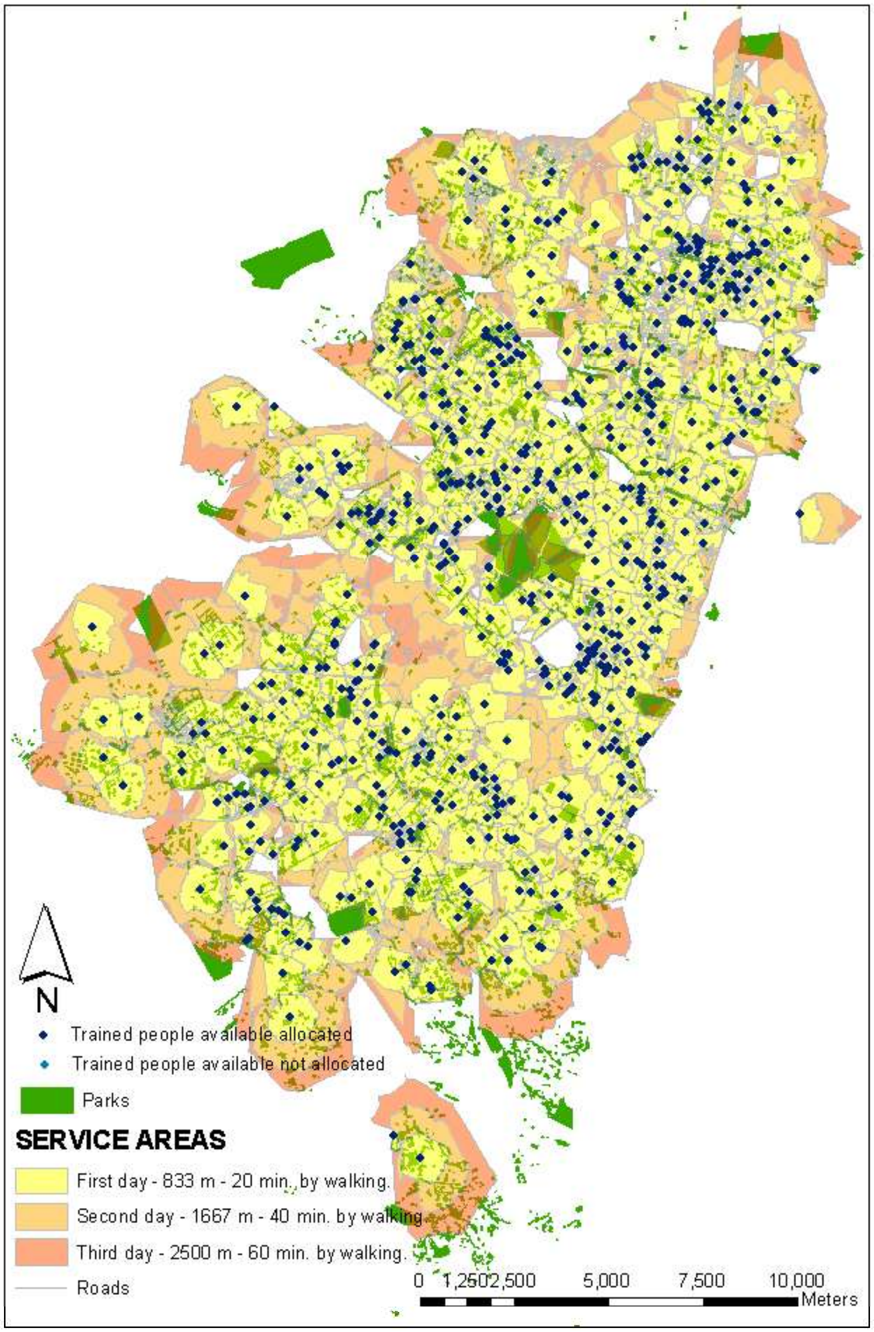


Figure 4-10 Visualization of the spatial distribution of the parks compared with the walking-distance-service areas.

It is necessary to include districting criteria to allocate the meeting points in Bogotá. By using tools like *central feature*[ii] or *mean center*[iii], the most equidistant park to the group of inspectors is selected. An example of the result of this analysis for one group of inspectors can be seen on figure 4-11.

