RISK MANAGEMENT SYSTEM OF ROADS (SIGRAV/2009) USING GEO-INTELLIGENCE ON HIGHWAYS OF THE STATE OF SANTA CATARINA - SOUTHERN BRAZIL.

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ABSTRACT

With the rapid growth of traffic accidents and disasters occurring in the roads of Santa Catarina - Southern Brazil, building a system of risk management road (SIGRAV/2009) was aimed. The SIGRAV/2009 is a prototype applied to the highways of the State of Santa Catarina, developed based upon geo-intelligence, and aimed supporting the decision making on prevention, monitoring, treatment and response activities, with the aim of improving the different steps in a risk management process. Numerical databases and cartographic analysis were built in SIGRAV/2009, allowing the analysis that measure risks for both traffic accidents and disasters on highways. Results can be presented in tables, graphs or maps. The system has been methodically built on conceptual, logical and physical models. Finally, we can affirm that the SIGRAV/2009 is a stimulus for effective road risk management on the highways of the State of Santa Catarina.

1. INTRODUCTION

Road risk is the topic addressed in this research, including the risks of accidents and disasters and their consequences as social impacts by the dead and wounded victims as well as economic impacts.

For traffic accidents on federal roads in the State of Santa Catarina, we highlight Diesel (2005), who points out in her study traffic accidents and rainfall. With these results, it was found that, on days with rainfall occurring in the range of 0.1-10mm / h, this represents an aggravating factor for traffic accidents to occur. Also in this study, road stretches with high and low occurrence of traffic accidents, with and without rainfall were identified, as well as stretches with the highest and lowest rates of morbidity and mortality, with and without rainfall. We also emphasize that, for the Northern stretch of the BR -101 (two lanes), there was no reduction of fatalities during the period 1998 to 2005.

Hirasawa and Asano (2003), Research Institute of Civil Engineering, developed a system for analyzing traffic accidents in Hokkaido, Japan. This system manages data on accidents, road infrastructure and facilities, using GIS technology (Geographic Information Systems). This system allows for the analysis of frequency of accidents, rates and seasonal effects on accidents.

Efficiency in risk management on public roads depends on the complexity of the topic of risk and the dynamics of the movement and transport of each considered region. In regions where the circulation and transport system satisfactorily meets the demand, the efficiency in risk management is easily attained. If this demand presents a growth rate and/or oscillations, considered in the control process of soil use and occupation, it is still easy to manage risks, as long as information on both quality and quantity are provided.

Risk management information should at least help identify the phenomenon (characterization, location, causes) and intervention alternatives. The interventions are done in four stages: prevention, monitoring, treatment and response of the damage caused by occurrences. Such information must be continuously updated and available to different people in different formats and scales. It must allow for quick responses during the occurrences and control of decision making and interventions done, adding new information, such as subsidies to develop plans for rehabilitation of affected areas and prevention plans for hazardous areas. This is information of different kinds, which must be continuously updated and fed back to be used by different people for different steps in the process of risk management, resulting in large amounts of data to be processed.

To Lavell (1996), risk management should not be considered as separate and discrete set of measures, but a line of analysis and concern that affects all human activities. Also according to the author, risk management has a feature that crosses many areas of institutional action, relating to the management of natural resources, with regional and sectoral urban planning, sometimes with the management of citizen security, sometimes with sustainable development, amongst others.

As an application of geo-intelligence in risk management it is possible to highlight Di Pace and Fiduccia (2006) who applied the geo-intelligence for territorial planning, based on emergencies and homeland security. According to the authors, sectors benefited by geo-intelligence are public safety, military, intelligence agencies. These sectors depend on the interaction, centralization and operability of the system of decision support for:

- The emergency operations centres;
- Inter-operability between ways of communications, and
- Authorization to collect the data access and update information in real time for decision making.

In the case of risk management of accidents and disasters, there is an urgent need to use all possibilities to increase their effectiveness, given the growing threats in relation to human populations and their activities. This contribution is the advancement of scientific knowledge and its application in human activities.

1.1. Objective

The objective of this research was to construct a Risk Management System of Roads - SIGRAV/2009 using theories Geo-intelligence (Geographic Information System + Artificial Intelligence – GIS + AI) in support of decision making for the prevention, monitoring, treatment and response activities, in order to streamline the different steps in a process of risk management.

