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GIS BASED PROJECTS INFORMATION SYSTEM FOR CONSTRUCTION MANAGEMENT

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ABSTRACT

This paper explores the potential of geographic information system environment in developing a construction project information system for rate analysis, safety and quality control recommendations for different activities. Geographic Information Systems (GIS) is a relatively new branch of information technology for managing the spatial and non-spatial data and can effectively be used to develop a database related to construction resource and safety and quality control recommendations for possible construction activities. ArcView 3.2, which stores all data sets in tabular format, is used in present study. Resource data for materials, labours, equipments, recommendations for safety and quality control are stored in the different tables and separate tables are used for each construction project for rate analysis. Scripts using *avenue* language are added to the GIS software enabling the planner to access and manipulate the available database, which finally helps in speeding up the decision making process. This paper suggests that the proposed GIS based methodology may replace the manual methods to extract the information from the available database and can easily be updated as most of the information is in digital format.

Keywords: geographical information system, rate analysis, quality control, safety

1. INTRODUCTION

People involved in the construction industry believe that saving in time and money can be achieved in actual construction rather than applying any structural procedure for construction project management such as cost estimation, planning, scheduling and control. Further, success or failure of a building contract largely depends on the quality and timing of the information available to the contractors from the database. Thus, requiring a proper information system to manage the construction projects. Use of a computer based information system may help in reducing the redundancy as well as saving time and cost. [1] suggested that an information system designed for construction industry should be capable of integrating various types of data and provide the required information and data timely that

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will finally support various decision and operation.

Construction industry is considered to be one of the most hazardous occupations and ranked low in the safety standards. Construction safety is one of great concern for construction industry. Failure of managing construction safety may results in injuries, financial loss, human conflicts, and penalties. Thus, construction industry needs a tool that may help them to actively integrate safety and health measure into project planning. Therefore the need of development of a database, that solicits project specific-data from the user and provides, as output, applicable safety and quality control recommendations [2].

Complex and vast amount of information available for a construction project requires a coordinated system that may help in integrating whole information together. With the advances in the field of information technologies, construction industry has started taking the advantages of some of these developments. GIS is a relatively new branch of such technologies for managing the spatial and non-spatial data. Database is the essential part of any information system employed for construction management so the usefulness of geographical information system need to be explored [3].

GIS not only speed up the modelling process and data extraction from the various resources but ensures data integraty and accuracy also. GIS form an effictive foundation for planning construction activities. The MaterialPlan [4], a GIS based tool to replace the manual methods in quantity takeoffs and assessing materials layout design is one such example. The system incorporates rules of thumb and experience for sizing material storage areas and placement of the material. MaterialPlan proves that GIS is a promissing tool for solving quantity takeoffs and materials layout problems and opens a new way of thinking in the management of spatial information for construction planning and design using a GIS [4].

The aim of the present study is to assess the feasibility and the potential of GIS to develop an easy-to–use construction project information system for contractors. A methodology is developed to design an information system for safety, quality control, man, and material requirement in GIS environment. Proposed GIS based approach may help the planner to access and manipulate the available database, which finally helps in the decision making process and may replace the manual methods to extract the information from the available database for construction industry.

2. RESEARCH OBJECTIVE

The primary objective of the paper is to test the feasibility of using GIS for rate analysis and effectively integrating various types of the data used in the construction in GIS environment.

The following sub objectives were also achieved in developing this system: (1) Development of the construction database in GIS environment, (2) Use of GIS functionality to replace the manual methods to extract the information from the available database and (3) Integrate safety and quality control recommendations with various construction activities.

The objectives are accomplished mainly through the development of a database, that stores various types of information required for construction project. The required information can than be extracted form the database for a given activity of project by using *avenue* scripts written for different purposes.

