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A GIS Solution for an Integrated Underground Coal Mine Management: A Conceptual Framework

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Abstract

Geographic Information System (GIS) is a computer software package that links information about spatial objects and the data related to that object. GIS is considered as a powerful tool for storing and retrieving, transforming and displaying spatial data from real world for a particular set of purposes. For application in mining, GIS packages normally fall under 'toolbox' classification of software. GIS contains various commands by which the user can perform various discrete tasks similar to word processing software. In this paper, an attempt has been made to analyze the entire coal mining system and have designed the maps and databases required. We also try to design an enterprise GIS structure of the system that integrates the entire coal mining activity right from strategic down to the mining face level. Finally, we try to show how this system will help taking accurate decisions and will make monitoring of mining activities easier.

Keywords: GIS, Spatial Decision Support System, Underground Coal Mine management, Intelligent Coal Mining

1. Introduction

GIS can be defined as „a computer system that can hold and use data describing places on the earth‟s surface‟ (Rhind: 1989-28). Fuller (1986-6) has defined it as „a set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes‟. In general, these definitions of GIS cover three main components.

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They reveal that GIS is a computer system more than just a series of computer boxes, but includes Hardware, Software and appropriate procedures. It uses spatially referenced data that carries out various management and analysis tasks. It draws on concepts and ideas from many different disciplines like Cartography, Computer Science, Engineering, Surveying, Landscape etc. Thus GIS involves not only the study of fundamental issues arising from the creation, handling, storage and use of geographic information, but it also examines the impacts of GIS on individuals and society and the influences of society on GIS (Goodchild, 1997). GIS is a computer software package that links information about spatial objects and the data related to that object. It is a combination of a map and data linked with the map. Unlike with a paper map, where „what you see is what you get‟, a GIS map can combine many layers of information comes from a database and is shown only if the user chooses to show it [4].

For application in Mining, GIS packages normally fall under „toolbox‟ classification of software. This means that GIS contains various commands by which the user can perform various discrete tasks similar to word processing software [4][9]. Thus, it‟s simple, easy to use and user friendly. However, the basic difference between a word processing software and GIS is that later can be trained to perform the same actions with different data with the aid of macro program [5]. In this way, GIS can be customized to use by scientists, engineers, managers and surveyors, rather than by GIS specialists only. The major applications of GIS are in the field of land development [8], social sciences, resource management [6], and environmental assessment [10], understanding population dynamics of human, animals, birds, insects and others [11].

2. GIS applications in Underground Coal Mining - Literature Support

2.1 Overview of GIS Backbone System

The major applications of GIS are in the field of land development, social sciences, resource management, environmental assessment, understanding population dynamics of human, animals, birds, insects and others [1]. Application of GIS in Mining is relatively a new and fast evolving concept [5]. Geography provides the framework to acquire, develop, and interpret the complex spatial and tabular datasets used for Mining and the Earth sciences. Mapping, spatial concepts, and time / space operations technology is absolutely essential to effective mining [9].

GIS technologies create efficiency and productivity opportunities in all aspects of mineral exploration and mining [4]. GIS enables a mineral exploration geologist and mine operator to mine intelligently, efficiently, competitively, safely, and environmentally. In this way, GIS integrates exploration, operation and environmental issues with mine management [4].

2.2 GIS for Pre-Production Phase

The major applications of GIS during pre-production phase are surface topography, land acquisition, land development, procurement of mining equipments, man power planning and development of mine site [9][8]. Assuming that surface elevations at various locations are known from either borehole data or from elevation contours; GIS can generate surface topography along with overburden and coal seam thickness [6]. It can be viewed using three-dimensional plots. Volume of overburden, stripping ratio and overall production can also be computed from these maps. Moreover, GIS can successfully manage the process of site selection such as property ownership, lease holding, mineral rights, etc. It is often difficult to visualize the „acquired‟‟, „forest‟‟, „not-acquired‟‟, and „disputed‟‟ land before a project can be undertaken [3]. GIS provides an easy solution to this problem by giving up to date information about any particular area. For example, just by asking GIS to show all „disputed‟‟ land, the management can view those areas as a thematic map and get all latest information about the dispute. Similarly, man power planning and location of various HEMM in the mine site can also be performed with related database attached to them.