The specific objectives defined for this study were:

1. To characterize (discover and describe) the practice of road risk management in Santa Catarina.
2. To characterize (to find out, analyze and select) existing data on traffic accidents and natural disasters in the federal and state highways of the State of Santa Catarina, as well as data on land use and occupation, traffic flow, water system, climate, vegetation, topography and soils.
3. To define the conceptual model of management system (territorial unit, range of data, databases, analysis routines, feedback system, data output).
4. To define a logical model of management system (GIS software and AI; tools and techniques for analysis and feedback system, decision-making routines and hardware).
5. To build a prototype information system, with a structure that allows the application of the technique of Case-based Reasoning (CBR), an integral part of geo-intelligence, for instruction routine on decision-making processes of road risk management in its various phases: prevention, monitoring, treatment and response.
6. To test the prototype through its experimental application in federal highways in the State of Santa Catarina, Southern Brazil.

1.2. Materials and methods

Steps for the construction of SIGRAV/2009 included the construction of databases, data integration, storage on a general basis (GeoDataBase) data mapping, analysis, preventative actions and generation of risk indicators, as well as online input and output data.

In this research, building a system of risk management was chosen, applied to a case study: road hazards on roads of Santa Catarina in Southern Brazil. The case study allowed to process data in real scale and to verify the performance of the proposed system.

The development of this research was divided into stages of activity, as described in the methodological procedures that follows.

1.2.1. Survey Methodology

Methodological procedures that include descriptions that must record stages of work, techniques used and results sought at each stage, in addition to receiving the data processed through all the steps. The steps in this research were: construction of theoretical basis; research design; field survey and data collection; construction management system; experimental application of the system.

1.2.1.1. Construction of Theoretical Foundation

The construction stage of the theoretical framework was developed through literature and documentary review, in bibliographies that hold the definitions and state of the art in relation to traffic accidents, natural disasters, risk management and geo-intelligence. From what has been studied, we can define the research design, as presented in the next section.

1.2.1.2. Research Design

In theoretical basis, the need for management tools was raised, allowing helping public managers that are responsible for prevention, monitoring, help and answer activities, in cases of accidents and disasters. As these risks have a strong relationship with the geographical context, the first possibility would be to propose a GIS technology. However, from the international literature review, the possibility of moving in the direction of new geo-intelligence theories was raised, i.e., linking the GIS to AI techniques, thus leveraging the results of the risk management system.

1.2.1.3. Field Research and Data Collection

Based on generalized technical recommendations (Cardona, 2001; and Velásquez Jiménez, 2004; Velásquez and Rosales, 1999; Wilches-Chaux, 1998 and Veyret, 2007), on the need to first explore the phenomenon of administering, before designing a system management, one should know the organization, staff and routines adopted to "risk management". Thus, the field research took two approaches: guided visits to field actions and inventory data to government agencies.

The field researchers started approaching the organs of road risks management in Santa Catarina, and to programme field visits accompanying public agents in attending accidents and finding out their causes. The used technique during these visits was observation of agents in action. Data collected were important to define the conceptual model of the system and its adaptation to limits imposed by the logical adopted model.

At the same time, existing data was being inventoried, to feed the databases of the system being built. Visits were also conducted to critical highways and miles, in order to find out the reason for the occurrence of these accidents, assessments such as: type of locality, existing road signs, neighbouring communities and others.

The consolidation of knowledge acquired during visits to government agencies and monitoring their activities in the field allowed to define the needs in terms of information for risk management activities and the nature of interesting data, to feed the system: roads, traffic, transit accidents, natural disasters and local geographical features such as topography, climate, hydrology, etc. The inventory data showed the availability of such data in different formats and not always as recommended in technical terms, especially regarding the degree of detail and completeness of such data.

At the Federal Highway Police Department of Santa Catarina (DPRF/SC) and State Infrastructure Department (DEINFRA) data on traffic accidents that occurred during the years 2007 and 2008 were collected. Accident data are composed of: date, miles, meters, highway, injured, deaths, time of accident, cause, type, climatic conditions, type of location, land use, vehicles involved and others. All data posted were provided in digital format, Excel file (Microsoft).