3. GIS AS MODELLING TOOL

GIS is a computer system for capturing, storing, quarrying, analysing, and displaying geographic data. GIS is a special class of information system, which can be divided into four components involving a computer system, GIS software, human expert, and the data [5]. GIS activity can be grouped into spatial data input, attribute data management, data display, data exploration, data analysis, and GIS modelling [6]. GIS can handle both spatial and attribute data, spatial data relate to the geometry of the features, while attribute data describes the characteristics of the different features and stored in the tabular form. Each row of the table represents a feature while column represents the characteristic of features. The intersection of a column and a row show the value of particular characteristics of a feature. In the georelational data model, split data system is used to store spatial and attribute data in separate files and linked together by the feature *identification descriptor* (ID). These two sets of data files are synchronized so that both can be quarried, analysed, and displayed [7].

By using the data management feature of GIS, a prototype construction project information system (CPIS) was developed in ArcViewGIS 3.2 [8] using a sample data set. *Avenue* (scripting language for ArcView 3.2) was used to write different scripts for this system. Few basic features of ArcView GIS such as JOIN and LINK were also used to develop the proposed model of construction project information system.

3.1 Resources Database

Designing a Construction Project Information System (CPIS) in GIS environment involve in creating different tables to store the sample data. Storing, maintaining, and updating sample resources database are at the core of proposed prototype CPIS. Separate tables are used to store the informations about labour, material, equipment requirements, safety, and quality control recommendations. Additional information can be incorporated in all tables of the database to ensure expansion and update the system at later stages. This option is designed in a way that only selected users such as the owner or the system developer may use it. Following tables are created in the design of proposed CPIS:

Material: This table is designed to contain ten fields: *key; list of activities; cement; sand; course aggregate; lime; impervious material; steel; stone; and bricks*. Number of fields in the table can be extended as per the requirement of the contractor. A *key* is the common field in all data tables. The field *key* is used to establish the connection between the corresponding records of different tables. Field *list of the activities* contains different possible activities. Each row (record) contains amount of material required for an activity in the corresponding fields (column). Quantities are entered for 10 work units (in m^3or m^2 or m) in order to avoid fraction.

Labour: This table also contain ten fields: *key, list of activities, mason, helper, T&P, blacksmith, carpenter, waterman, scaffolding, and shuttering.* Each row contains number of different class of workers required for an activity in the corresponding fields. Numbers of workers are again entered for 10 work units in order to avoid fraction.

Equipment: Key, activity, equipment, and rate are the four fields available in this table, rates are entered for 10 work units in order to avoid fraction.

Safety: The safety table contain only two fields: key, and safety recommendation.

Quality: The quality table contain the two fields: key, and quality control recommendation.

Project: Figure 1 shows *project* table contains five fields: *key, duration, EST, EFT, and amount*. Field *duration* provides the information about the activity duration for the particular project. Fields *EST* and *EFT* contain earliest start and earliest finish time of activities, both field are drawn form any standard project management software. Field *amount* contain the amount of the work involved in different activities of the project. Separate *project* tables are used for each construction project for rate analysis. Planner has to fill all entries of *key* field as they are in database table. All tables storing different type of information can later be extended to include more information as per the project requirements.

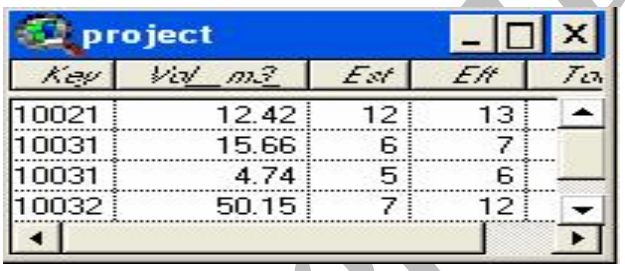

Figure 1. Project table used for rate analysis

4. PROPOSED GIS BASED INFORMATION SYSTEM

An information system is a set of the interrelated data parts operating together to provide appropriate feedback to the decision maker in a way that entire information is available on time and when needed. The information needs of the contractor include detail of activities to be carried out, from which the types and quantities of the manpower and the amount of materials can be obtained [9].