2.3 GIS during Production Phase

The decision of mine site selection, mine pit layout, optimum utilization of HEMM, location of central workshop and railway siding, blasting pattern, slope stability issues and others are major consideration during production phase [9]. The management would like to map the entire area showing all mine boundaries and formations, topography, drainage patterns, service buildings, coal seams, mine entries, etc. in one layer, all power supply feeder lines, sub-stations, transmission towers, gate end boxes, ACBs and OCBs, switches, circuits, mining and lighting cable diagrams, etc in another layer [7].

Now the General Manager of the area can view a particular coal seam by zooming into the map and then merge the electrical transmission system layer on the coal seam layer and decide whether a new line needs to be drawn to meet the need of mine advancement. Similarly, it becomes easier to monitor history of machine breakdown, power grid failure, condition of haul road, stock and consumption of gasoline for dump trucks and any other day-to-day operation [5].

Decision can also be taken for ecologically sensitive areas by creating a buffer zone of „nointerference" with mining activities. If an entire village or a cluster of houses need to be rehabilitated during production phase, GIS will be the ideal tool for alternative site selection, providing water and electricity lines, developing new roads and computing inter-visibility between points, etc. [12]. Monitoring of water and air quality at different parts of the mine is also possible by querying the digital maps, as well as by displaying results from the database. In this way, the General Manager has the capability to view any particular features on the map just by clicking on a particular object [3]. Pipelines, electric lines, roads, ramps, and other mining facilities change frequently. Engineers and operations staff use GIS for facility planning applications. Keeping track of existing infrastructure and integrating with the mine plan and block models can be achieved with GIS. GIS can be used to integrate recent survey data with block models or mine design data from other mining software packages such as SURPAC2000™ , or DATAMine™ which is currently being used in Coal

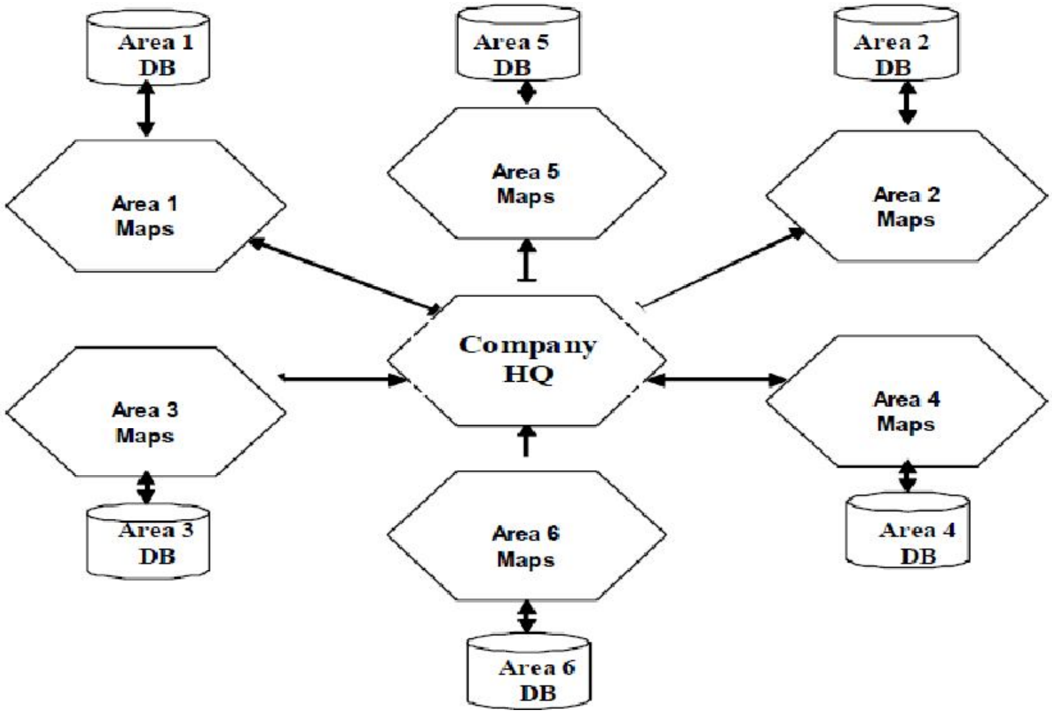
Industry. Often, items positioned along a linear feature such as a pipeline are referenced by station numbers or mileposts. A high-end GIS can create special features that can be referenced by this stationing. Valves and other point features can be placed along the pipeline by a single station reference, while attributes that apply to a section of the pipe can be associated by referencing a beginning and ending station.