Weather data were obtained from Climerh (Integrated Centre of Meteorology and Water Resources, Santa Catarina) and covered the years 2007 and 2008. The following data were requested: rainfall, temperature, relative humidity, atmospheric pressure, direction and speed of wind, frost, fog and mist. Climatological data were collected three times daily - 9:00 am, 3:00 pm and 9:00 pm h – at 17 meteorological stations belonging to the State of Santa Catarina at the following cities: Araranguá, Blumenau, Campos Novos, Chapecó, Concórdia, Curitibanos, Florianópolis, Indaial, Itajaí, Joinville, Lages, Major Vieira, Rio Negrinho, Ponte Serrada, São Miguel do Oeste, Xanxerê and Urussanga.

The base map used for the construction management system was obtained from the IBGE (Instituto Brasileiro de Geografia e Estatística), in 2003, in digital format (shapefile) with the cartographic caneva in UTM coordinates (Universal Transverse Mercator), in the Geodetic Reference System SAD69 (South American Datum), with equivalent representations at scales of 1:100,000 and 1:50,000.

The design of digital Federal and State Highways in the State of Santa Catarina were obtained from DEINFRA/SC also in digital format (shapefile) with the same reference geodetic base map.

The digital hydrograph, terrain elevation, topography, soils, vegetation and contour lines maps were obtained from Climerh/ CIRAM/EPAGRI in digital format (shapefile). These maps are in UTM coordinates referenced to DATUM SAD69. They belong EPAGRI/SC (Agri Pecuary Research Company from Santa Catarina) and to SDS (Sustainable Development Secretariat of Santa Catarina) and are protected by copyright Brazil, under Law 9610/98. These letters are in http://ciram.epagri.rct-sc.br:8080/mapoteca/ site and can be used for non commercial purposes, provided that the right of ownership of EPAGRI and SDS is clearly stated.

1.2.1.4. Construction Management System - SIGRAV/2009

The model was built in three stages - conceptual, logical and physical - running as a process of experimentation, seeking the best proposal. The result is a general model of System Risk Management Road - SIGRAV/2009, composed of a set of databases in GIS structure, a program such as expert system (ES), to operate the analysis, and input mechanisms and online output data, to assist primarily in emergency decision-making in risk management.

The Expert System (ES) is part of the Artificial Intelligence tool, which associated to the GIS structure make up geo-intelligent. In this research, the used ES was the case-based reasoning (CBR).

CBR is a technique that uses stored experiments (older cases) to solve problems (actual cases), identifying affinities amongst them (BITTENCOURT, 2006). The CBR has the ability to describe and accumulate description of cases and tries to find out by analogy, when a new case is equal to another one already solved. Therefore, the solution used in the previous case might be used in the new case, and thus the new case becomes part of the data base of available cases.

The SIGRAV/2009 has in its structure the possibility to insert progressive data, either being inserted manually or automatically. In the manual way, the operator types data directly into the data base. In the automatic, data reach the database sent online from smarphones, palmtops, computers and the internet. The system also foresees online outcome results of consultations and analysis, just like data entry.

1.2.1.5. Experimental application of SIGRAV/2009

This research deals with a real problem, through the application of new knowledge to build a new applicable model, which was tested to check functioning through consultations and sample analysis.

The Road Risk Management System is fed with information on the highways of the State of Santa Catarina. The analysis results are stored to instruct the memory system knowledge, as appropriate, adopt the technique of Case Based Reasoning (CBR) to support decision making in management activities.

The experimental analyses conducted by SIGRAV/2009 are of two types: statistical analysis and decision support. Statistical analyses were: absolute risk, relative risk, morbidity rate, mortality rate, indices of traffic accidents on federal roads of Santa Catarina, for stretches of 1 km of highway. The analysis on CBR refer to search for decisions already made in previous situations, or else for suggestions by a decision set by an expert to assist the manager to make decisions relevant to each situation.

2. RESULTS

2.1. Construction of SIGRAV/2009

2.1.1. Modelling System

The conceptual model of SIGRAV/2009 foresees a system that allows detailed analysis of the road network, to support accident and disaster risk management. Whereas risk management is a process composed of several phases - prevention, monitoring, service and response - and there are several types of risks, with different causes and different alternatives of intervention for each event handled, therefore a system besides the Geographic Information System (GIS) is required; in this case its association with models of Artificial Intelligence (AI), the Case-based reasoning (CBR). The Case-based reasoning performs the consultation in the data base of stored cases (knowledge research) and when a new problem is inserted, it rescues similar cases already solved and proposes possible solutions for these cases.