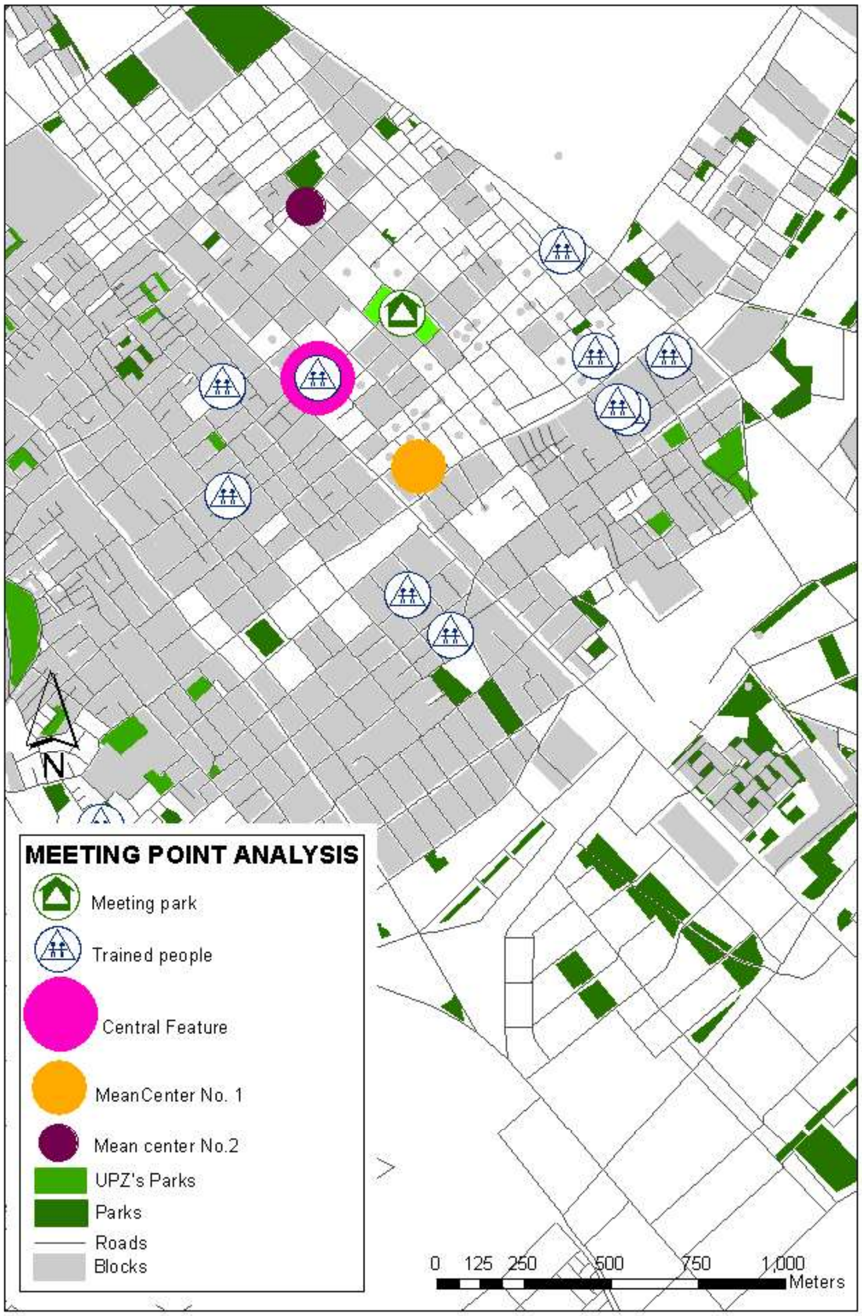


Figure 4-11 Example of meeting point allocation in the Planning Unit Zone (UPZs) No. 75, Bogotá D.C. (Colombia).

The flow information model shows in the left two alternatives to capture data. In the upper half, the period of time to carry out every process 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 extended process can be seen on figure 4-12.