Live GPS is becoming commonplace for monitoring and dispatching dumpers or drills and for providing grade control on shovels. These data can also be tied to a GIS to monitor the location of all equipment, in real time.

Thus, here there is a need to have a holistic and integrated platform that can reduce production delays and can improve productivity and thus can result in a better underground coal mine management.

3. Proposed GIS System for Underground Coal mining

An enterprise GIS system may be implemented with distributed desktop GIS applications running in the areas at the area offices and also at the headquarter offices of an underground coal mining organisation. A company wise shared mapping environment backbone may be created, which will act as an integrated map database for the entire company. The conceptual model will look like the following:



3.1 Users of the System:

The users of the system can be looked from three conceptual perspectives. They are:

Doers: The lowest rung of the data will be at the field level. Various types of data can be downloaded from different „points-of-use", collected in a sequential and systematic manner, saved in suitable databases to be used for future queries and analysis. *This data will be used to create base maps and other analysis.*

At the individual field and functional areas, the users will generate and retrieve georeferenced information, create thematic maps and regularly monitor the various processes based on information posted from the database. Thus at this level, the GIS project is developed using the raw data and the interpretation of geo-referenced data is undertaken.

Users: The data collected and stored at the sites will now be shared by the GIS users at the area level. The basic maps of the areas will be converted into digital formats at this level and given to the GIS *doers* at the field levels, where they can attach data with the map features.

The planners at the area level (**GM / CGMs of the area**s) can analyze the map features, calculate necessary parameters and depict them with desired calculations. These information and reports will then be sent to the GIS *doers* at the fields.

Thus the preliminary GIS project will be created, analyzed and vector maps prepared for further use at the field sites for advanced GIS applications. At the area level the GIS system can be completed with the technical inputs from the *Users* and the field data from the *Doers.*

Viewers: The completed GIS system can now be ported to company headquarters for use by the highest rung of the decision makers. This acts as the backbone of the GIS activities. The analysis results can be viewed by the decision makers at the top level by accessing data and projects created at *User* and *doer* levels. This can be done with a Web browser and Internet connection. With the aid of such Web-enabled applications, the planners and decision makers are now able to get answers of their queries immediately. Thus it can access data from any where using the intranet and the internet.

3.2 Components of the System:

The components of the system would be as below:

1. Maps

Field and colliery maps of all user departments like:

- **Geological** : Formation maps, soil and alluvium, structural set up, strike and dip, faults, folds, coal seams, sequence, roof and floor ,dirt bands, grade wise reserves, outcrop, etc.
- **Mining** : All mine boundaries, mine plans and layouts, formations, structure, mine area, sequence of coal seams, physico-mechanical properties, strata control details, ventilation, explosive magazines , etc.
- **Excavation** : All work faces and benches with survey maps, dragline and shovel locations, blast hole drills, dumping yards, haul roads, unit, regional and central workshops, HSD oil depots and dispensing units etc.
- **E&M** : Pumping installations, drainage maps, power transmission units, overhead conductor lines, mining and lighting cable maps, Trailing cables, sub-stations, trans-switch units, all indoor and outdoor installations, coal handling plants, conveyor systems, vehicle repair and maintenance units etc.
- **Civil Engineering** : Residential and office buildings, water supply and sewerage units, service buildings, approach roads and culverts, land records and status map for land acquisition, canals, rivers, etc.
- **Safety**: Rescue Stations, ventilation installations, cap lamp stores, dust extraction and water spraying systems, rescue training centers, fire hydrants, lighting and signaling arrangements etc.
- **Personnel and welfare:** Miners quarters, welfare stations, primary schools, community centers, banks, post offices, police stations, training schools and vocational training units etc.
- **Environmental:** Forest covers and a forestation maps, wild life, plantation maps, sewerage treatment plants etc.
- **Materials Management:** Unit, regional and Central store units, HSD depots, scrap and disposal yards, etc.
- **Despatch:** Road transportation routes, railway yards, marshalling and goods yards, wagon handling and shunting yards, major dispatch routes to coresector linked customers, alternate routes etc.
- **Medical:** Hospitals and dispensaries units.
- Area level maps integrating all mine level maps for the above user groups.
- Head-Quarter level maps integrating all area level maps for the above user groups. This map will also show the state and district boundaries, rivers and canals, national and state highways, bridges and culverts etc

