Volume 2, Issue 3, March 2012 ISSN: 2277 128X

International Journal of Advanced Research in Computer Science and Software Engineering

Research Paper

Available online at: www.ijarcsse.com

Development of SDSS for Ensuring Insurers

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Abstract— ***In arena of catastrophe management in India, managing risk at varied levels along with timely and effective decision making by Insures/Reinsurers is a complex task. This unique dynamic system makes the assessment and management of enterprise-wide risk much more multidimensional and uncertain resulting in failure of connection between lines of business. Geospatial technology viz. remote sensing, GIS and SDSS has emerged as powerful aid to assist risk managers and decision makers to manage risk for several years. However, if used alone, it has limited functionality. This paper presents the conceptual design and development of remote sensing and GIS-assisted Spatial Decision Support System (SDSS) to improve property insurance underwritings that involves procedural and declarative knowledge. SDSS, coined as Insurance Profiler (InsPro), integrates geocoder, multi-criteria risk evaluation techniques and state-of-art web interface framework which is applied at three phases viz. geospatial visualization and querying of insured points, multi-criteria comprehensive evaluation of risk and report generation. It is flexible in that it can be adapted in evaluation of any property type. It is scalable because the system can be designed at local, regional, national or international level as being data driven .The system is integrative because it incorporates a number of different data types and sources (e.g., multispectral remote sensor data, numerous thematic information on hazard and vulnerability), and geo-statistical tools and techniques, and human expert knowledge of the seismic region. The system is designed to be flexible, scalable and integrative. Thus, this SDSS tends to cater the needs of users at all levels viz. risk analyst, insurer, brokers, reinsurers etc. to manage share and interact effectively and reliably.***

Keywords— ***Catastrophe, SDSS, Insurers, GIS, Real Estates, InsPro***

I. INTRODUCTION

Risk analysis is a complex task that entails consideration of complex parameters which are difficult to interpret and quantify ([1]–[3]). In addition, risk analysis involves a comprehensive database to model uncertainty and vagueness. As a consequence, insurers/reinsurers fail to evaluate and underwrite actual risk. In addition, there are other shortcomings, such as poor visualization of insured points and risk zones ([4]–[7]) slow model based update of information that further contributes to complexity and underestimation of potential loss from natural hazards and even failure and insolvency of some insurance companies.

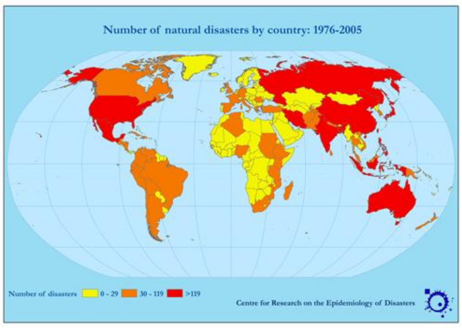

Fig. 1 Country-wise total natural disaster events: 1976-2005 (Source: EM-DAT)

The catastrophe imposed risk in India can be described as worst as being high on number of events and intensity as depicted in Figure 1, owing to an elevated probability of hazard occurrences and high exposure due to geographical, topographical and socio-economic settings [8]. This trend is expected to continue as higher concentration of populations and built-ups continue to develop in areas susceptible to natural hazards. India's vulnerability to natural catastrophes coupled with rapid growth and transformation of the insurance market, it is crucial to address this high level vulnerability in order to avoid the present scale of losses and damage. Despite leveraging such transfer of risk through integrated product choices and schemes, there are very limited sections of population (0.5%) in India those have any kind of property insurance [9].

There are various other inadequacies such as poor location identification of insured exposures on paper maps, primitive modelling assumptions and slow update of information that add to complexity of insurers/reinsurers. Such limitations aid to underestimation of severe nature of disaster and associated potential loss resulting in unexpected significant drop in surplus and bankruptcy of some insurance companies. Beside these, there are other reasons which could be attributed for such low profiling. This include a general lack of awareness about insurance practices, two-dimensional nature of spreadsheets and reports which requires skill set for understanding, lack of spatial database that could provide easy visualization and data querying, absence of scientifically designed enterprise solutions focused for insurance underwriters to promote faster and effective decision making. Against the above-stated deficiencies of current systems, adoption of geospatial technology for niche areas such as actuarial underwritings, claims management, risk based pricing, could be very useful as much of the data required within these domains contain geographic component ([11]–[14]).

II. Geospatial tool & technology in insurance

Remote Sensing (RS) and GIS together have emerged as useful tool for insurers/reinsurers because of spatio-temporal component involved within [15] and its ability to integrate large volume of information through repertoire of analytical tools for disaster risk management ([16], [17]).The system is further aided by development of modelling approaches such as catastrophe models with basic components including hazard, exposure, vulnerability, and loss ([18], [1]). The derived models tend to quantify the likelihood of disasters occurring and estimate the extent of incurred losses, both from single event and multiple events and eventually help in development of spatial decision support system (SDSS). In the basic framework of risk management, a combination of RS, GIS and SDSS; RS & GIS can be used in potential hazard zonation, inventory preparation, whereas SDSS for vulnerability assessment, loss estimation and in decision processes by key stakeholders [16]. Insurance companies are increasingly using SDSS as an essential business tool [15] to mitigate exposure to risk by ensuring a wide spatial distribution of policyholders.