In a GIS based information system, all resource data are available in tabular form. The tables used in the proposed model are shown in the Figure 2. Each project in the proposed CPIS is presented in a separate table to define the activities and corresponding keys for the rate analysis purpose.

4.1 Relationship and Database

Three types of relationships i.e. *one-to-one*, *one-to-many*, and *many-to-one* (Figure 3) are used in this work. To explain the relationships, source (from) and destination (to) tables need to be defined. For example, if the purpose is to add data from database table to the project table, then project table will be destination table while the database table will act as a source table. The *one-to-one* relationship means that one and only one record in the destination table is related to one and only one record in the source table. The *one-to-many* relationship means that one record in the destination table may be related to more then one

record in the source table, while in *many-to-one* relationship, two or more records in the destination table may be related to one record in source table (Chang, 2002).

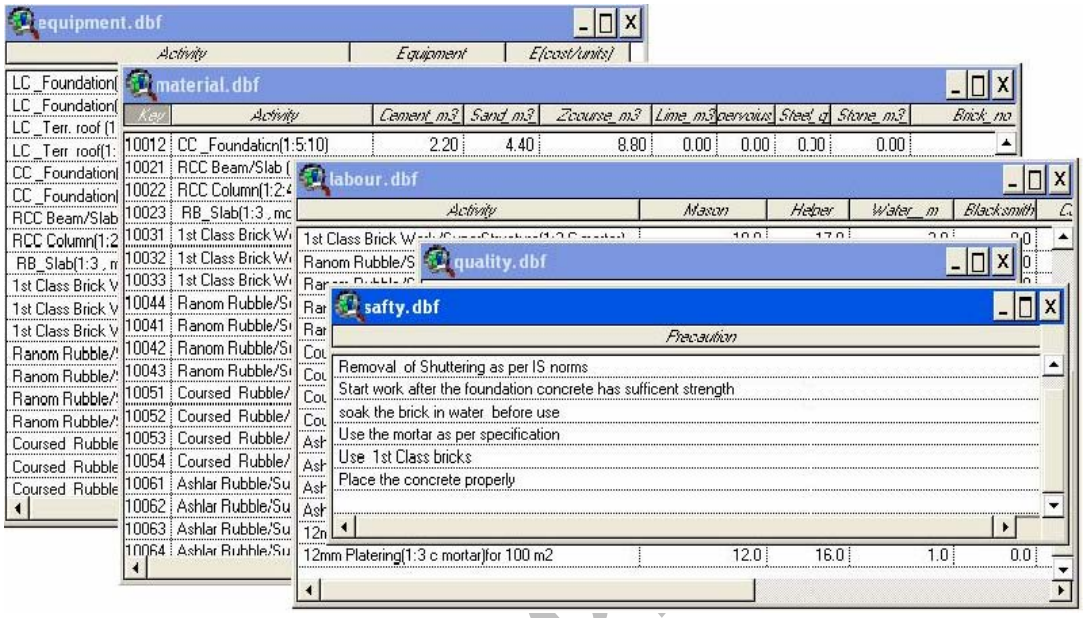

Figure 2. Resource database developed in Arc View

ArcView's JOIN function establishes a *one-to-one* or *many-to-one* relationship between the destination table (the active table) and the source table. Two tables are joined on the basis of a field called *key,* available in both tables. The data type of field *key* has to be same in both tables being joined. The contents of the destination table reflect the changes by including the joined attributes from the source table. ArcView's LINK function establishes a *one-to-many* relationship between the destination table (the active table) and the source table. Unlike joining tables, LINK function of ArcView defines a relationship between source and the destination tables without changing any of the input tables. After a Link is established, selecting a record in the destination table will automatically select the record or records related to it in the source table.