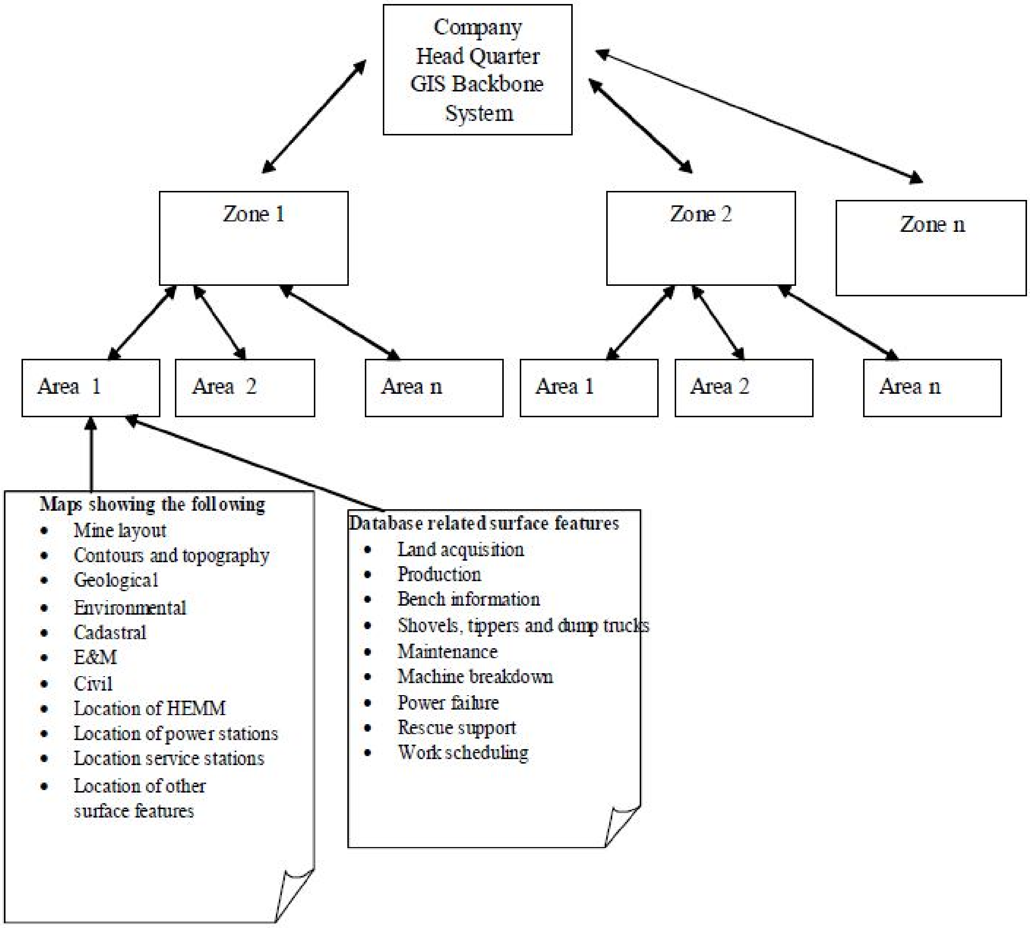
2. Databases

All object level databases in industry standard RDBMS format showing related data for each item, namely:

- All **plants and equipment**: specifications, year of commissioning, maintenance history, details of spare parts requirement, availability and utilization, whether working or under breakdown, etc.
- All **roads and service buildings**: Year of construction, name of contractor, last maintained date, area, covered area, surface type, width, gradient, type of use, etc.
- All **workshops, CHPs, Washeries** : Detailed layout plans showing individual equipment, their specifications, year of commissioning, maintenance history, details of spare parts requirement, availability and utilization, whether working or under breakdown, etc.
- All location units like **schools, hospitals, community centers** etc. showing no. of students, name of in-charges, beds, list of facilities, name of doctors and their specialties, whether having operation theaters, whether having emergency and trauma control centers, etc.
- All **residential units** showing name of occupants, designation, phone no, etc.
- All **rescue stations, ventilation units** etc. showing facilities available, name of in-charge, phone no. number of rescue equipment available, whether in working condition or not, last date of rescue drills carried out, etc.
- All **mines** with capacity, production, dispatch, cost data, target of production and achievement, etc.
- **Man-power data** attached to the relevant units, grade, scale of pay, age, date of retirement.

4. Solution Architecture

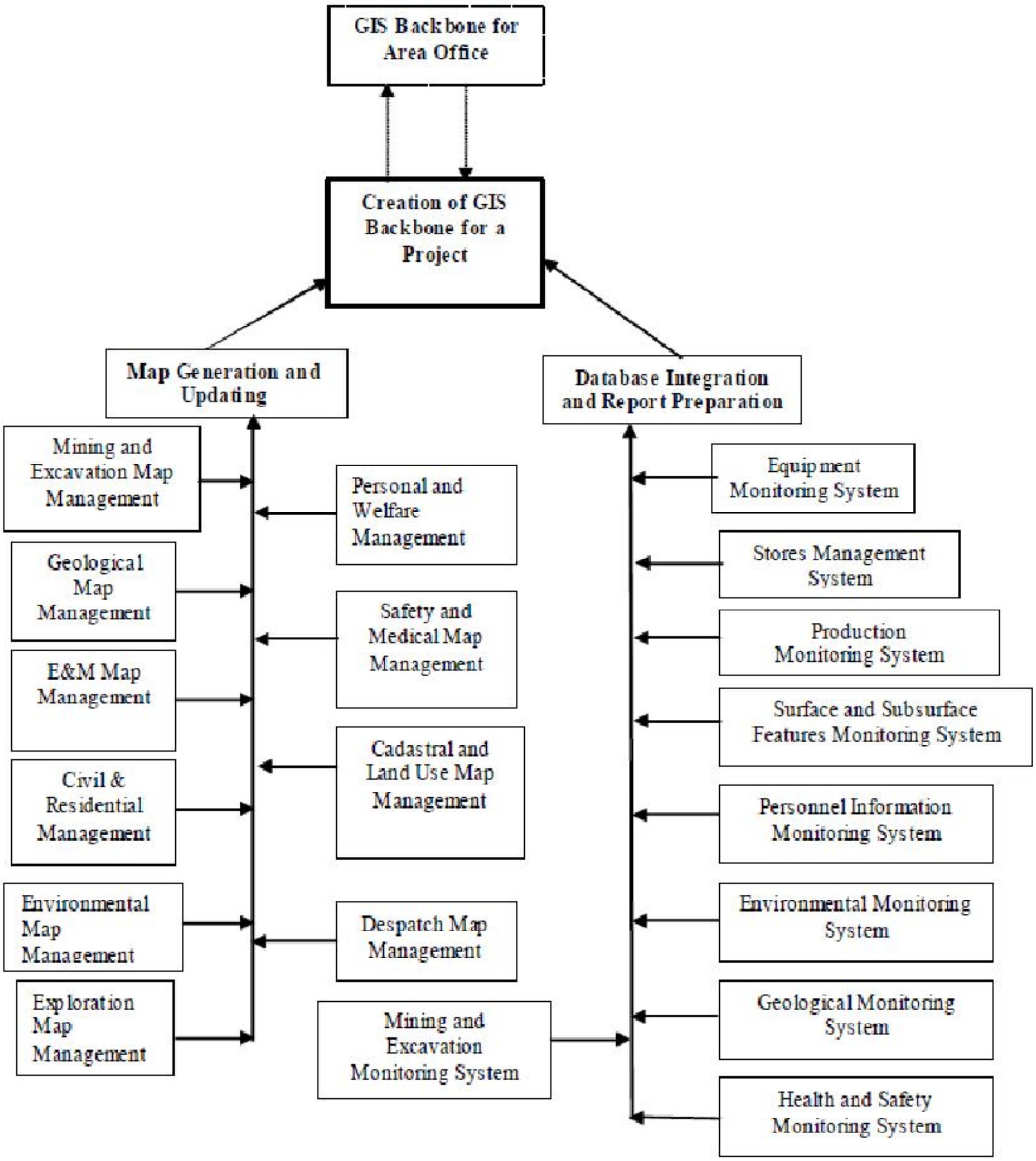
4.1 Information Flow Model:



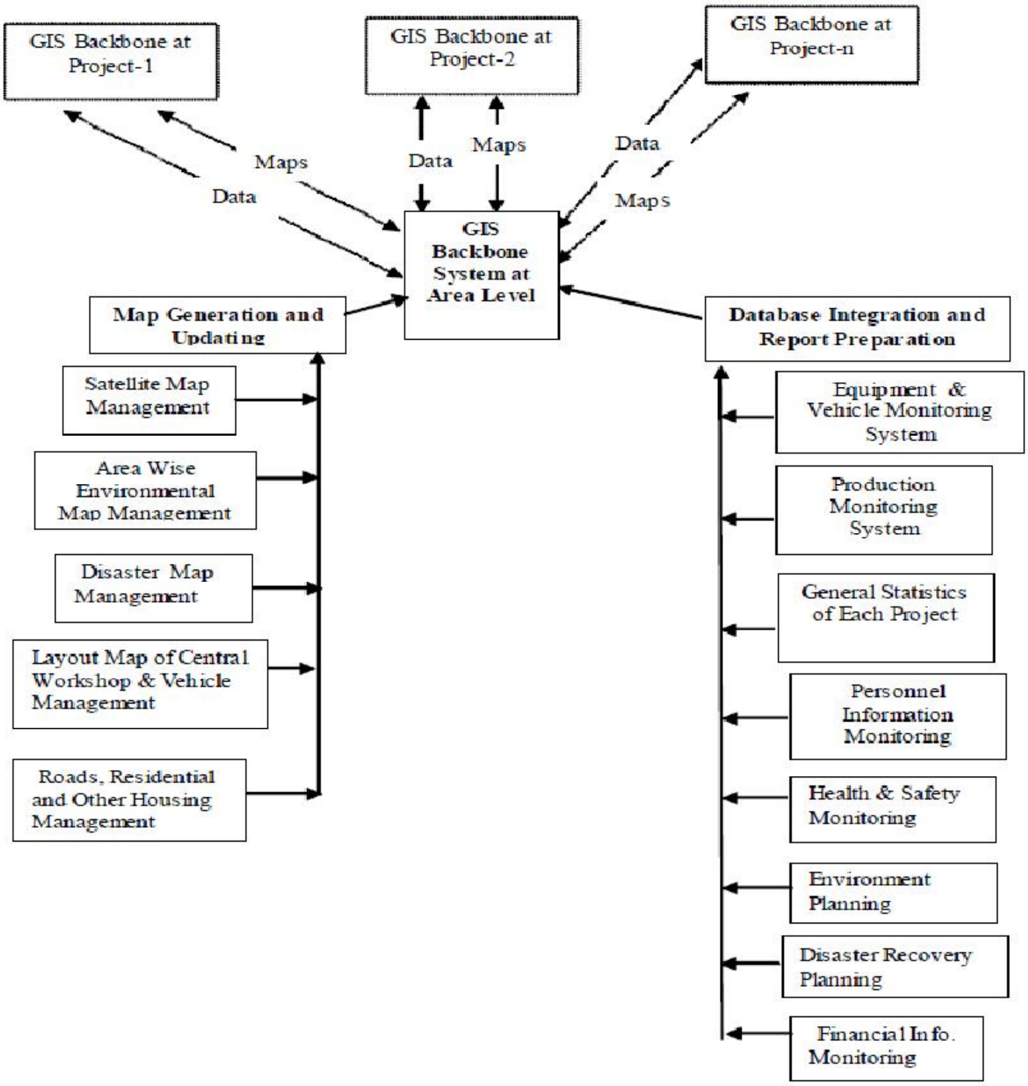
Each project office will be consolidating the maps and related information of day-to-day operation. The project office may continue with their existing system for such consolidation or may opt for implementing the appropriately customized version of computerized map updating and GIS data entry. Then, project office will send the computerized maps and data in a prescribed format to the respective area offices. At this stage cross validation can be made to eliminate any data reduplication.