From the initial concept, and on a good knowledge of risk management practiced by public administrators on the highways of the State of Santa Catarina, important variables for analysis can be defined which go beyond the physical structure or form of use the highways. It is necessary to also consider their surroundings, such as: vegetation, water, relief, use of soil and others.

Knowing the subject, the available data and study area the progressive definition of the logical model of the system, began: types of databases, structure, computer program, for example. This model was called model SIGRAV/2009 general, as shown in Figure 1.

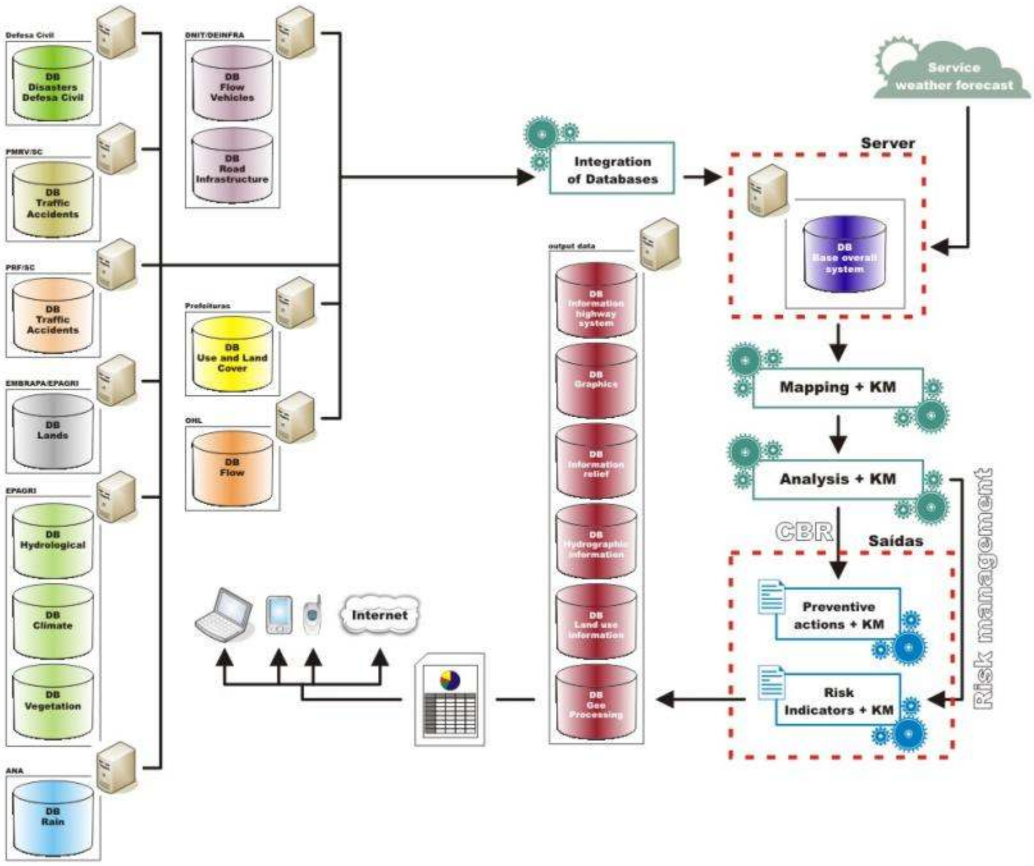

Figure 1: General Model Road Accident Risk Management System - SIGRAV/2009.
Source: developed by the authors.

SIGRAV/2009 is composed of two groups of database arrays placed at the GEODATABASE: a set of databases with structures used in GIS, with numeric data and a set of graphic database like shapelife and satellite images, which can also receive online data to feedback the system.

A data integration subsystem communicates between the numerical and cartographic databases, to aid in the steps of analysis, consisting of: mapping of useful data to a particular analysis; analysis of data itself; and the answers in the form of suggestion for preventive and/or risk indicators actions. These responses can have outlets in different formats - tables, graphs and maps - and different receivers - computer, PDA, phone, internet.