III. Multi-Criteria Decision Based Risk Assessment

Solving problems and taking rational decisions in a complex domain such as risk assessment needs integration of information, knowledge and expertise from a wide range of disciplines. It also needs some kind of support mechanism (i.e. tools) that can assist planners and decision makers in informed and rational decision making. Risk assessment being a problem of multiple dimensions; involving multiple criteria, conflicting objectives, and its planning is considered as a multi-criteria decision making (MCDM) problem that needs specialized tools and techniques that can support a systematic approach of decision analysis. MCDM is characterized by the need to evaluate a finite set of alternatives on the basis of conflicting and incommensurable criteria of quantitative, qualitative or both in nature and based on preference values of the alternatives on permissible scale measure the overall preference values ([19], [20]). For this reason, there has been a growing interest in applying GIS and spatial MCDM to risk analysis which is very much evidenced by an increasing number of published articles on this topic. Entrenched in a GIS milieu, MCDM technique provide the framework of a SDSS which improves the effectiveness of decision making process by incorporating decision maker's judgments and computer based programs ([19]-[22]). In the domain of risk planning, MCDM approach is considered essential because of its demonstrated ability to integrate multiple criteria, preferences of different groups, expert's knowledge, and with-standing spatial; non-spatial and inexplicit data from various sources. The most significant characteristics of this methodology are that they are transparent to the participants. Such methodologies make it possible to integrate risk assessment information in knowledge structures and networks, and opens prospects for improved risk mitigation and planning to investigate a number of multiple objectives (criteria).

With this backdrop, it is obvious that the deductive, well-structured problem-solving methodologies are inadequate when it comes to the analysis of urban area risk assessment as there are multiple representations or understandings on this concept. Therefore, identifying an appropriate design structure for assessment procedure among competing options is perhaps the most important part of analysis. The design must recognize divergent perspectives of urban morphology and hence associated risk. In this paper, we deduce that one of the useful alternatives to design risk assessment procedure is to adopt an inductive approach based on spatial MCDM. We have chosen earthquakes as a subject of this research not only because of their severe impacts on urban area, but also because they have provided the basis for some of the fundamental physical, technological and social research in field of natural hazards: work that has often been a model for studies of other hazardous natural agents. The objectives formulated for current study focuses on development of a geospatial and web analytics based actuarial solution for insurers/reinsurers which would minimize uncertainty and cater to their needs for profiling overall scenario of property risk.

IV. Research needs

A small region of capital city Delhi, India is taken up to demonstrate this concept of risk assessment using web based solutions. The study area is characterized as susceptible to earthquake and as majority of the population dwell in urban areas and even the slightest structural and physical damages will affect lives immensely. The prime objective of present research is to develop a generic methodology which is applicable to any study area. Nevertheless for initial development, a test site is required. One of the main considerations of selecting study site was availability of several experts from different discipline who are well acquainted with study area. Also, being the metropolis and capital city, spatial and non-spatial data for several themes were readily available. Most importantly, study area characterizes a typical urban landform with socio-economic activities revolving around risk planning and mitigation. Such characteristics suit selection of area for case study to demonstrate applicability of methodology.

Despite of gaining importance and widespread acceptance of multi-criteria analysis based decision-making in risk assessment and regional planning; it is still in its infancy stage in India. In this respect, this study will have a significant contribution to explore potentials of this approach to address issue of risk management.

V. SDSS Architecture - insurance profiler (InsPro)

The development of SDSS solutions for actuarial Industry, coined as InsPro – Insurance Profiler, involved four (4) critical areas of development (Figure 2), as illustrated stepwise in subsequent section:

- Development of geocoding engine
- Creation of hazard, vulnerability score maps
- GIS database integration
- Development of Web-based solution - InsPro

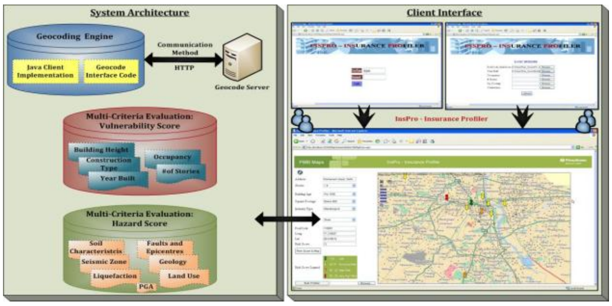

Fig. 2 Schematic architecture of Insurance Profiler (InsPro)

A. Development of geocoding engine

Geocoding is the process of assigning geographic coordinates to data that contain addresses. The coordinates assigned to each address turn each record into a geographic object that can be potentially displayed on a map. This was designed as first "gateway" into InsPro application. The development of geocoder involved:

1) *Electronic Research work and use of local knowledge:* The first and foremost step in this was identification of administrative hierarchy. In administrative structure of India it was seen that it is composed of states which are further divided into districts (zila) and districts are further split into into sub-districts, locally known as Tehsils/Talukas. The block is the next level of administrative division following tehsil. Villages are often the lowest level of administrative divisions in India. Thus, these datasets were captured to be used for address identification. In addition, building footprint data was created with house numbers/name for urban centres so that geocoder was capable of approximately locating houses. These datasets were used for tagging POIs, streets, localities and town datasets as these are building block for geocoder. Second step was determination of postal formats determination. In India, there are 8 PIN regions and the first digit indicates one of these regions. Postcode is however six (6) digits long where the first 2 digits together indicate sub region or one of postal circles, first 3 digits together indicate a sorting / revenue district and last 3 digits refer to delivery post office. Thus, recognition of postal hierarchy helped in creating an approximate postal reference data for India. This was another milestone in development of Geocoder. Third step was to extract address patterns/ formats. General pattern of address followed in India includes writing of recipient's name in first line followed by house number/street name, locality name, district, postal code and state name. The address pattern identification helped in development of various permutations and combinations of address being entered by user and hence further enhancement of geocoder to fetch correct results or nearest match on hits being made by user by using these permutations and combinations of address pattern. The fourth and last step was determination of thoroughfare types: In India, different thoroughfare types identified include motorized ways, non-motorized ways and waterways. The local terms used for these thoroughfares such as highway, flyover, expressway, lane, way, avenue, gali, path, road, marg, sadak, walk, street, channel were added to the geocoder configuration files in order to determine best possible match. Also, prefix and suffixes used with road names such as NH4, directional words viz. north etc were incorporated which further assisted in enhancement of Geocoder.

2) *Data build:* Geospatial files viz. GeoInfo, PostInfo, POIs (Point of Interests) and StreetRef files were created to be used as input for Geocoder. GeoInfo files were point data containing information on capitals, cities, towns, villages whereas PostInfo file were polygon data with information on postal codes. StreetRef file were polyline data with details on streets names, their types, pre-post fix, house number ranges. POIRef was point file with information on landmarks viz., business hubs, commercial centres, stations, scenic places, shopping centres. All these spatial files were tagged with administrative level information.

3) Component build:

Based on electronic database searches, data build, and local knowledge, configuration files, to be used by MapMarker geocoding engine, was created which contained following information besides spatial data files:

- Coordinate precision information: This was to determine number of decimal places of coordinate values should be used to precise the results. This was set as 6.
- Word dictionaries: Created with words generally being used by locals in writing address. Minimum quality of words used for searching areas, streets and postcodes with values assigned between 0.0 and 1.0, with a value of 1.0 indicating the words have to be perfect matches.
- Pre filtering information –This allowed showing up of results with candidates having matching search area words thereby reducing false positives and speed up matching process due to reduced number of candidates.
- Searches based on alternate key: This was used to determine the use of alternates keys based on transposed characters, missing characters, incorrect characters, extra characters etc.
- Soundex parameterization: This involved grouping of characters or group of characters to get best possible match based on sound property. For example - soundex_replace_1=C,ts; soundex_replace_2 = A,aw.
- Weights assigning: The street information and post address were assigned with scores for obtaining better results during reverse geocoding. For example: POIs data (such as landmarks) was given high scores while matching data as in Indian context these POIs are taken as identifier such as near XYZ place. Hence, better geocoding precision.

- Assigning precision code: Coordinates to an address based on how well it matched in address dictionary was assigned a code based on precision of matched results. The code represents success or failure of geocoding operation and conveys information about quality of match. Each character of code provides information on how precisely geocoded results matched each address component. The code is an alphanumeric code of 1–10 characters and falls into the categories such as single unique match; postcode centroid match and geographic match. Each category is further subdivided into sub-categories. Table I enlist geocoded precision code results and their accuracy description.

TABLE I: GEOCODING PRECISION CODE DESCRIPTION

Single* unique *match (S category): This implies record was matched to single address candidate. First character (S) reflects that geocode component found street address that matched record. First two characters of S result code indicate type of match found.	
Results	**Accuracy Level**
S5	match located at street address position
S4	match located on the street centroid
SX	match located at street intersection
Street level geocode result, codes S4 and S5 are followed by additional characters, indicating details of match precision. These result characters appear in order, immediately after S4 or S5.	
H	Exact match on house number
P	Street prefix direction
S	Street suffix direction
C	Exact match on town name
Z	Exact match on postcode name
A or U	A if address is returned from the address dictionary. U if address is returned from the user dictionary
-	If any field does not have an exact match, then its position will be replaced by a dash
Example of geo-coding results explained below:	
S4-PSCZA	Street centroid match (S4) with exact match on all other criteria except house number
S5HPS—A	Street centroid match (S5).Exact match on house number, but no exact match on town name or postcode
SX	Street intersection match
***Geographic centroid matches (G category)*:** The matches under this category indicate that a match was made at geographic (town or locality) level. This may be because no street match was possible and geocoder results fell back to geographic area.	
Results	**Accuracy Level**
G3	geographic match with town centroid - areaname3
G4	geographic match with locality - areaname4
If Areaname3 input matches both town and locality names, then G3 candidates appear at top of candidate list followed by G4 candidates. When both town and locality is provided as input, highest scoring candidates are listed at top. Exception is when geographic input matches both town and locality.	