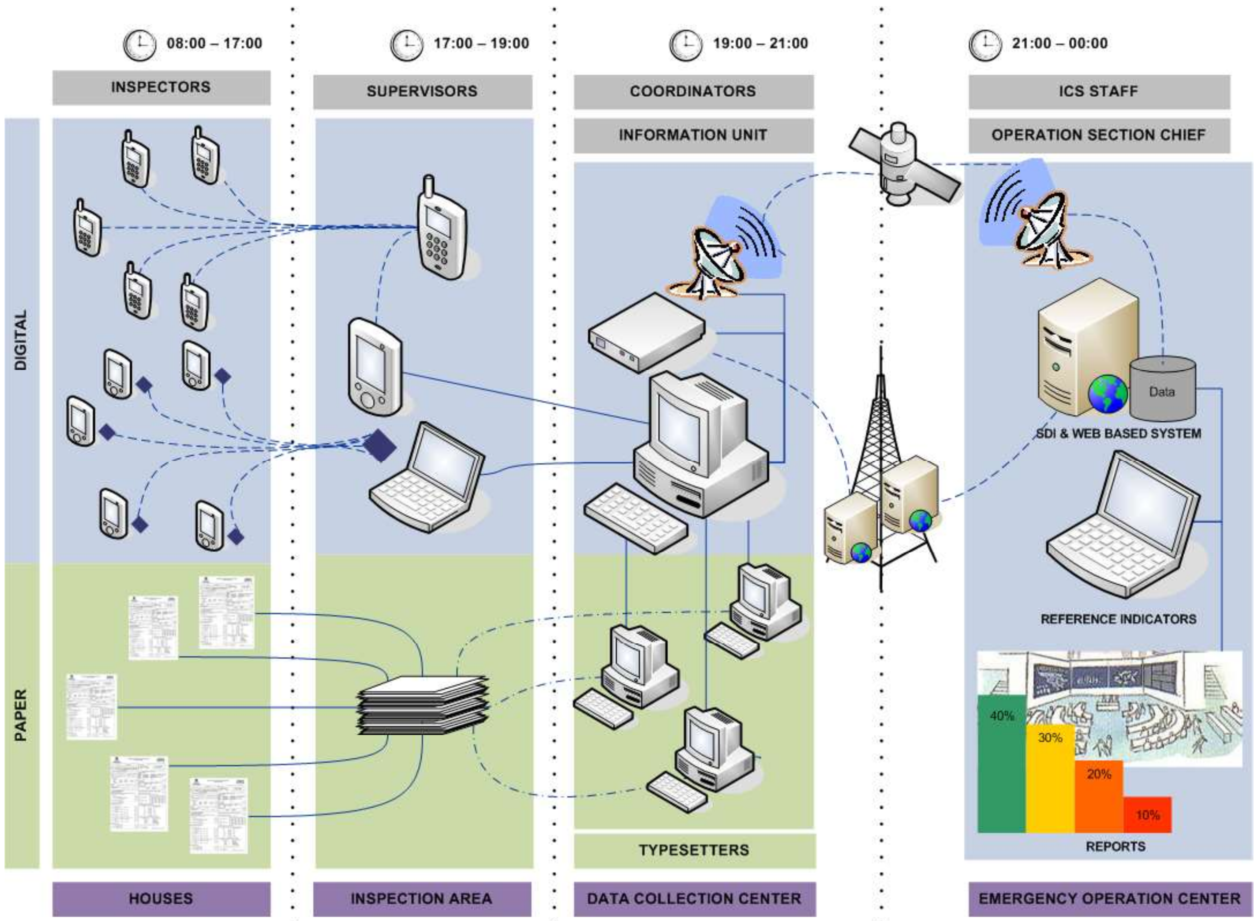


Figure 4-12 Flow information model

5. DISCUSSION, CONCLUSSIONS AND RECOMMENDATIONS

The survey to inference about availability must be split to differentiate between desirability and capability, because trained people who were well prepared with all task of inspection some years ago; currently, 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 of personnel; this is necessary in order to know the percentage of trained people who having expressed their availability before the event, and actually available to carry out the inspection.

After the event, the information to determine the *space-parameters* will be built based on the reports made by phone calls from people, aerial photography or videos, the information from field and space data obtained through mechanism as *International Charter*[iv]. At the same 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 of inspection.

Before the event, the model to estimate the number of trained people required generate different values that should be used by the emergency response planners to demand resources for training people.

The inspection times predicted by the model must be calibrated and validated in every city where the model will be applied, through simulation exercises; this activity allows not only calibrating the *time-parameters* but also testing the performance of the trained people. However, even if an earthquake occurred, 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 of the epicenter) and also the vulnerability conditions, which always are dynamic.

The accuracy of the results not only depends on the right assumptions in the analysis, but also they depend on the accuracy and completeness of the data. Aiming to reduce the uncertainty in the loss estimation and making the right preparedness, it is important to invest funds in seismic hazard research and monitoring and updating of census, cadastral data and vulnerability assessment.

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 and their connectivity will increase the accuracy for efficient allocation of the service areas. If the level of the service area estimation through route allocation is achieved it will increase the effectiveness of the inspection because owners can beforehand meet the inspectors who will be in charge to check their houses after the earthquake, avoiding security problems.

The research also tested the viability of using *CommunityViz* as spatial planning support system, in the process to plan the emergency response. This software application was originally designed to develop scenarios aimed at taking decisions about land-use planning. In the present research, the usefulness was on demarcating areas that need attention on a priority through the use of proxy indicators. Both activities , land-use planning and emergency response planning are based on a group of factors that must be weighted, in order to take the best decision. The final result was useful in spite of the technical limitations like the need to convert the layers to raster data because of the computation time, then the subsequent problems with the projection, etc.

The government must encourage the creation of a SDI as a framework for the development of total web-based system. It is recommended 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 and after any disaster.

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.

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 options included in the software application to control the efficiency of the building inspectors; the objective is to collect data and calibrate the process model aim to calculate the number of trained people required. In this way, it also is possible to validate models and provide feedbacks to improve the next emergency response operation and finally gain a better understanding of the issues involved in the emergency response.

ABOUT THE AUTHOR

Diana Contreras is currently working on her PhD studies about geospatial indicators for disaster management at the Centre for Geoinformatics Z_GIS in Salzburg University, Austria. Previously, she attended a MSc in geo-information science and earth observation in the domain of urban planning and management at the International Institute for Geo-information Science and Earth Observation (ITC), in the Netherlands. Between 2001 and 2007, she worked at the District

Office of Emergency Prevention and Management (DPAE), in Bogotá D.C (Colombia). She carried out postgraduate degree studies in the fields of laws in the construction industry (2007) at the Piloto University; project management (2003) at La Sabana University and risk evaluation and disaster prevention at the Andes University (2002), in Colombia. She studied architecture at the National University of Colombia, until 2001, where she graduated with a meritorious mention for her thesis entitled: "Assistance coordinating base for attention of disasters".

Annex A. 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.

REFERENCES

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

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

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

Benini, A., C. Conley, et al. (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. DPAE. Bogotá D.C, DPAE,Alcaldía Mayor de Bogotá D.C.**:** 119.

Chiu, Y.-C. and H. Zheng (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.

Contreras, D. (2002). Estrategia Metodológica para la conformación de grupos inspectores de edificaciones después de un sismo en Bogotá D.C. Ingenieria Civil y ambiental. Bogota D.C., Universidad de Los Andes. **Especializacion:** 116.

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.

Fiedrich, F., F. Gehbauer, et al. (2000). "Optimized resource allocation for emergency response after earthquake disasters." Safety Science **35**(1-3): 41-57.

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.

Hoard, M., J. Homer, et al. (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.

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., A. Rajabifard, et al. (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.

Ozdamar, L., E. Ekinci, et al. (2004). "Emergency logistics planning in natural disasters." Annals of Operations Research **129**(1-4): 217-245.

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

Patricelli, F., J. E. Beakley, et al. (2009). "Disaster management and mitigation: the telecommunications infrastructure." Disasters **33**(1): 23-37.