Area office will then be generating queries, thematic maps and reports using newly developed GIS backbone system and will then forward the consolidated data to the company Headquarters, in the prescribed format, through established communication links. Headquarters will further generate queries, thematic maps and required reports using this system.

4.2 Application System Design at Project Level



4.3 Application System Design at Area level

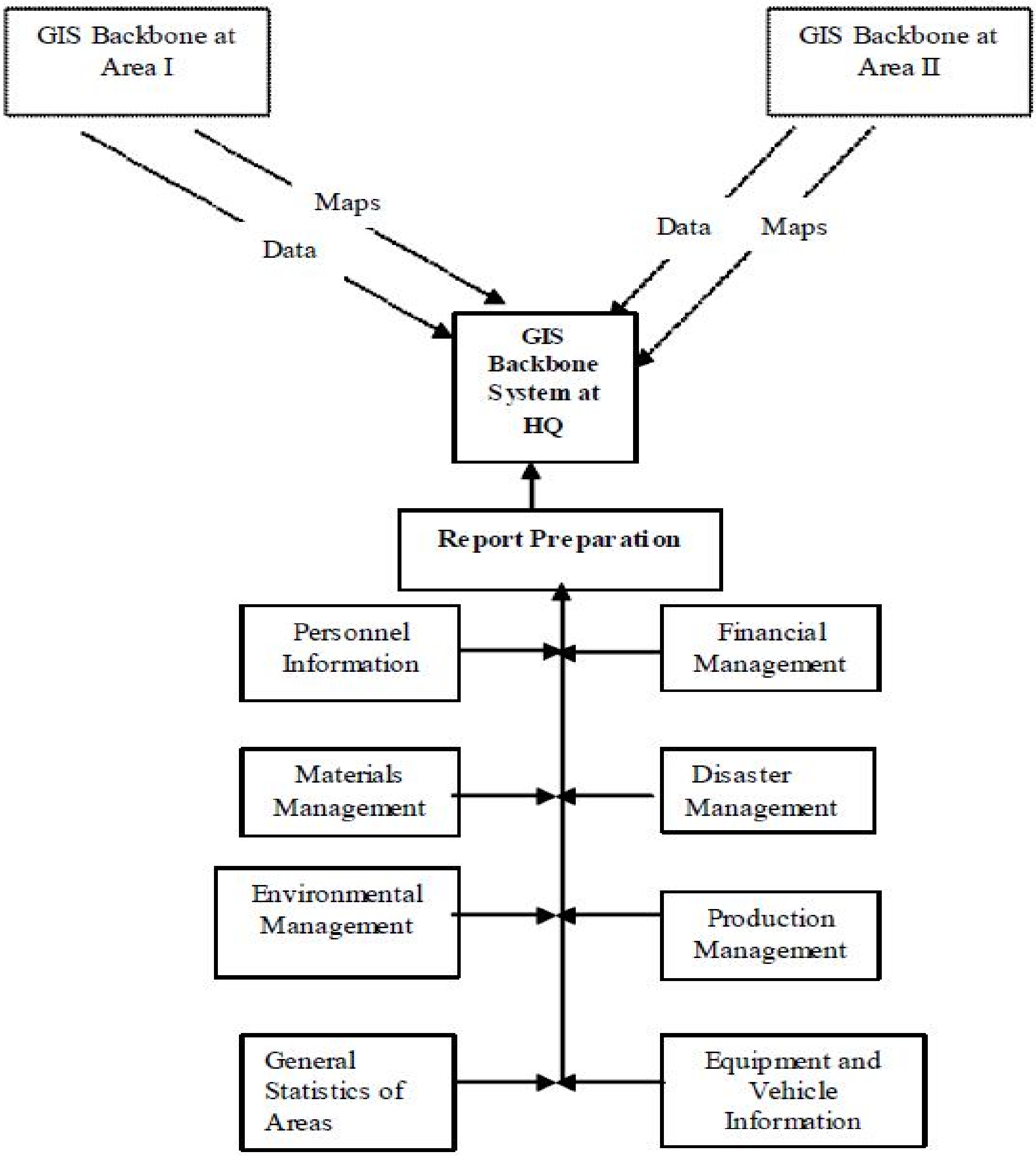


4.4 GIS Database and Softwares at the Area/Project Levels

We would develop and supply proper GIS engine, customized to meet the specific information need of the mining areas. Industry standard GIS, mapping and viewing software will be integrated with the solution to be developed and configured on desktops connected on a LAN. One desktop based GIS application systems will be developed and implemented at each area, at the area office.

The company will need no further investment on GIS software count. A fully featured remote sensing processing software will also be provided by us at each area for viewing and analyzing raw satellite image data.

4.5 Application System Design at the company Head Quarter



5. Implementation Strategy of the Proposed System

For the implementation of GIS backbone system for the company, a top down approach with *three phases* has been adopted. These three phases together will form the backbone of Geographic Information Infrastructure for *enhancing the quality and the effectiveness of managerial decision.*

Phase I: During this phase, an extensive GIS backbone will be created at the project and area level and integrated into a company GIS Backbone. This is the heart of the GIS system and will focus the development of an enterprise GIS system in a modular, flexible and scalable GIS backbone, which will encompass all maps and database in each project operated by the company.

During this phase, digitization of the entire range of maps and drawings depicting all spatial information e.g. maps such as cadastral, geological, land acquisition, mining, environmental etc will be carried out along with acquisition of all attribute data related to such surface and subsurface features. This will lead to standardization of computerized map generation, platform, technology and application across the project level.

At this level, every department starting from surveying, mining, excavation, E&M, environment and others will play an active role in sharing maps (paper/digital) and related data (paper/digital) to build a successful GIS backbone for that project. This will also pave the way for the development of customized front-end GIS solution for easy manipulation of mine maps and updating of relevant data. This integrated GIS backbone will be totally customizable, scaleable, smart and robust and completely user-friendly.