Thus, configuration and data build binary files were used in geocoder engine to create geocoding components which was capable of handling Single/Multiline input, address correction, reverse geocoding and bulk/batch geocoding.

However challenges faced during the development of Delhi Geocoder were non-availability of street names, unorganized addresses, house numbers etc. and variation in address pattern. Thus, this aroused difficulty in geocoding at street level as most of addresses do not include street names and hence geocoded at geographic levels than street level. Besides, street interpolation can't be done because of non- standard house numbers. Also, address search precision is poor due to above stated deficiencies. Thus, with these limitations, geocoder works on the hierarchy of identifying pincode and locality, identifying the street (as already segmented), identifying POI/Landmark, and identifying administrative boundaries for getting precise results.

B. *Creation of hazard, vulnerability score maps*

The integrated system designed here, is divided into two phases of risk score generation: static and dynamic phase. a) Construction of composite hazard and vulnerability layer score map which was preset in SDSS formed static component and run-time generation of risk maps formed dynamic component based on user's permutation and combination of vulnerability classes. Hence, an aggregate risk score map was developed for a particular property under insurability consideration.

For seismic hazard score map generation, Saaty's (2000) analytical hierarchy process, a MCDM methodology, in a participatory decision-making framework was used to rank and develop seismic hazard and vulnerability layer score map of study area [23]. Nine experts (two academic researchers, three from government organizations, and four from nongovernment organizations who work closely in seismic risk assessment areas) were engaged to perform pair-wise comparison of criteria and weights were determined at two levels of hierarchy i.e attribute values of the map layers and map layers to generate hazard and vulnerability layer score maps.

Pair-wise comparisons were carried out based on Saaty's semantic nine-point scale which relates numbers to judgments (Table II).

TABLE II: PAIR-WISE COMPARISON SCALE

Intensity of Importance	Definition	Explanation
1	Equally important	Two elements contributes equally to the property
3	Moderately important	Experience and judgment moderately favor one element over other
5	Strongly important	Experience and judgment strongly favor one element over other
7	Very Strongly important	An element is strongly favored and its dominance is demonstrated in practice
9	Extremely	The evidence favoring one

	important	element over another is of the extremely highest order of affirmation
2, 4, 6, 8	Intermediate values	Compromise is needed between two judgments
Reciprocal of above numbers		If an activity has one of the above numbers assigned to it when compared with a second activity has the reciprocal value when compared to the first.

In this way different criterion were weighted with homogenous measurement scale. Through this method, the weight assigned to each single criterion reflected the importance which every expert involved in the project attached to objectives. Once experts were through with comparative analysis, weights and consistency ratios besides calculating eigenvalue, Consistency Index (CI) and Random Index (RI) were calculated (Refer Saaty and Vargas, 1993 for calculation steps). The pair-wise comparison matrices for each expert that met the consistency ratio (CR) i.e CR < 0.1 were then aggregated using geometric mean (Saaty, 2000). A geometric mean was used instead of arithmetic mean when comparing different criteria and finding a single "figure of merit" for these criteria as geometric mean "normalizes" the ranges being averaged and hence no range dominates the weighting, and a given percentage change in any of the properties has the same effect on the geometric mean. Thus, through MCDM approach of pair-wise comparisons weights of criterions were determined for below enlisted criteria and final hazards score maps was generated.

1) Seismic zones: A seismic zone is a region in which the rate of seismic activity remains fairly consistent. There are five seismic zones named as I to V as details given below:

- Zone V - Covers the areas liable to seismic intensity IX and above on Modified Mercalli Intensity Scale. This is the most severe seismic zone and is referred here as Very High Damage Risk Zone.
- Zone IV - Gives the area liable to MM VIII. This, zone is second in severity to zone V. This is referred here as High Damage Risk Zone.
- Zone III - The associated intensity is MM VII. This is termed here as Moderate Damage Risk Zone.
- Zone II - The probable intensity is MM VI. This zone is referred to as Low Damage Risk Zone.
- Zone I - Here the maximum intensity is estimated as MM V or less. This zone is termed here as Very Low Damage Risk Zone.

2) Peak Ground Acceleration (PGA): Peak ground acceleration is the maximum value observed from an accelerograph recording in an earthquake. Because it is a value derived readily from ground motion records, there is a much larger global dataset of PGA available.

3) Soil characteristics: The soil parameter controls relative amplification of ground motion. The soil value is actually an index related to the shear-wave velocity (Vs) of the top 30 meters at a site. This material property has been shown to correlate well with shaking amplification; lower Vs generally result in a larger ground motion than hard materials with a high velocity.

