MANAGEMENT INFORMATION SYSTEMS FOR CONTRACTORS

by

A. A. D. A. J. Perera

ABSTRACT
For successful management proper information related to cost, time and quality are vital to contractors. The construction activities are related to material, plant, labour and subcontractors. Therefore at any given time the position of the project with respect to profit achieved, progress achieved and many other important factors is almost impossible to determine using current methods. The management information systems provide the information required by construction managers for effective management of construction activities. The implementation of management information systems in contractor organisations is an ongoing activity even in the developed countries. Surveys conducted on the use of computers by contractors in Sri Lanka revealed that the uses are limited to word processing, spreadsheets for estimating activities and planning work. However, within the last five years production of drawings by consultants has changed from manual systems to computer aided drafting systems, mainly using AutoCAD drafting software. Therefore trends can be seen in the construction industry in the use of computers for more and more activities.

The research work presented in this paper was undertaken to introduce management information to contractors related to cost and progress of projects. The objectives of the research were to develop a method to capture site information, to identify construction managers’ information requirements and to automate routine reports such as labour payment schedules, calling for quotations, purchase orders, monthly bills, measurement sheets and plant payments.

Firstly, an analysis of data related to construction activities was carried out and data were structured using data modelling techniques. Secondly, the procedures involved in various data flows within a contractor’s organization were identified and analysed using system theories. Thirdly, a system was developed using Microsoft Access2000 software and results were demonstrated to potential users. Finally, the outputs were reviewed with surveys conducted among the professionals of the industry. It was concluded that the developed management information system could provide the information that the construction managers were dreaming to gather for a long time.

1. INTRODUCTION
Income and expenditure of a construction project are interconnected to many activities such as material purchases, labour payments, plant hire payments and income from interim bills. Construction activities are estimated based on Bills of Quantities. Therefore it is important to compare the expenditure and income of construction activities based on Bills of Quantities. However, this is a near impossible task unless a computer based system is used. Further, managers at different levels demand expenditure and income summaries of projects on different formats. These are long felt needs of construction managers not only in Sri Lanka but in other countries as well.

In the past many attempts have been recorded to capture site information related to material, labour, plant etc. (Komori 1990). Further, many have given details of various aspects of development of Management Information Systems for the construction industry (Abdulayyeh 1997, Norton 1995, Shash & Al-Mir 1997, Marsh and Finch 1998, Oxman 1995). In the recent past several attempts have been made to collect information related labour and material by use of bar-code methods (March & Finch 1998, Ahmand et al. 1995, Finch et.al.1995).

Pemasiri(2000) has conducted a survey of the use of information technology in the construction industry of Sri Lanka. General systems such as word-processing and spreadsheets are dominating the construction industry while computer-aided design and drafting are the next popular categories. There is no record of the use of computers for stock control,
order processing and plant management. Chandrasinghe (1994) had reported the development of management information systems while keeping the key conventional controls. Vijayananda (1995) has investigated the details of management information systems for Grade I (now M1) contractors. It is clear that integrated management information systems connecting material purchasing, plant management, labour management and providing necessary cost information of construction activities of a construction project are yet to be developed in the local construction industry.

2. OBJECTIVES

The main objective of this research project was to develop and test a management information system for contractors related to the cost estimate and to the expenditure of construction projects. The sub-objectives were:

1. To identify the information needs of contractors for the successful management of construction projects.

2. To analyse the information related to construction projects.

3. To design methods to capture site cost information.

4. To design and implement a management information system to contractors for the identified needs.

3. MANAGEMENT INFORMATION SYSTEMS

Management information systems share a common life-cycle pattern. After a system has been in operation for some time, it will start to decay gradually and become less and less effective, because of the changes in its environment, to which it has been forced to adapt. It is, at first, possible to overcome the problems, which arise by minor modifications to the system, but it eventually becomes necessary to face the need for fundamental changes. From this stage problems of the existing system and the requirements for a new system need to be established. Once these requirements have been adequately identified, a new system can be designed and implemented. For example, many contractors prepare final accounts for projects to assess the profitability of the project. However, a good construction manager wants to know the profitability of the project at any given time. The present manual systems cannot meet this demand and this requires the implementation of computer-based cost control systems. However, the computer-based cost control system too will be subjected to further changes.

The new system will in its turn operate for a time before it too grows obsolete, so that the cycle begins once again. Fig. 1 illustrates this cycle of activity. However, at any stage in the cycle, there will be a system in operation, which is subject to repeated modification, review and maintenance, by either the system operators or specialist staff.

![Life Cycle of a Management Information System](image-url)

Figure - 1 : Life Cycle of a Management Information System

103
Development of a management information system can be identified in three major steps (Rajaraman, 2000). They are:

1. System requirements; i.e. identification of outputs and inputs;
2. System design; and
3. System development and implementation.

4. SYSTEM REQUIREMENTS

Several studies have been carried out to identify the requirements of management information systems for contractors in Sri Lanka (Beligaswatte et al. 1997, Chandrasinghe 1994 and Vijananda 1995). Beligaswatte et al (1997) have given the requirements of construction organisations with special emphasis on large road construction work. Vijananda (1995) has given the requirements of large building contractors and Chandrasinghe (1994) has given the requirements of the Engineering Division of Sri Lanka Army. Based on these studies the following can be derived as the requirements of a management information system for contractors in Sri Lanka.