2.1.2. *Stages of Construction SIGRAV/2009*

The steps for building SIGRAV/2009 include the construction of databases; integration of data; storage in the general base (GeoDataBase); data mapping; analysis; preventive actions; risk indicators generation; and online input and output data.

2.1.3. *Database Construction*

In order to build a system based on the model previously presented, a large number of data formats and different sources have to be considered. In the current scenario, the data sources are: EPAGRI/SC, Civil Defense/SC, DPRF/SC, PMRV/SC (Military Road Police of Santa Catarina), EMBRAPA/SC (Brazilian Company for Agro Pecuary Research in Santa Catarina), DNIT/SC (Infrastructure National Department in Santa Catarina), DEINFRA/SC and meteorological services. In order to reduce the complexity of processing data from various sources, in their places of origin, data was imported from these "n" sources into a single data set, forming the GeoDataBase SIGRAV/2009.

SIGRAV/2009 holds numerical database of traffic accidents occurring in federal and state highways of the State of Santa Catarina, with impacts of natural disasters on these roads as well as climate and context (physical, social and economic) areas of coverage along the highways. Data on the menu are: soils, vegetation and hydrology. Database infrastructure, soil use and occupation and traffic flow were also structured.

The maps database consists of a shapefile from Santa Catarina territorial base, federal and state roads design, relief, vegetation, hydrology and land numerical model as well as some satellite images.

2.1.4. Integration and Data Mapping

In order to facilitate and standardize data, the import process performs some activities such as data standardization. Together with the integration of databases is the GeoDataBase. In the GeoDataBase numerical and cartographic databases are stored.

Mapping of the Database is an internal process, which is activated whenever there is an analysis demand to the system. This process covers all databases, selecting relevant data for a particular analysis. The mapping is a way of consulting the database.

2.1.5. Analysis

During this step the following is performed: queries to databases that can be simple or relational; calculation of risk indicators, and searching analysis for intervention suggestion (prevention and/or care for accidents and/or disasters), using the technique of Case-based reasoning (CBR).

Analyses of indicators, which are part of database consultation, are generated automatically, where the user can simply set what will bring the best answer for the moment. The types of indicators to calculate the modeled SIGRAV/2009 were: Absolute Risk, Relative Risk Coefficient Severity of Morbidity, Mortality Rate, indices and indicators for traffic accidents, and Absolute Risk and Relative Risk for natural disasters.

Risk management has the data input for analysis. Then, variables to be calculated by risk indicators are chosen, which will give the best answer for the moment. The process begins with the entry of data for analysis through the choice of miles and highway to be analyzed. With such information the system switches to the complete generation of all the variables of risk management.

These surveys serve as input to the process of risk indicators that are generated as an example for Absolute Risk (AR) and Relative Risks (RR), during calculation of risk indicators.

The analysis based upon the Case-Based Reasoning (CBR) can be summarized into three steps: data entry; choice of best case; and a suggestion of prevention action.

When performing the indicators analysis phase which is the entry of data into Santa Catarina's road network, the system triggers the CBR, using as input the values of predefined variables by the expert. Thus, the system may (or may not) suggest preventive measures for a particular kilometre of the road network. This analysis is performed in the extension where there was some kind of accident.
The preventive action which best serves the received request in the values of input variables is then made available to the user, via the web or a mobile device.

2.1.6. Georeferencing

Upon completion of the previous stages, the user may choose to hold SIGRAV/2009 geo-processing or not. For the implementation of GIS a library has been developed, where the analysis of generated results can automatically be mapped, where the user can choose to view or print. At the SIGRAV/2009, the mapping is generated in ArcMap 9.2 GIS software.

On the server digital data and cartographic data are stored. The numerical data consist of databases. The cartographic data are digital maps in the shapefiles format, which can be digitally displayed or printed.

All letters are referenced by the South American Datum - 1969 SAD, with the Cartographic Projections System Universal Transverse Mercator coordinates - UTM Zone 22S (Zone 22, Southern Hemisphere), with Central Meridian of 51 º WGr.

2.1.7. Online Input and Output

During the online import process the installation and configuration of an application that performs automatically synchronizing data takes place. This application must update the target database every ten minutes.