4) Liquefaction: Liquefaction is form of ground failure that can be triggered by strong shaking. It is the temporary transformation of a solid soil into a liquid state. It can occur when certain types of saturated, unconsolidated soils are subjected to repeated, cyclical vibration and therefore most commonly occurs during earthquakes.

5) Geology: Geology is the study of the Earth, the materials of which it is made, the structure of those materials, and the processes acting upon them. Geology plays an important role in determining seismic hazard as regional geology enables in assessment of sources and patterns of earthquake occurrence, both in depth and at the at the surface.

6) Land use: Most of the Delhi area has changed land use from the forest to agricultural areas to urban centres to business hubs especially in the central portion. This has actually led to increase in the urban population, decrease in open spaces and forested areas. Delhi has also experienced a large population in growth in the last decades and this combined with rapid infrastructure development has intensified the seismic vulnerability in the area.

7) Proximity to the fault: A fault is a break in the earth's crust along which movement can take place causing an earthquake. When an earthquake occurs on one of these faults, the rock on one side of the fault slips with respect to the other. Faults can be centimeters to thousands of kilometers (fractions of an inch to thousands of miles) long. The fault surface can be vertical, horizontal, or at some angle to the surface of the earth. Faults can extend deep into the earth and may or may not extend up to the earth's surface. Faults with evidence of Holocene (about 10,000 years ago to present) movement are the main concern because they are most likely to generate future earthquakes. If the earthquake is large enough, surface fault rupture can occur.

8) Proximity to the epicenters: The epicenter is the point on the Earth's surface that is directly above the hypocenter or focus, the point where an earthquake or underground explosion originates. In the case of earthquakes, the epicenter is directly above the point where the fault begins to rupture, and in most cases, it is the area of greatest damage. However, in larger events, the length of the fault rupture is much longer, and damage can be spread across the rupture zone

The weight maps were standardized by applying a linear function. Linearity was chosen to limit discussion with stakeholders for selecting other membership functions. The composite hazard score map generated herein formed the static framework of risk analysis in InsPro.

Multi-criteria evaluation (MCE) technique was adopted for creation of vulnerability score map. MCE was applied with following factor maps:

- Building height
- Year built
- Construction type
- Building area (square footage)

Each vulnerability score map generated herein also formed the static component ofInsPro.

C. GIS database integration

Workspace was created which is a simple text based scripting resource containing commands to open tables, create and position the necessary map, browser and other windows, define layer style and thematic settings. The layers included in workspace were: administrative, gazetteer, point of interests (POIs), streets layers. This workspace was used as base map and formed the front end visualization component of the InsPro on which analysed results were to be depicted.

Microsoft Access® 2007 was used for data storage and queries and contained non-spatial data assembly including hazard and vulnerability score tables. Hazard score table contained pre generated composite hazard score at pincode level derived using MCDM techniques. MCDM was too applied to obtain vulnerability score tables with individual score tables of building height, year built, construction type, and building area (square footage) of case study region which. The advantages of storing it in access lies in the fact that these, tables are not static and can be updated, revised at any given point of time by the administrator of Ins Pro.

Ahlers and Boll (2008) introduced five classes in terms of spatial granularity (country, region, city, street, and building) for geocoder development. For the current study street level geocoder engine was developed and integrated into InsPro using C# language. The geocoder was incorporated enabling geocoding functionality to fetch and show search results to the user on web interface.

D. Development of Web-based solution - InsPro

Cognizant of the need for a risk assessment tool for better underwriting and actuarial engineering, and to provide a system that can generate and manage risk information for acquisition of insurance/reinsurance facilities and catastrophe cover, GIS assisted SDSS wascalled as Insurance Profiler (InsPro) was developed. The codes were developed for integrating geocoding components and multi-criteria score mapsand layers to create sync between them. Besides for visualization of results of search, query, geocoder, statistical analysis web interface was created using MapXtreme framework. The SDSS were built with basic functionalities such as zoom, pan, search and locate, address validate, bulk geocode, on the fly risk score computations, report generation, print and save. Computation of risk score involved using multiplicative function of hazard potential and vulnerability i.e. *Risk = Hazard potential x Vulnerability*which is also the definition of risk. To be able to portray the risk of region, the risk scores/map is based on an aggregated hazard map and an integrated vulnerability map, and it enables us to see the level of risk related to a region. This concept was applied in InsPro where hazard score map was pre-computed and stored in database, vulnerability criteria classes were selected by user and dynamic risk score was computed as output using multiplicative function. However, such simplification doesn't devalue flexibility and usefulness of the SDSS tools in disaster insurance underwriting. In support of the robust expert-system shell, more use can further populate the knowledge bases of hazard, vulnerability and risk assessment making them more complete, more sophisticated and easily adjustable by satisfying demands for decision-making. Besides these, in InsPro, the flexibility for calibrating data, parameters and even risk computation logic and limits, as per user's requirement were provided. The better visuals and array of the applications has capability to draw more acute fascination of customer toward insurance underwritings/pricing. The application will tend to bring in uninsured segment of population into insured segment by giving a logical view of where and why asset should be insured.