4.2 System Functions and Usage

According to the capabilities of software and the information needed by the users for rate analysis, the functions of the present system are enhanced. Based upon the assessment of the user's needs, the requirements are translated into system functions with the help of *avenue* programming language used within ArcView 3.2. Five functions for *material, labour, equipment, safety and quality* are developed and used in present CPIS. Working of different functions is discusses below.

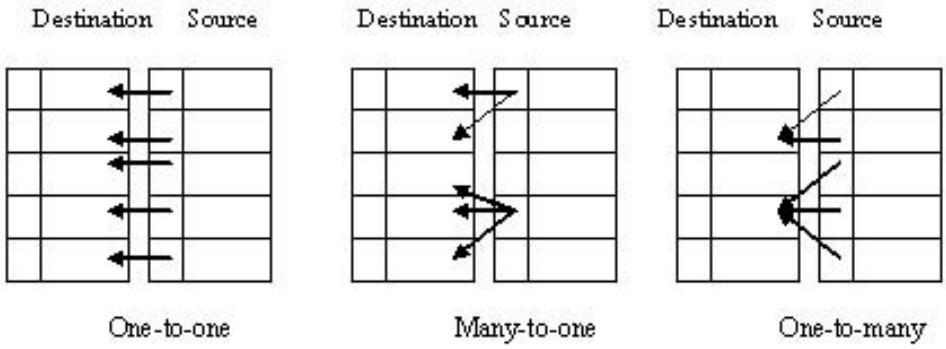

Figure 3. Three types of relationship used between tables (adapted from [7])

4.2.1 Material

If the project table is the active table, this function extract the records of material required from source table (*material* table) for each activity of project, and add it to corresponding rows of destination table (*project* table). The contents of the *project* table changes to include attribute from the database table. While the database table remain unchanged. Tables are joined basis if a field called *key,* which is available in both tables. This function then displays an input dialog box to specify the field in the *project* table containing the volume of work for different activities in the project, while another dialog box allows to input the rate of the different material. Another field *total* is added to the *project* table, if it is not already present. Fields of *project* table containing the amount of various types of material are multiplied with their corresponding rates and added. The resultant values are entered into the field *total*. The field *total* is then multiplied by field *volume* and finally all entries are divided by a factor of 10. After processing, this functionality shows the total cost of the material for the project through the information box. The field *total* contain the cost of the material for a particular activity. A self-explanatory flow diagram of GIS–based material rate analysis process is given in Figure 4 while Figure 5 provide the working of proposed CPIS in ArcView environment.

4.2.2 Labour

This function extract the records of labour required from *labour* table for each activity of project and add it to corresponding rows of the *project* table. The content of the *project* table reflects these changes by including attribute from the database table, while the database table remains unchanged. This function then displays an input dialog box to specify the field in the project table that contain the volume of work for different activities in the project and another input dialog box to enter the rate of the different class of workers. After processing, this functionality shows the total cost of the labour for the project. GIS–based labour cost estimate process will exactly be as shown in Figure 4.