3. APPLICATION OF SIGRAV/2009 SAMPLES FOR ANALYSIS

Here are examples of this item analysis could be made by SIGRAV/2009.

3.1. Absolute Risk Indicators of (AR)

These tests were carried out by deaths from accidents recorded in the BR-101 in Santa Catarina, Southern Brazil, during the years 2007 and 2008; these tests were performed by kilometres of highway. The Figures below show the absolute risks of death by traffic accident on the entire BR-101 in the State of Santa Catarina.

Figure 2. Mortality from traffic accidents, at BR101, State of Santa Catarina. Year 2007. Source: developed by the authors.	Figure 3. Mortality from traffic accidents, at BR101, State of Santa Catarina. Year 2008. Source: developed by the authors.

Based on figures shown, it is observed that some kilometres in 2007 did not show the absolute risk of death (AR), but they are present in 2008.

This analysis shows the need to implement risk management in order to prevent that these stretches become even more critical. The first action to be taken is the identification of reasons why these accidents happened and why the victims died.

One of the actions of risk management, resulting from SIGRAV/2009, is to promote and maintain this reduction of traffic accidents through participatory activities between state and society.

3.2. Using CBR to suggest intervention alternatives

It is important to notice the potential of SIGRAV/2009 generating response in the prevention, monitoring, care and response to a traffic accident or disaster on highways. A satellite image of high resolution was used to show the stretch of the BR101 in Santa Catarina, which crosses the city of Balneário Camboriu. This stretch was selected from the analysis in the previous item. BR101 cuts the urban area of this municipality, which has a large population and high economic dynamism.

Regarding the stretches presented here, identified elevated Absolute Risks (RA's) were identified as follows: 131km, 132km and 133km of the BR101, in 2007; and 131km and 133km in 2008.

Figure 4. AR for death at BR101 in Balneario Camboriu in 2007.
Source: developed by the authors.

Figure 5. AR for death at BR101 in Balneario Camboriu in 2008.
Source: developed by the authors.

For the application of Case-based Reasoning (CBR), the example of the AR death identified at 131 km at the BR101, which includes the city of Camboriu, in 2008, will be used.

To search for the solutions of cases AR's death, CBR lists the variables identified by a multidisciplinary group of experts in road hazards and properly classified by the system operator on a finite set of values, as shown in figure 6.

Number of tracks	Flow	Location	Land use	Tracing	Condition tracks
1 track	Intense	Commercial	Urban	Crossing	Good
2 tracks	Moderate	Residential	Rural	Straight	Bad
3 tracks	Low	Industrial	Urban and Rural	Curve	Reasonable
4 tracks		Not built		Straight, crossing and curve	
		Commercial and Residential		Straight and curved	
		Commercial and Industrial			
		Commercial, Residential and Industrial			

Figure 6. Table of variables and values of CBR, for traffic accidents from km131 at BR101.
Source: SIGRAV/2009 - CBR module.

Consultation to the CBR was done taking these principles as basis. In this consultation, which variables were needed to make a good index of cases was asked. It was also observed, with the CBR which was the number of minimal solutions to evaluate the efficiency of the system. The result was the construction of cases, with 2008 data, as shown in Figure 7.

C A S E 1	PROBLEM	
	BR	101
	KM	131
	Type of accident	Rear-end collision
	Number of repetitions	37
	Wounded	25
	Deaths	1
	Total victims	75
	Land use	Urban
	Location	Commercial
	Tracing	Straight
	Runway conditions	Good
	Visibility	Good
	Solution	
	Actions:	Intensifying the surveillance and education activities
		Preventive actions

Figure 7. Example of building a case at CBR for accidents at km131 of the BR101.
Source: SIGRAV/2009 - CBR module.

Other possible actions stored in the module CBR SIGRAV/2009 for this case are:

Suggested Actions
Construct access road on the pedestrian level
Construct access road sub-level pedestrian
Intensifying surveillance and prevention activities
Intensify surveillance

Figure 8. Universe of possible actions to prevent pointed out by a multidisciplinary group of experts risks on road.
Source: CBR Module - SIGRAV/2009.

Another possible outcome to be generated on SIGRAV/2009 is through the weather forecast, coupled with other databases and images.