Perry, R. W. and M. K. Lindell (2003). "Preparedness for Emergency Response: Guidelines for the Emergency Planning Process." Disasters **27**(4): 336-350.
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. and F. D. Balogh (1985). "Decision Support Systems for Disaster Management." Public Administration Review **45**: 134-146.
Yan, S. and Y.-L. Shih (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

ACKNOWLEDGMENTS

I want to express my thanks to ITC and to my supervisors there: Dr. Johannes Flacke and Dr. Cees van Westen to guide me in the present research with their experience and to DPAE, because of their support on my fieldwork to collect the data. Finally, I extend my most sincere thanks to Dr. Mauricio Sánchez-Silva, Dr. Verónica Botero and to my colleagues Bhamidipati Srirama, Rifai Mardin, Juan Pablo Ardila, Fernando Sierra and Mila Luleva for their significant contribution to this research.

[i] Return period is the average time span between large earthquakes at a particular site
[ii] *Central feature* is a GIS tool which identifies the most centrally located feature in a point, line, or polygon feature class.
[iii] *Mean center is a* GIS tool which identifies the geographic center (or the center of concentration) for a set of features.
[iv] International charter is a cooperation agreement to provide space data after a disaster through authorized users. The aim of this agreement is contribute to mitigate the effects of disasters.

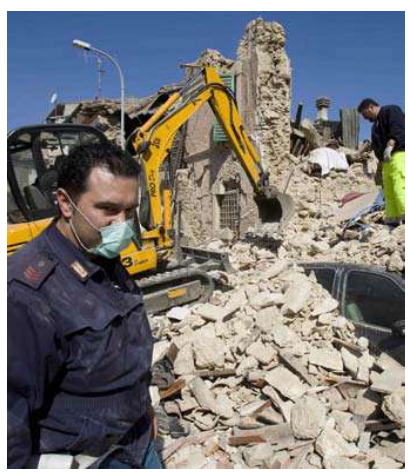
ANAHEIM, CA
September 29–October 2, 2009

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

MSc. Diana M. Contreras M.
ITC
University of Salzburg
Dr. Johannes Flacke - Dr. Cees van Westen

OUTLINE

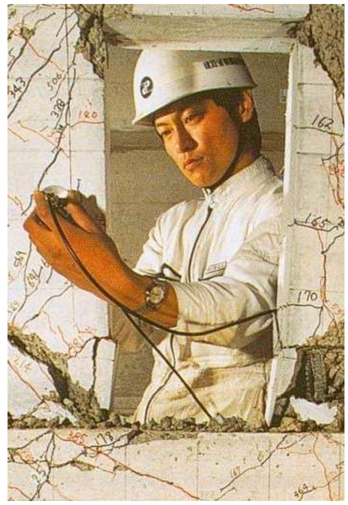
- Introduction
- Research problem
- Research objectives
- Conceptual framework
- Research methodology
- Case study city
- Analysis
- Conclusions



Earthquake in L'Aquila – Italy (2009).
Photographed by Chris Helgren.

INTRODUCTION

- ***Procedure*** to ***determine*** the ***effects*** of an ***earthquake*** in a building
- ***Collective consumption service***
- ***Loss estimation scenarios***



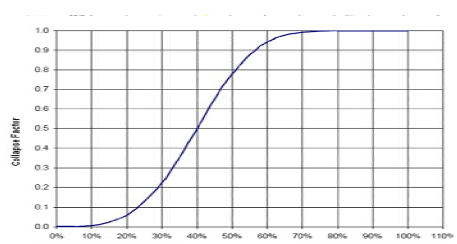
Building inspector in a detailed survey. Source: Natural disasters strategies for mitigation and disaster response. (Plate et al., 1999).

BACKGROUND (1/3)

scenarios formulation

Pre-earthquake loss estimation:

- Seismic hazard assessment
- Vulnerability assessment of the built-up areas
- Risk assessment or damaged expected

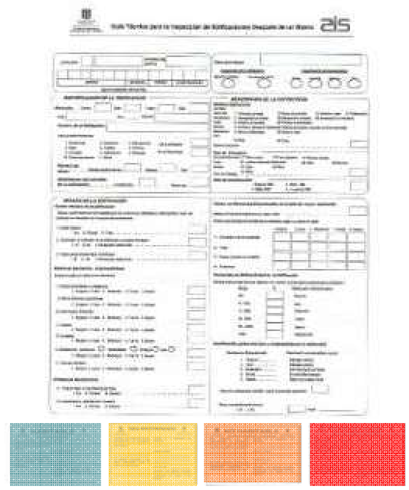


Collapse factor (FC) according the loss obtained in the seismic risk study. DPAE (2005), fig. 5.1, p. 37.

BACKGROUND (2/3)

Methodologies

- American (ATC -20 procedure)
- Mexican methodology
- Japanese methodology
- Macedonian Methodology (Kiril and Metodij University)
- Colombian methodologies (Pereira and Bogotá D.C.)

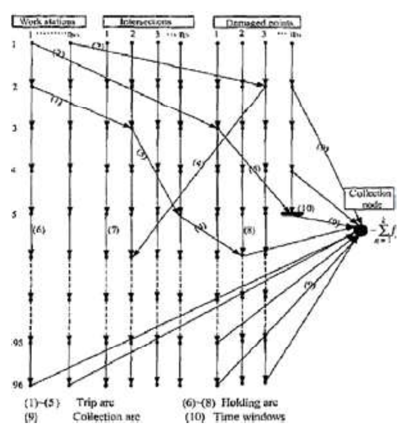


General building damage survey form and habitability announcements in the methodology formulated to Bogota D.C. DPAE, (2002).