Phase II: During this phase, the GIS backbone will be connected on-line to the respected area offices and the company Headquarters. At this stage, all the projects under the jurisdiction of a particular area will be integrated into one system to share and interchange spatial and non-spatial information. The entire GIS backbone of the maps and databases will be made web-enabled to be able to be ported on a web server and connected in a closed group intra-net or Internet using TCP/IP protocol. Suitable telecommunication links through V-Sats will be installed by the company to activate this type of data sharing.

The area office can obtain real-time spatial information about any colliery. As for example, information regarding the current mine layout, land acquisition, production, washeries, CHP and others for any colliery will be available with map interface just by the click of a button. The CGMs and GMs will have greater flexibility to obtain spatial information with respective maps from any colliery and execute timely decision on any particular problem.

Phase III: In this phase GIS backbone system will be connected to the company head office. All the subsidiary companies will be linked either by the Internet or through intra-net to access real-time GIS information from any collieries and areas or subsidiary headquarters. Company Head Quarter will be able to access all maps and database related to every projects and area offices as mentioned in Phase I and II. The integrated GIS backbone system will be hosted on a remote server to access any maps in real-time and get information regarding day-to-day operation.

6. Conclusions

A grand, unified, GIS compatible, integrated, smart, digital platform for the underground coal mining company would definitely remove all data redundancy and duplication of efforts. The system will help all tiers of people right from the project to the head quarter in taking real time decisions and thus can do away with retention, distribution, preservation and deterioration of quality of cumbersome paper maps. So, a transparency among various departments and cross-checking facilities to improve spatial data accuracy and to reduce the scope of spatial data manipulation would prevail among various departments. The successful implementation of the system will enable management to have greater controls for day-today operation. This will help in having a quick and fast response to any accident with the power of GIS and thus enhancing security mechanism of the company. Moreover, this integrated and holistic system will bring more uniformity among all collieries within the Company to have a „better‟ management in reducing delays, man-hours and thus improving productivity.

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