With weather forecast data it is possible to know which areas have the highest rates of rainfall, and then locate the roads, rivers and bridges. After this identification, distances that the river is from the highway network needs to be known, and through probabilistic geometric calculations, monitor the possibility of the water reaching the highway or not.

Figure 9 shows the occurrence of disasters on highways during the periods from January/February and November 2008. During this period of January/February 2008 there was an excess of rain and several stretches of highways were interdicted due to a large volume of water on the track. As for November 2008, besides the volumes of water on the track, there were numerous landslides, fallen barriers, runway dips amongst others.

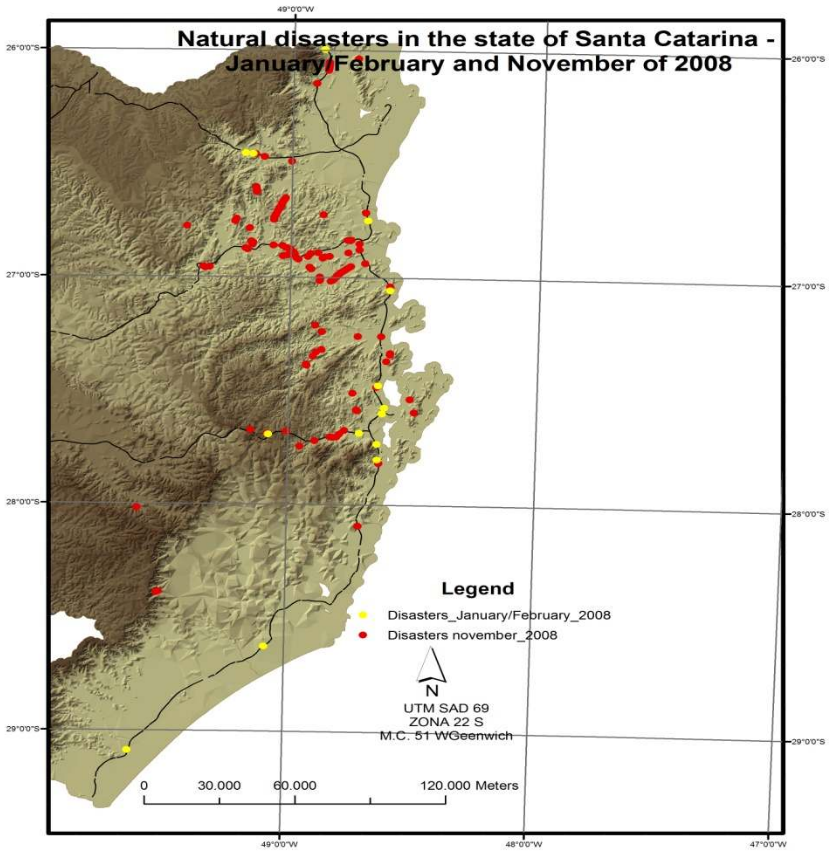

Figure 9. Natural disasters in the state of Santa Catarina - January/February and November 2008.
Source: generated automatically by SIGRAV/2009 ("Georeferencing" Database Natural Disaster).

The application of CBR in case of disasters follows the same logic of the risk of traffic accidents, but with specific variables.

CBR consultation takes place through automatic search of the areas defined by the expert/user. Here, km 166 of BR101, in Tijucas, is the defined area for the consultation of the CBR. The CBR lists all variables that are classified related to the kilometre being surveyed, into a set of values, as shown in Figure 10.

Number of tracks	Flow	Location	Soil type	Tracing
1 track	Intense	Commercial	Urban	Crossing
2 tracks	Moderate	Residential	Rural	Straight
3 tracks	Low	Industrial	Urban and Rural	Curve
		Not built		Straight, crossing and curve
		Commercial and Residential		Straight and curved
		Commercial and Industrial		
		Commercial, Residential and Industrial		

Figure 10. Table of variables and values of CBR, for disaster occurred in the Km166 of BR101.
Source: SIGRAV/2009 - CBR module.

Based on the consultation submitted to the CBR, variables of index cases are analyzed. At the time of the research, efficacy of the system is analyzed through an analysis of model accuracy performed by a specialist. Thus we have the construction of the case presented in Figure 11.