BACKGROUND (3/3)

Research

- ***Resource performance*** and efficiency for different ***tasks*** related to response
(Fiedrich, Gehbauer, & Rickers, 2000)
- Simultaneous mobilization destination, traffic assignment, and departure schedule for multi-priority groups ***(SMDTS-MPG)***
(Chiu & Zheng, 2007)
- ***Locate rescue personnel*** and disaster sites/ bottlenecks/ optimal routes
(Kircher , 1997)
- ***Minimize time*** needed **for emergency repair,** subject to related operating constraints
(Yan & Shih, 2007)

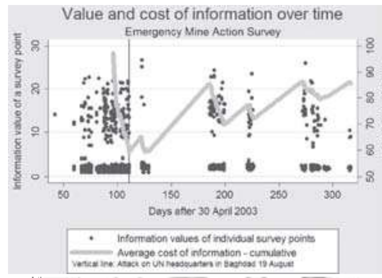


The emergency repair time-space network. Yan Shangyao; Shih Yu-Lin (2007), fig.1, p. 65.

BACKGROUND (3/3)

Research

- Generation of new ***plans*** incorporating new requests for ***aid material,*** new ***supplies and transportation***
  (Ozdamar, Ekinci, & Kucukyazici, 2004)
- Use of ***Voronoi diagrams*** to solve ***location-districting problems*** specially transport and logistic applications.
  (Novaes, Souza de Cursi, da Silva, & Souza, 2009)
- Guided **decisions to deliver relief** to affected communities
  (Benini, Conley, Dittemore, & Waksman, 2008)
- ***Reliability and accuracy*** of the rapid humanitarian assessment
  (Benini & Conley, 2007)



Information value and average survey cost. Iraq case (2003-2004).
Benini, A., and Conley, C. (2007), fig. 2, p. 42.

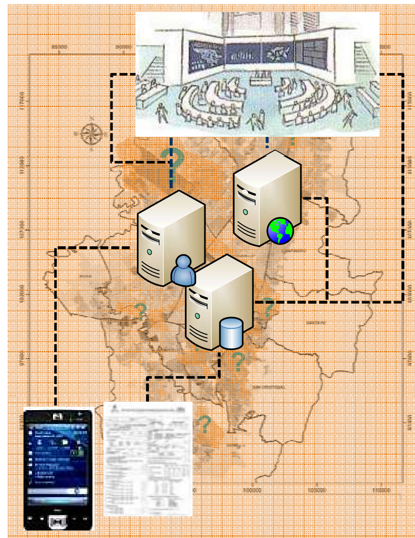
RESEARCH JUSTIFICATION

- Challenges and opportunities to the governments
  (Waugh, 2000)
- Saving lives in a short period from unsafe buildings
- Effective and efficient activity to be modeled
- Non-excludability characteristic
- Equity criteria in the distribution of the resources
- Planning: the best use of resources available

Building damage inspector.
Drew by Diana Contreras.

RESEARCH PROBLEM

- Conflict among reliability, accuracy, speed, completeness, security, safety, access, etc.
- Requirements in information management
- Restricted use of GIS for urban disaster management
- SAR, evacuation, lifelines restoration schedule and plans to supply aid material according to demand levels and resource availability
- Building damage survey methodologies



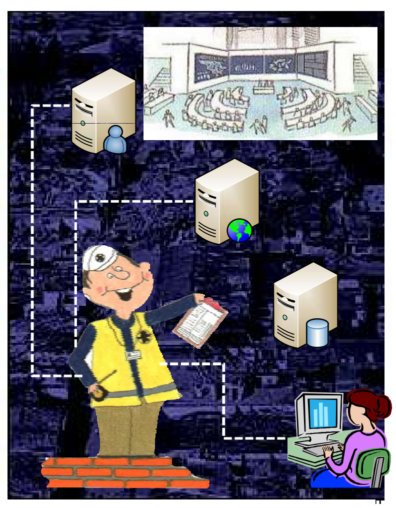
RESEARCH OBJECTIVES

MAIN OBJECTIVE

Procedure for the planning of ***rapid building survey*** after an earthquake and ***managing*** the collected spatial **information**

SUB-OBJECTIVE

1. Process model for ***estimating the number of trained people required***
2. Process model for ***allocating resources***
3. Conceptual model: ***information management***



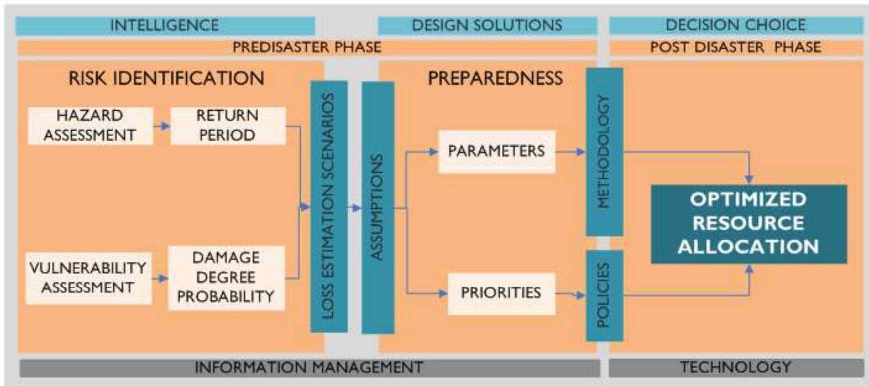
How to design the model of information management?