1. Automation of the material purchasing process. For this purpose records of suppliers should be maintained. Quotation calling, placing purchase orders and payments for materials should be automated.

2. Capturing of cost data of construction activities based on BOQ items. Reports should be produced showing the expenditure and estimated costs and variations. The reports should be produced in detail form; i.e. material, labour, plant and subcontract costs for the site personnel and in summarised form on item basis for senior managers.

3. Automation of production of monthly bills. This should incorporate the production of measurement sheets.


5. Automation of payment process to subcontractors.

5. SYSTEM DESIGN

System design has two major steps (Rajaraman 2000, O’Brien 1988). They are:

1. Development of a data model diagram based on data analysis;
2. Data flow diagram; and

5.1 Data Model Diagram

Data analysis is an important part of the development of an information system. Poor analysis of data will result in a low performance information system or will produce errors in the final outputs. Data analysis can be defined as “a method used to understand, analyse and document a complex environment in terms of its data resources”.

The emphasis during data analysis is to analyse the pure state of the data, rather than the organizational functions. The tasks within Data Analysis are to identify entities and data across “applications” and identify shared data, both between systems and within systems. The results of data analysis are summarized in a diagram known as data model diagram. Detailed results are documented on specially designed formats or (preferably) by definitions entered into a computerized data dictionary. A database is defined as “a unified collection of data that is to be shared by all authorized personnel in an enterprise” (Rajaraman 2000, O’Brien 1988).

Identification of Entities and Relationships is an essential part of data analysis. An entity is defined as being a thing that is of interest to the enterprise while a relationship is an association, or connection, between two or more entities. An attribute is a property of an entity. The attribute used to identify an entity occurrence is termed as the entity key (in Access 2000 this is called a primary key). The final stage of data analysis is the normalization of data. The normalization is the proper identification of file structure. For this, one could use first normalization to fifth normalization. Almost all the Management Information Systems development environments including Access 2000 require data to be normalized. Part of the Data model diagram (for material management) of the proposed management information system is shown in Fig.2.
5.2 Data Flow Diagrams

The data flow diagram (DFD) was introduced by DeMarco (1978) and Gane & Sarson (1979), and is an important tool used for information system development. DFD models a system using entities, data flows to a process, transforms the data and creates output data flows which go to another process or other entities. The main advantage of DFD is that it can provide an overview of what data a system would process, what transformations of data are done, what files are used, and where the results would flow (Rajaruman 2000).

Four symbols are used in drawing data flow diagrams. First, a circle is used to depict a process. Both inputs and outputs to a process are data flows. The process is numbered and given a name (Fig. 5). Secondly, data flows are represented by a line with an arrow. The arrow shows the direction of flow of data. The name of the data appears next to the line (Fig. 5). Thirdly, external entities of the system are represented by rectangles. These external entities either supply or consume data. Entities supplying data are known as sources and those that consume are called sinks. A data store or file stores data. The process may store or retrieve data from a file. Fourthly, a file is represented by a thin slant line. The direction of the arrow on the line indicates the flow of data to the file.

As the first step, an entire system can be depicted by one data flow diagram, which gives a system overview. It is called a context diagram (Fig. 3). Details of a few selected data flow diagrams of the management system are shown in Fig. 4 and Fig. 6.
Figure - 4: Expanded Material Acquisition System

Figure - 5: Logical Diagram for Plant Cost Calculation
5.3 Process Specifications

There are requirements to be met by a system. For example, in a site information system there can be a condition related to the plant rate or cost such as "minimum usage per week is 8 hours and if usage is more than 20 hours per week a 10% discount is available". This situation can cause a lot of difficulties unless identified and arrested. Two main techniques are used to express these computational procedures. They are:

(i) Structured English; and

(ii) Decision Tables.

Structured English is a technique used to express verbal statements in a more logical framework. Decision Tables are appropriate when a large number of conditions are to be checked in arriving at a set of actions. The above example with respect to plant can be written in Structured English as given below.

IF Plant usage is less than 8 Hours per week
    Then
    Cost of plant = 8*Rate
    Else
    IF Plant usage is more than 20 Hours
        Then
        Cost of Plant = Usage Hours *0.9 * Rate
        Else
        Cost of Plant = Usage Hours * Rate
    End if

Generally, Structured English is a computer program language oriented and Decision Tables technique is not. Decision Table for plant example is given below.