VI. Results and Discussion

A. Multi-criteria evaluation based Hazard Score Map for SDSS

In the present study the Spatial-MCDM method was used in which different hazard criteria were appraised in order to establish their validity and usefulness, and eventually amalgamation of the different factors were provided in form of a composite hazard score map for study region. Following a multi-criteria decision making - analytical hierarchical process (AHP) (Saaty, 1980), each theme and features were assigned weights and rankings respectively according to their perceived relative significances to seismic hazard (Refer Tables III -IX).

TABLE III: Scores of Seismic Zones

Seismic Zone	**Risk Zone**	**Weight**
Seismic Zone-1	Very Low Damage Risk Zone	0.009793
Seismic Zone-2	Low Damage Risk Zone	0.009838
Seismic Zone-3	Moderate Damage Risk Zone	0.424964
Seismic Zone-4	High Damage Risk Zone	0.546386
Seismic Zone-5	Very High Damage Risk Zone	0.009019

TABLE IV: Scores of Peak Ground acceleration

Peak Ground acceleration (PGA, in g)	**Susceptibility**	**Weight**
0 – 0.12	Very Low	0.091047
0.12– 0.14	Low	0.128602
0.14 – 0.16	Moderate	0.189169
0.16 – 0.18	High	0.266218
0.18 – 0.20	Very High	0.324964

TABLE V: Scores of Soil characteristics

Soil characteristics	**Soil Susceptibility**	**Weight**
Very Hard to Hard Rock	Very Low	0.091047

Loamy Sand	Low	0.128602
Soft Rock to Older Alluvium	Moderate	0.189169
Younger Alluvium	High	0.266218
Fill to Shallow Bay Mud	Very High	0.324964

TABLE VI: SCORES OF LIQUEFACTION CHARACTERISTICS

Liquefaction characteristics	Liquefaction Susceptibility	Weight
Rock very stiff or cohesive clays, sediments older than Pleistocene (>1.6 Ma); sites with deep water table	Low	0.101103
Holocene to Pleistocene (11Ka to 1.6Ma) alluvial fan deposits	Very Low	0.127001
Modern alluvial fan deposits	Moderate	0.2673707
Modern floodplain or beach ridge deposits	High	0.504526

TABLE VII: SCORES OF GEOLOGICAL CHARACTERISTICS

Geological characteristics	Susceptibility	Weight
Polycyclic sequence of brown silt-clay with kankar and brown to grey fine to medium grained sand	1	0.0421679
Yellowish fine to medium grained sand with minor silt and siliceous kankar	2	0.109563
Quartzite with interbanded schit and phyllite	3	0.113868
Multiple fill alternate sequence of grey micaeous fine to medium grained sand	4	0.212850
Grey micaeous fine to coarse grained sand and overbank silt	5	0.521552

TABLE VIII: SCORES OF LAND USE

Land use	Risk Zone	Weight
Group 1	High Density Vegetation, Waterbodies	0.068837
Group 2	Low Density Vegetation, Open, Quasi open area	0.112326
Group 3	Industrial area, Residential/village, Agriculture	0.225349
Group 4	Skyscrapers, Urban low density , Urban High Density, Airport	0.593488

TABLE IX: SCORES OF PROXIMITY TO FAULTS

Proximity to Faults (Neotectonic, Subsurface)	No. of faults	Weight
0-20 km	1	0.006543
21-40 km	1	0.005479
41-60 km	4	0.168103
61-80 km	7	0.286638
81-100 km	12	0.545258

TABLE X: PAIR-WISE COMPARISON SCALE

Proximity to Epicenter	No. of epicenter	Weight
0-25 km	0	0.021693
26-50 km	4	0.255663
51-75 km	6	0.4091855
76-100 km	2	0.191668
101-125 km	1	0.121790

The composite seismic hazard score map of Delhi region involved evaluation of different seismic hazard components namely seismic zones, peak ground acceleration at seismic bedrock, soil characteristics, liquefaction potential, land use, geological characteristics, proximity to faults and epicenter. These layers were, thereafter, integrated through MCDM techniques to obtain composite seismic score map addressing site specific hazard scores for seismic micro-zonation. A composite hazard score map was generated with indices value from 0.17 to 0.89 (Figure 3).