CONCEPTUAL FRAMEWORK

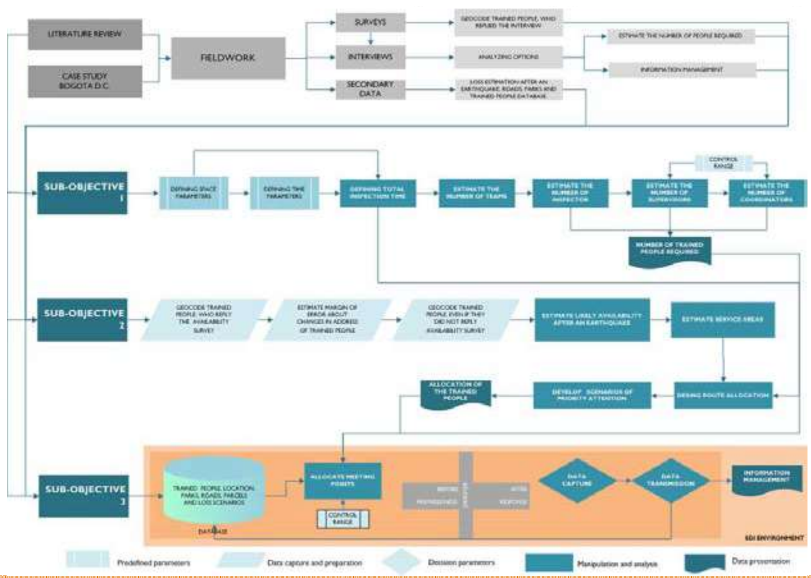
EARTHQUAKES

DISASTER MANAGEMENT

PLANNING AND DECISION SUPPORT SYSTEMS (PSS/DSS)



RESEARCH METHODOLOGY



CASE STUDY CITY: BOGOTA D.C. - COLOMBIA

Building inspection group link DPAE.

Building inspection group - admission form . DPAE

Building inspection group

FIELDWORK (1/2)

- ***Meetings and interviews*** with official entities
- ***Requirements*** made to carry out the fieldwork
- Review of ***documents*** related to the topic
- ***Questionnaire*** applied in the survey
- ***Survey*** of the trained people
- Exploration of the ***databases***
- Technology to ***capture*** and alternatives to ***transmit data***

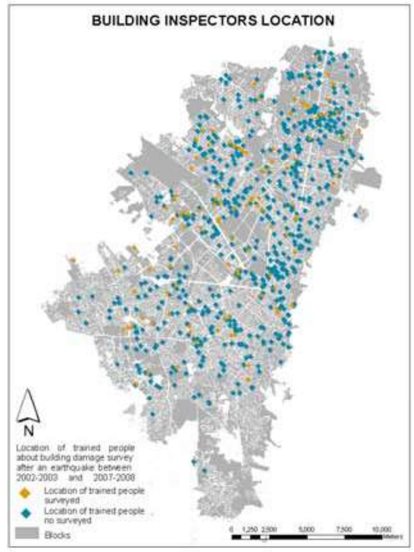
HP IPAQ 2411. DANE.

MTC 100 Handheld computer. Motorola.

FIELDWORK (2/2)

TRAINED PEOPLE by 2002 - 2003	751
People TRAINED in 2007 - 2008	40
SAMPLING DESIGN	Accidental sampling
OBJECTIVE	Availability
E- MAILS	824
PHONE - CALLS	986

SAMPLE SIZE 2002 - 2003	99 (13%)
SAMPLE SIZE 2007 - 2008	22 (55%)
TOTAL (2002-2008)	121 (15%)

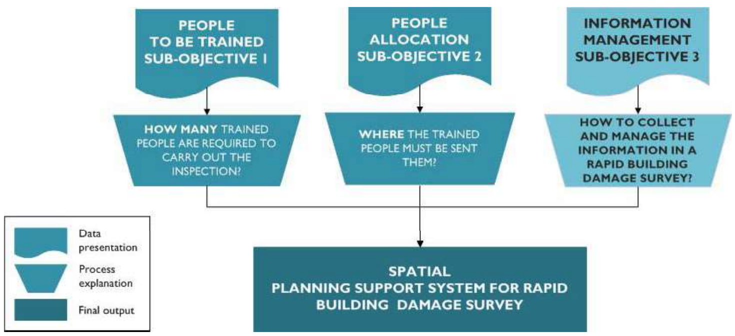


OBJECTIVES

MAIN OBJECTIVE

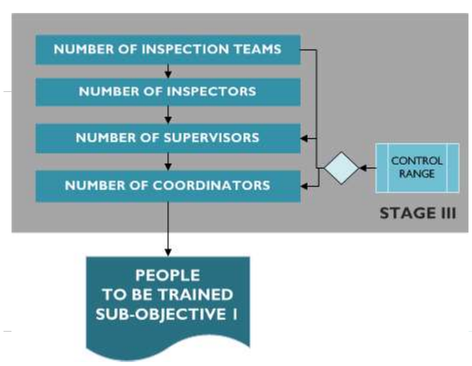
To design a **PROCEDURE** for the planning of a **RAPID BUILDING DAMAGE SURVEY** after an earthquake and **MANAGING** the spatial **INFORMATION** collected