CASE 1	PROBLEM	
	BR	101
	KM	166
	Type of disaster	Water on the track
	Number of repetitions	1
	Land use	Rural
	Location	Not built
	Tracing	Straight
	Runway conditions	Good
	Solution	
	Actions:	Drainage on the runway

Figure 11. Example of building a case by CBR for disaster occurred at Km166 of BR101.
Source: SIGRAV/2009 - CBR module.

The CBR also list other possible solutions to this case.

Suggested Actions
Drainage on the runway
Change route - alternative paths
Protection of slopes
Doubling of track
Signalling to drop barriers

Figure 12. Universe of possible solutions indicated by a multidisciplinary group of experts in road hazards.
Source: CBR Module - SIGRAV/2009.

Therefore, for disaster risk management, CBR indicates possible solutions: drainage on the runway and route changes - alternative paths. These possible solutions can be worked preventively, before a new event takes place, as well as emergency measures.

One of SIGRAV/2009 possibility is to analyse accidents and disasters as a whole, i.e. in the same analysis in the CBR for a given kilometre, solutions will address both accidents and disasters. In this case, the CBR lists suggested actions for both accidents and disasters.

4. CONCLUSION

This research was motivated by the severity of road traffic problems in Brazil. Being a country of continental dimensions and having almost total concentration of movement in road transportation, traffic accidents, in addition to natural disasters which impact on the road network, has attracted the attention of scholars, public managers and politicians in Brazil. The growing risks if not managed effectively, can represent high social, economic and environmental loss, with negative effects on the sustainable development of the country.

During the construction of SIGRAV/2009, an information gap in both quantity and quality needed for risk management was identified. The SIGRAV/2009, besides providing greater flexibility in road risk management, allows this management to progressively become more effective, with historical record of adopted measures and actions taken as well as obtained results.

The structure of SIGRAV/2009 can be adapted to various risk management, which are not only related to public roads.

REFERENCES

1. Bittencourt, G. Inteligência artificial: ferramentas e teorias. 3. Ed. rev. Florianópolis: Ed. da UFSC, 2006. 371p
2. Diesel, L. E. (2005). SIG na prevenção a acidentes de trânsito. Florianópolis, SC, 2005. 171 f. Dissertação (Mestrado) Programa de Pós-graduação em Engenharia Civil - Centro Tecnológico. Universidade Federal de Santa Catarina, UFSC.
3. Hirasawa, M.; Asano, M. (2003). Development of traffic accident analysis system using GIS. In: Proceedings of the Eastern Asia Society for Transportation Studies. Vol. 4, pp. 1193–1199.
4. Lavell, A. (2003). Gestión local del riesgo : Nociones y precisiones en torno al concepto y la práctica. Centro de Coordinación para la Prevención de los Desastres Naturales en América Central (CEPREDENAC);PNUD; 101 p. ilus.
5. Di Pace, R., Fiduccia, A. (2006). Le soluzioni Intergraph per la Geospatial Intelligence e la Data Harmonisation nel contesto di standardizzazione dei flussi informativi delle SDI. http://www.amfm.it/conferenza2006/atti/intergraph.pdf. Acessado em: 30/06/2007.
6. Cardona, O. M. A. (2001). Estratégia de Divulgación e Información para la Gestión de Riesgos. LA RED. Santo Domingo. 58 p.
7. Velásquez, A.; Jiménez, N. (2004). La gestión de riesgos en el ordenamiento territorial: inundaciones en cali, la c.v.c y el fenómeno enso. 2004 Disponível em: http://osso.univalle.edu.co/doc/congresos/2004/A_Velasquez_Articulo_OSSO-UV.pdf Acessado em: 23/03/2007 as 20:08hs
8. Velásquez, A.; Rosales, C. (1999). Escudriñando en los desastres a todas lãs escalas. Concepción, metodología y análisis de desastres en América Latina utilizando DesInventar. OSSO / ITDG / LA RED. Colombia.
9. Wilches Chaux, G. (1998). Auge, caída y levantada de Felipe Pinillo, mecânico y soldador. Guía de La Red para la gestión local de los desastres. La Red, Quito, Ecuador. 103 p.
10. Veyret, Y. (2007). Os Riscos – o Homem como Agressor e Vítima do Meio-ambiente. São Paulo, ed. Contexto.