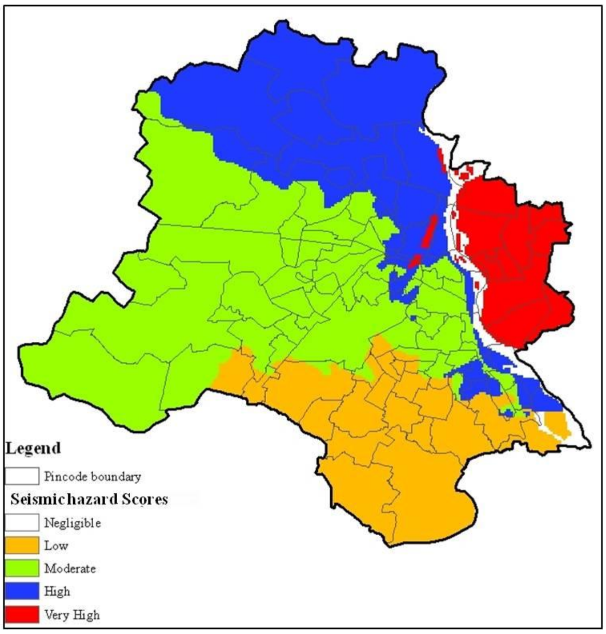

Fig. 3 Seismic hazard score map of Delhi

The hazard scores were set into five categories, negligible (0), low (0.01 - 0.25), moderate (0.26 – 0.50), high (0.51 – 0.75) and very high (0.76 – 1.00). The map depicted that seismic susceptibility of Delhi region follows the order: east > north > west > south areas. East regions of Delhi are considerably high vulnerable area because it is positioned in high seismic zone and greater liquefaction potential. Overall, parts of central Delhi are also subjected to greater seismic scores due to social-economic assets accumulation. Accumulation of people and their assets seemingly become major cause of the hazard risk. The generated composite hazard score map was integrated in InsPro.

Vulnerability score maps were too integrated into the InsPro application so that in the fly final risk computation can be made using hazard and vulnerability layers.

B. SDSS – Insurance Profiler

Insurance underwritings, risk pricing and claims management are a number of objectives by which an insurer can reduce the volatility and liquidity in characteristics of risk to 'homogenize' it, and make it fall in to the basket of 'risk pools'. The booming geospatial technological have made possible to build geo-analytical custom insurance solutions that leapfrog capabilities of traditional offerings. InsPro – Insurance Profiler is an upshot of such offerings, coming out with hitherto hard-to-obtain location data with integrated risk scores. Delhi region is used as case study site to showcase few of the functionality of InsPro. The details of further offerings of InsPro are explained in Table 3.

1) *Mapping:* Insurers/reinsurers/Risk managers can locate address and visualize spatially (Refer Figure 4). The mapping solutions incorporated in InsPro enables to depict myriad of themes. All visualizations that user can see is rendered from workspace. The series of standard procedures were involved from conversion of data from OSL (Oracle) format to MapInfo *.TAB format and forms the background for geospatial results visualization based on functionality executed in InsPro. For example, locating address Central Cottage Industrial Corporation, Delhi. InsPro was able fetch this result by making use of geocoding engine. Reverse was also possible i.e. on entering Latitude/Longitude values, address could be returned.

Fig. 4 Insurance Profiler (InsPro) - Web based mapping solution for Insurers/Re-insurers

2) Risk Assessment: InsPro generates comprehensive assessment of location under consideration by insurer/reinsurers to produce more objective patterns of risk assessment in lieu support of the expert knowledge base (Figure 5). Besides these, InsPro has inherent functionality of data analytics. For example, if a zone presents an unacceptable risk for insuring new property then such risk can be pre-screened by underwriters by varying the vulnerability parameters. If the new risk falls in the alarming range of score, it means there is already a concentration of risks, and they should be careful while writing risk based on the actuarial guidelines.

Thus, its very well evident from the above case study that close association of geospatial technology with insurance decision making processes, InsPro application is perfectly suited for insurance domain to address its deficiencies.

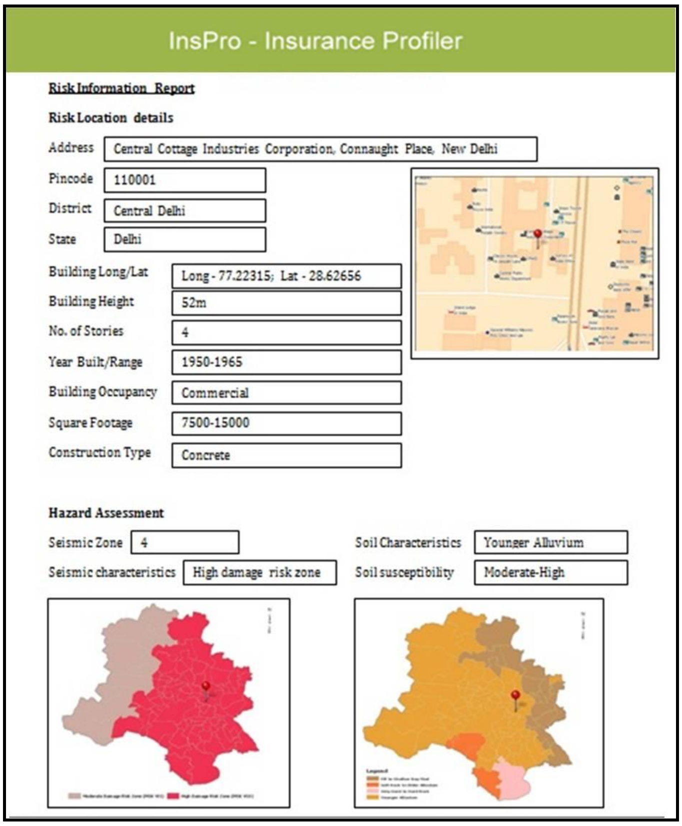

Fig. 5 Insurance Profiler (InsPro) - Web based mapping solution for Insurers/Re-insurers