SUB OBJECTIVES

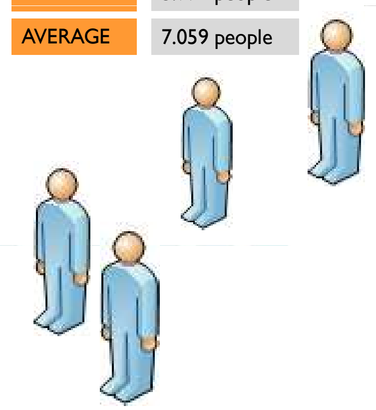


3 To design a **CONCEPTUAL MODEL** of **INFORMATION MANAGEMENT** between the different levels of the organization

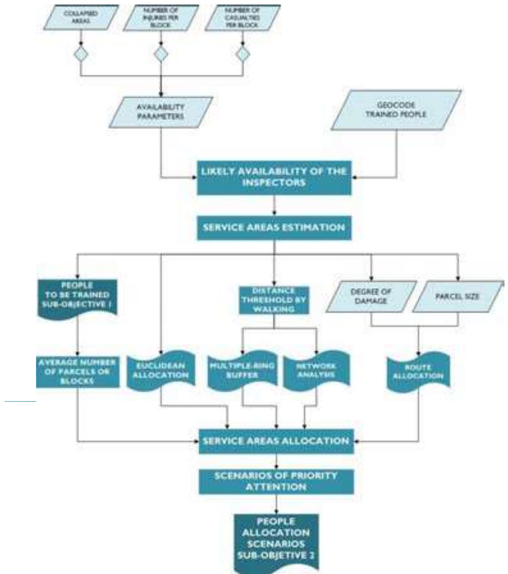
SUBOBJECTIVE 1: PEOPLE TO BE TRAINED

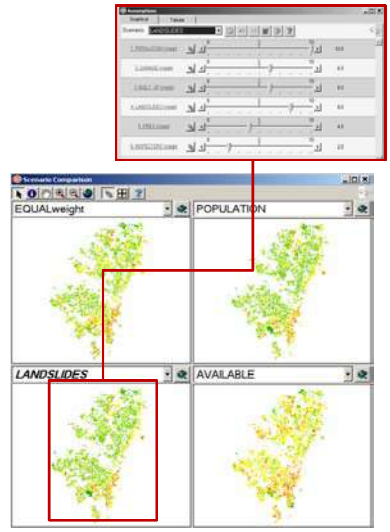


RANGE	1.111 – 18.750 people
MEDIAN	5.972 people
AVERAGE	7.059 people

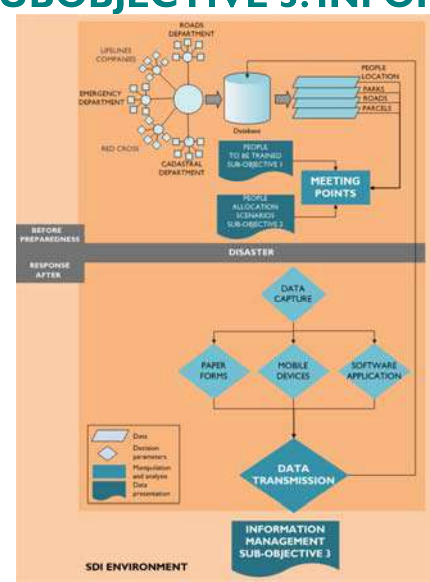


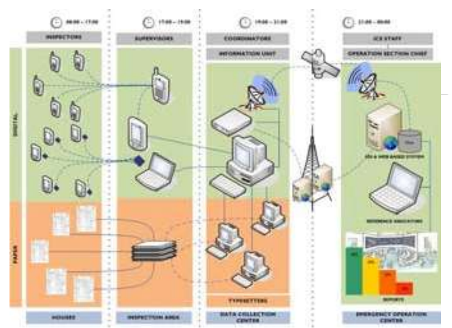
SUBOBJECTIVE 2: PEOPLE ALLOCATION



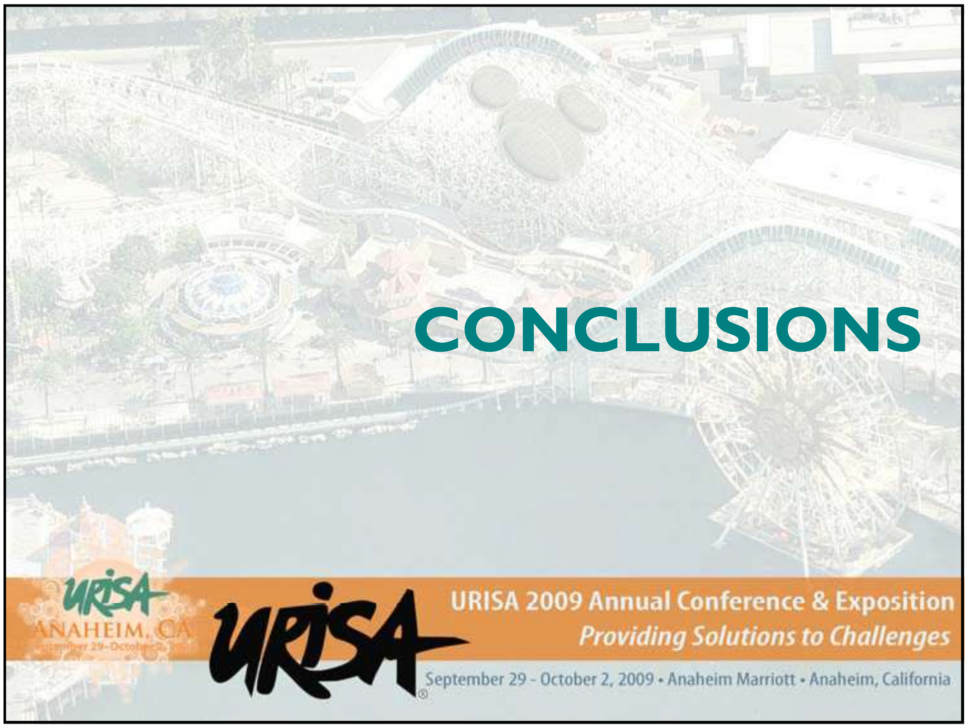


SUBOBJECTIVE 3: INFORMATION MANAGEMENT



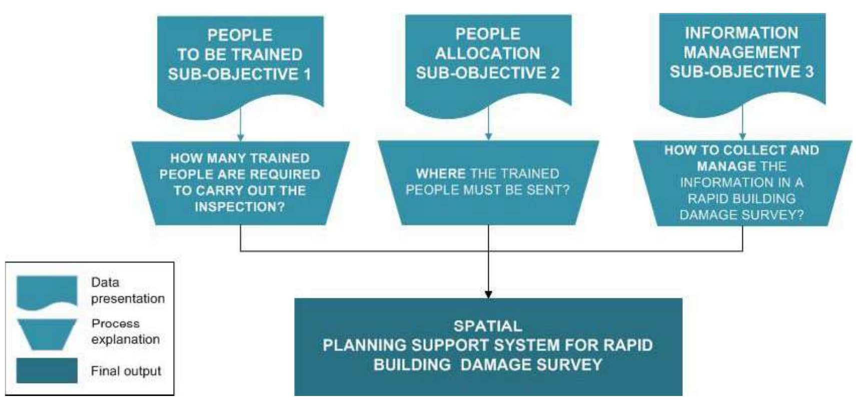


Flow information model



CONCLUSIONS
URISA ANAHEIM, CA
URISA 2009 Annual Conference & Exposition
Providing Solutions to Challenges
September 29 - October 2, 2009 • Anaheim Marriott • Anaheim, California

BASIC MODEL



PEOPLE TO BE TRAINED SUB-OBJECTIVE 1
PEOPLE ALLOCATION SUB-OBJECTIVE 2
INFORMATION MANAGEMENT SUB-OBJECTIVE 3
HOW MANY TRAINED PEOPLE ARE REQUIRED TO CARRY OUT THE INSPECTION?
WHERE THE TRAINED PEOPLE MUST BE SENT?
HOW TO COLLECT AND MANAGE THE INFORMATION IN A RAPID BUILDING DAMAGE SURVEY?
SPATIAL PLANNING SUPPORT SYSTEM FOR RAPID BUILDING DAMAGE SURVEY
Data presentation
Process explanation
Final output

SUBOBJECTIVE 1: PEOPLE TO BE TRAINED

- ***Space-parameters*** and ***time-parameters***:
  main inputs to estimate the number of trained people required

- The combination of ***the parameters, control ranges and operational times*** in different ***scenarios*** generate different ***values*** that should be used to design ***preparedness measures and/or organize the resources in the real time***

- The ***inspection times*** per parcel
  must be ***calibrated*** through ***simulation exercises,***
  which also allow to test the ***performance of the trained people***