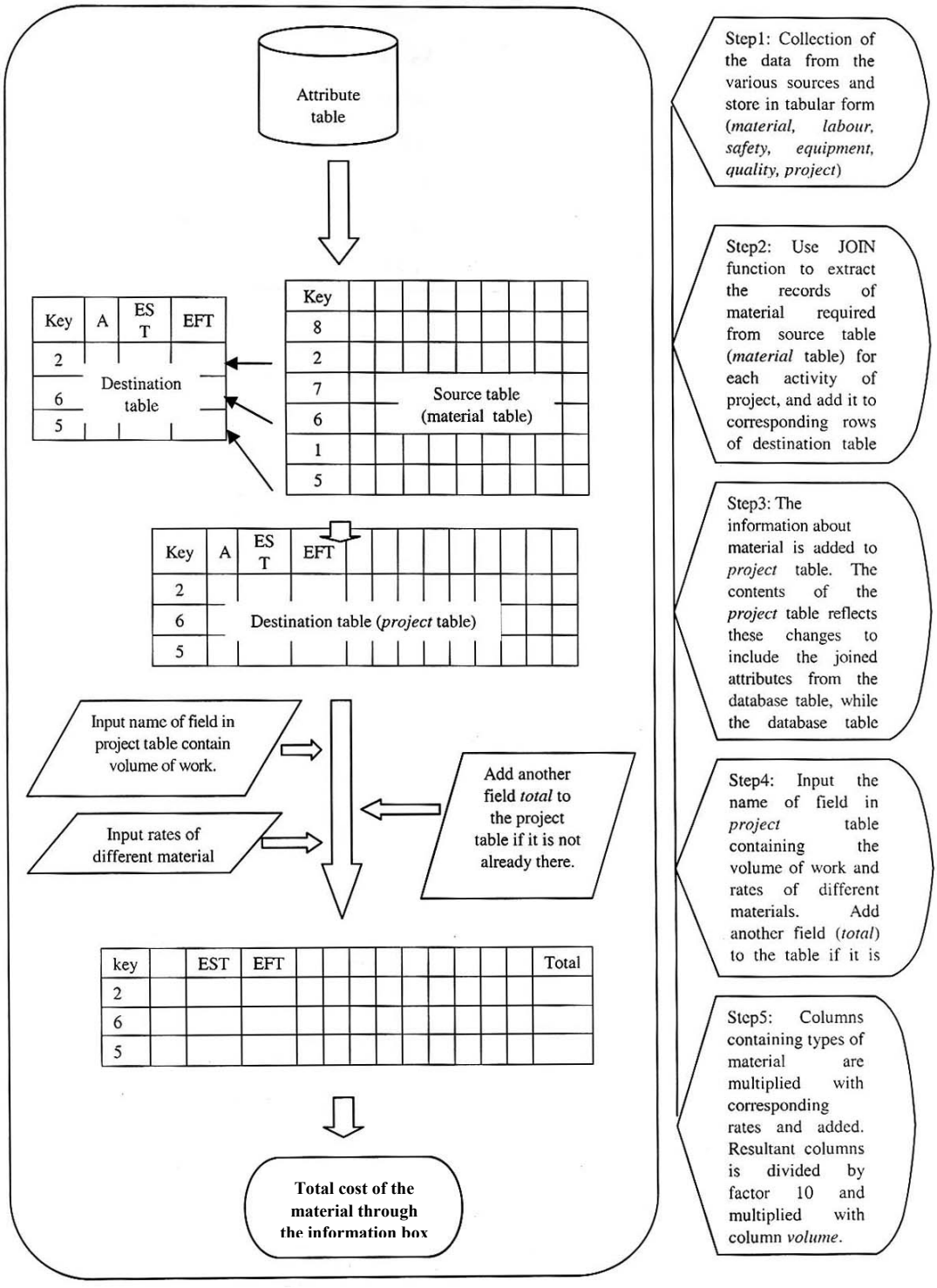

Figure 4. GIS–based material cost estimate process

Figure 5. GIS-based material rate analysis by proposed CPIS in ArcView environment

4.2.3 Equipments

Similar to earlier functions, if the *project* table is the active table, this function extract the records of equipment to be used from *equipment* table for each activity of project and add it to corresponding rows of *project* table. An input dialog box is displayed to specify the field in the *project* table that contains the volume of work for different activities of the project. Another input dialog box is also displayed so as to enter the rate of the different equipments running cost. After processing, this functionality shows the total cost of equipments.

4.2.4 Safety and Quality

Unlike joining tables in above functions, *safety* and *quality* functions uses linking facility of ArcView to define a relationship between two tables rather than appending the fields of the source table to those in the destination table. When tables are linked to one another, both input tables remain unchanged. After a *safety* function is performed, selecting a record in the destination table (*project* table) will automatically select the record or records related to it in the source table (*safety* table). Selecting a record in the *safety* table does not select the corresponding record in the *project* table. This is because the link only exists in the destination table (Figure 6). So to access the safety information about any activity from the database, the user only needs to click on activity row in the *project* table.