TABLE XI: INSPRO FUNCTIONALITY AND USAGE

Functionality	**Usage**
Assessment of spatio-temporal hazard risk patterns	The spatial decision support system can provide comprehensive analysis of hazard based risk score in addition to building parameters to produce more objective patterns of risk assessment in support of the expert knowledge base
Evaluation of spatio-temporal variation of exposure	Discrepant insured buildings have differential spatial variation of loss risk and thereby have their respective vulnerability and loss curve. Further, it is necessary to correctly estimate the regional total loss at risk from all kinds of properties so as to classify the insurance portfolios
The past claims and their correlation by different policies	Although the past claims data alone can’t provide enough accurate information concerning the occurrence patterns of natural hazards, they are an available indicator for the vulnerability and loss curve of exposures and contain important information for pricing and for determining insurance rates.
Mapping	Underwriters can examine specific regions on a digital map to see, how much of the current book of business is concentrated within a

	given radius or is proximal to historical claim records? This would give them a clear picture of the potential risk of the specific building/ pincode/ regions.
Analytics	Trend analysis with historical data can be performed to determine if a zone presents an unacceptable risk for insuring new industry in the area. Or by varying parameters of building contents, a new risk can be pre-screened by the underwriter. If the new risk falls in the alarming range of score, it means there is already a concentration of risks, and they should be careful while writing risk based on the current guidelines
Risk Search	A simple query interface for Risk Portfolio Manager to ease out the process of extracting information from the database using pre-stored policy and claims database.
Running an event footprint on the policy database	A geospatial footprint of any disaster viz. earthquake, flood or cyclone can be overlaid on insurance company's current portfolio using and this would help in estimating extent of losses due to event
Thematic Risk Reports	Map a portfolio and then determine its exposure to various risks or intensity of risk. These maps can be exported from Risk Portfolio Manager in an image format. Accumulate the insured value, premium, PML, net retention, treaty limits and limit either by a geographical point of reference like building, pincode, or various admin boundaries, risk zones, proximity to a selected location. Even the accumulation by risk parameters of a peril can be carried out. For example, in case of the earthquake peril, risk accumulation can be monitored by building characteristics like occupancy, construction type, construction quality, number of inhabitants by day / night
Tabular Accumulation Reports	Tabular reports generated on the fly incorporating some of the following key aspects of the portfolio such as *Premium Distribution*, *Claims Distribution*, *Loss Cost* etc.

Insurance Profiler (InsPro) developed herein in this paper, overcome some of the deficiencies of traditional actuarial assessment in India such as inadequate understanding of the geographical settings and its relationship to historical events [24], analysis based on anticipation and correlation of evidences ([25], [26]), small coverage and non-homogeneous information ([11], [27]), fixed scale analysis. In the current knowledge-based system shell, the geocoding engine, supporting multi-criteria evaluations and visual display facilitate insurers with the spatial visualizations, database management, data analysis, querying, trend analysis, estimating loss cost, avenue for new business expansion and underwriting risks. This system will even allow, risk managers to assess hazard concentration, determine degree of vulnerability and anticipate damage, in case of occurrence of catastrophe.

VII. Conclusion

Natural disaster and its vagaries contribute to complexity of the risk analysis. Insurance pricing of these involves manifold factors and interdisciplinary cooperation between disaster experts, meteorologists and actuaries ([29]–[31]). From the initial phase of hazard simulation, vulnerability and risk analysis to rate-making and premium-making, there is no clear-cut method or model that can give a comprehensive answer ([29], [32], [33]). The location based knowledge system designed specifically to deal with situation involving procedural and declarative knowledge is thus an appropriate choice of technology ([34],[35]). The SDSS - InsPro developed in this study incorporates the advanced expert-system shell, sophisticated visual GIS and robust spatial multi-criteria statistics components into a coherent and integral system using the industry standard interface protocol. Such a system is flexible, portable, extendable, low-cost and effective to provide a solid base for more accurate risk analysis and pricing of insurance policies. The application based on insurance guiding principles and scientific risk assessment considerations, has the potential to basically transform the lifecycle of most of the insurance business processes as known in present day. Because of its flexibility, scalability, user-friendliness GUI, despite some shortcomings (hazard assessment, unsystematic uncertainty analysis), InsPro can be easily enhanced and become more powerful with continuous update of knowledge bases, enhancement of data to support geocoding and incorporation of developed risk models. This suite of product developed as prototype for insurance sector, can also replicated for various domains.

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