<table>
<thead>
<tr>
<th>Condition</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 8 Hours</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>More than 8 Hours and less than 20 Hours</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>More than 20 Hours</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Action: Give 10% discount</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Action: No discount</td>
<td>X</td>
<td>X</td>
<td>-</td>
</tr>
</tbody>
</table>

Rule 1 If Plant usage per week is more than 20 Hours then give 10% discount
    Plant Cost = 0.9*Rate*Usage Hours

Rule 2 If Plant usage per week is less than 8 Hours then
    Plant Cost = 8*Rate

Rule 3 IF Plant usage per week is less than 20 Hours
    and more than or equal to 8 Hours
    Plant Cost = Usage Hours*Rate

The methodology used in Structured English description is similar to that used in block structured computer languages such as Visual Basic or Pascal. The following conventions are used in writing Structured English process descriptions.
(a) Imperative Sentences
This consists of an imperative verb followed by operations to be performed on variables.
Example: Multiply Plant Rate by discount amount

(b) Arithmetic and relational operations
Common symbols used in arithmetic are used in Structured English descriptions. Symbols used for arithmetic are:
+ add; - subtract; * multiply; and / divide.
Symbols used in relations are:
= equal to; > greater than; < less than; ≠ not equal to; ≥ greater than or equal;
≤ less than or equal
Symbols used for logical operations are;
And, or, Not
Symbols used as keywords are:
If; Then; Else; Repeat; Until; while; Search; Retrieve;
Do; Case; For; Of; End

5.4 Decision Structures
There are two types of decision structures used in Structured English statements. First type is "if then else" structure which is used to make a choice between two alternatives (Fig 6).
The second type of structure is to choose one out of a set of alternatives. Here a case keyword is used (Fig. 7).

6. DATA INPUT METHODS
The data, which is the input to a computer based information system, must be correct. If entering of data is not correctly done errors will enter into the system leading to incorrect results. Therefore it is important to design to prevent data input errors. Data input can be on-line or off-line. On-line data input will enter collected data through paper forms and the data entry operator enters data to the computer. On-line data input demands more computers while off-line will be less. For the construction industry, off-line data input is more appropriate since it is difficult to provide computers to construction sites. The following should be observed in input form design.

i. Leave enough space for writing legibly the required information.

ii. Give clear instructions to fill the forms.

iii. Use standard format to collect data. For example the format shown in Fig. 8 can be used to collect the data.

iv. Arrange entries in such a way that data entry operator can enter data by reading a form from top to bottom and left to right without missing out any data.

![Figure - 7: Material Estimate Data Entry](image-url)
Under this research project the following forms were designed to capture site information:

1. Daily labour usage form;
2. Daily material usage form (Fig.9 and Fig.10);
3. Daily plant usage form;
4. Daily work completed from;
5. Cumulative work completed form;
6. Daily subcontractor assignment form; and
7. Daily labour record form.

Therefore outputs were designed to give the following information and details:

1. To call quotations from suppliers.
2. To provide comparison of estimated cost and expenditure of material, plant and subcontractors (Fig.10)
3. To provide cost comparison based on BOQ items for senior managers.
4. To produce monthly bills and measurement sheets.
5. To provide a schedule of labour payments.

7. DESIGNING OUTPUT

Presenting the data processed by a computer-based information system in an attractive and usable form is very important. Very often the success and acceptance of a system depends on good output presentation. The following questions help to design good outputs.

i. Who will use the report?
ii. What is the proposed use of the report?
iii. What is the volume of the output?
iv. How often is the output needed?

8. SOFTWARE DEVELOPMENT

The computer programs were developed using Microsoft Access2000 and VBA (Visual Basic For Applications) provided in Access 2000. Firstly, tables (or files) were created for the Data Model diagrams (Fig.2). A total of 26 tables (files) were created for the entities such as BOQ, materials, labour, etc. A total of 22 tables were created for the relationships. In addition to data model diagrams, the data normalisation rules were used to design the tables. Secondly, computer screens (Forms of Access2000) were created to enter the input data (Fig.10 and
Fig. 11. A total of 22 screens were developed. Care was taken to minimise the errors in data entering. The form for data entry of material usage is shown in Fig. 10. Thirdly, query techniques were used to generate the outputs required. Finally, the report facility of Access2000 was used to produce the outputs required (Fig. 10). A total of 20 reports were developed.

Access2000 has the security facility where each user can be provided with an access name and a password. Each user can be provided with different levels of access to the system. For example, data entry operators will have access to enter data only while a manager can be provided with full access.

![Daily Material Usage Form](image)

**Figure - 9 : Daily Material Usage Form**

<table>
<thead>
<tr>
<th>BOQ Reference</th>
<th>Estimated Cost</th>
<th>Actual Cost</th>
<th>Cost Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick : common</td>
<td>39,468.00</td>
<td>35,673.00</td>
<td>3,795.00</td>
</tr>
<tr>
<td>Cement</td>
<td>15,778.95</td>
<td>15,789.90</td>
<td>-10.95</td>
</tr>
<tr>
<td>Send</td>
<td>4,295.25</td>
<td>4,295.25</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>59,542.20</strong></td>
<td><strong>55,758.15</strong></td>
<td><strong>3,758.05</strong></td>
</tr>
</tbody>
</table>

**Figure - 10 : Material Cost Comparison Report**
9. CONCLUSIONS

The system was demonstrated to more than 10 professionals and comments were obtained. Many agreed that the developed system provides the necessary information for better management of construction sites. The system was implemented in a contractor organisation and is being studied further for its applicability.

10. REFERENCES