Quality function performs in a similar way as the safety function and provides information about the quality control recommendations.

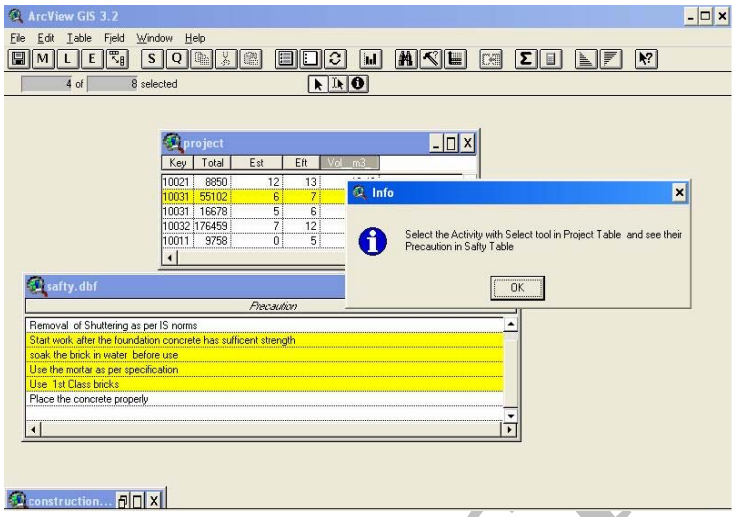

Figure 6. Safety information highlighted for the project activity

4.3 Schedule of Construction Activities

Schedule is the work programme or the timetable for the actions to be taken during implementation of a construction project. Bar chart method is one of the popular methods used by the contractors for scheduling. In a bar chart method, construction work is first split into different activities. These activities are then listed in order of construction priorities on the left hand side column, while the time scale is plotted horizontally on the bottom. ArcView GIS can also be used for generating bar charts using its in-built chart document. Figure 7 shows the ArcView's chart document, utilised to show the schedule of the construction activities. The main advantage of the ArcView's chart document over conventional bar chart is that when a bar on bar chart in ArcView is clicked, a window appears which provide the information related to that particular activity.

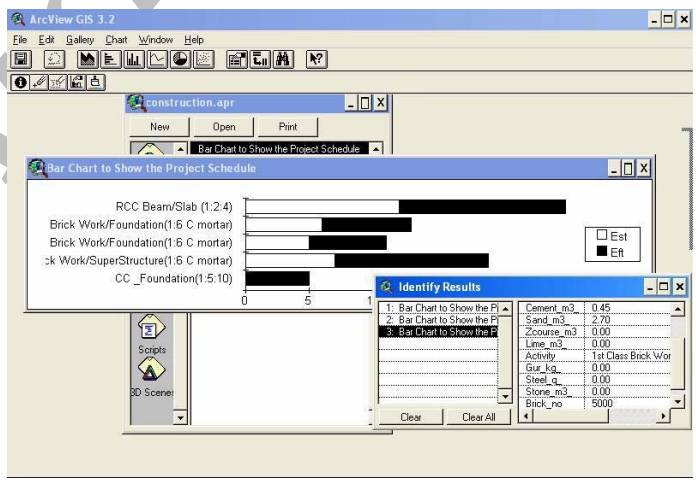

Figure 7. Schedule of activities in Arc View's chart document

5. CONCLUSIONS

This paper demonstrates the utility of GIS system in developing an information system that supports the rate analysis of a sample construction project. This is a system for information analysis, manipulation, storage, and retrieval of non-spatial construction project data. This information system is designed so as to incorporate the information about the safety and the scheduling in the form of bar charts. If the data is in digital form, it can be easily be updated, and enhance the procedures of rate analysis. The proposed methodology strongly promotes the concept of automated acquisition and storage of data in GIS environment to support construction project management.

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