SUBOBJECTIVE 2: PEOPLE ALLOCATION

- ***Route allocation method*** is the ***most accurate*** to **estimate** and ***allocate service areas***

  case study: coverage is ***very low*** (between 7 to 10%)
  and the South East of Bogotá is ***constant uncovered area*** **for** all the methods, in every seismic scenario.

- The use of ***Spatial Planning Support Systems (SPSS)*** in ***emergency management*** is still ***restricted*** because of the ***time required to carry out the analysis*** and the ***limitation*** in ***large scale problems***

  All the ***priority attention scenarios*** indicate that the ***South-East*** of ***Bogotá D.C.*** require priority.

SUBOBJECTIVE 3: INFORMATION MANAGEMENT

- The government must encourage the creation of ***Spatial Data Infrastructure (SDI)*** to ensure mainly the ***sharing*** of ***information before and after any disaster***
- The more suitable method to ***allocate*** a ***meeting point*** is "select the nearest park" to the ***mean center*** of the ***inspectors location***
- ***Data*** must be ***captured*** using ***mobile devices***, supported with paper forms, as the second alternative
- The ***software application*** in the mobile devices must allow the collection of ***geocoded data*** and it must have ***images*** that ***support*** the ***decision*** of the inspectors about the ***safety*** of the ***houses***
- The information management must be not only about the habitability of the buildings but also about the ***emergency operation*** itself

MSc. Diana María Contreras Mojica
Researcher
Centre for Geoinformatics (Z_GIS)
Salzburg University

Phone: +43 (0) 662 80445275
Fax: +43 (0) 662 80445260
Address: Schillertrasse 30 (Block 15, Third floor)
5020 Salzburg
dianamaria.contreras-mojica@sbg.ac.at
www.uni-salzburg.at/zgis/contreras