INTELLIGENT CONSTRUCTION PLANT INFORMATION MANAGEMENT

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Construction plant information management has progressed rapidly since the inception of paper based and electronic documentation formats. Collated plant management data (e.g. inventories, maintenance costs etc.) assists plant managers monitor plant performance and overall project economics. Traditionally, data are stored on paper based and/or electronic databases or local networks/intranets and maintained centrally within the organization. Pilot studies have revealed that this approach is often preferred even though hardware requirements are massive and accessibility to the system is usually also limited. The Internet, on the other hand, is a relatively new worldwide phenomenon that is rapidly enhancing information management. Information is near instantaneous whilst its open architecture facilitates appropriate user access throughout the company hierarchal structure. Based on this potential, the development of an intelligent web-based construction plant information management system is proposed.

This system incorporates models and algorithms that automate the analyses of plant history data. In this paper, particular emphasis is paid to the analysis of plant maintenance cost prediction. The generic approach adopted for this embryonic work is presented to act as a catalyst for wider debate.

Keywords: construction plant, information management, internet, intelligent models

INTRODUCTION

From the advent of civilization, man has sought to modify the natural environment in order to improve society's living conditions (Carroll, 2000). The Industrial Revolution further exacerbated the rate of change and moreover, witnessed the widespread development of major civil engineering and construction projects. As a result, machines were increasingly deployed as an economical alternative to costly labour resources. Initially, machines were steam powered, clumsy and inefficient but since the 1950's a new breed (and diversification) of modern diesel powered plant and equipment evolved. Today, machines are leaner, more efficient and effective. Conversely, they are also expensive, demanding (in that regular maintenance must be conducted) and have a high financial risk attached to them. Modern construction project managers must therefore, vigorously pursue the efficient utilization of their equipment fleets if business profitability and thus company survival are to be assured (Hendrickson, 2000).

Mobile construction equipment is typically utilized in a myriad of bespoke operational conditions and thus the range and type of machines available has increased exponentially (Anon 2000a). However for brevity and simplicity, they can be

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classified into two clear dichotomous groups. The first group is equipment, which remains largely within the confines of the construction site, such as cranes and graders. The second group includes machines, which transport materials to and from the site, such as dump trucks and ready mixed concrete trucks (Harris, *et al.*, 1991, Hendrickson, 2000). To whichever category a mobile plant item belongs, plant managers need to record and manage plant data (for example inventories, records of purchase, hire costs and maintenance details) (Edwards, *et al.*, 1998). In the absence of such data, the derivation of plant performance would be difficult if not impossible to ascertain.

The management of construction plant information commenced with the development and subsequent utilization of paper-based techniques (Barton, 1985). Routine manual entries onto paper history file records for individual plant items and then globally across the company fleet were created and stored. Due to inherent drawbacks (namely: the development of voluminous data; the rigours of implementing a filing system; and the difficulties in utilizing such history data for analysis and forecasts) this technique is gradually being replaced with more 'advanced' data collection mechanisms (Harris, *et al.* 1991). These include various electronic methods developed through research and software development (Boyd, 1995, Edwards, *et al.* 1998, Lundegard, 1998, Edwards, 1999). Advanced software often incorporates statistical models that facilitate the analysis of electronic documentation collated. Software typically comprises of a File System and/or a Relational Database Management System (RDBMS) resident on PC's or local networks/intranets. Examples of these include: Caterpillar's Repair, Rebuild or Replace (RRR) Analysis, Greg Sier & Associates' Customized Plant Management (CPM) and many others (Anon, 2000a). Similarly, some web-based plant information databases have recently been developed. Ironmax Inc., for example, developed and launched a suite of information tools (Anon, 2001). The tools allow on-line access to three plant management reference publications, which are useful for sellers, buyers and managers of construction equipment. Unfortunately, these are relatively few examples of the existing information management systems applicable to plant and equipment management. Moreover, none of the systems reviewed possess the intelligent capabilities that are required to adequately support modern day plant utilization. Rather, analyses of data collated remaining in the custody of the busy plant manager who finds it difficult to conduct any meaningful analysis.

AIM AND OBJECTIVES

The fundamental aim of this paper is to present a proposed methodology for the development of a web-based intelligent construction plant information management system. In realizing this aim the following objectives will be simultaneously met:

1. to review the limitations of existing document management systems as a basis upon which to propose an improved system; this will be largely based upon the outcome of a pilot study conducted;
2. to announce a schematic system architecture of the proposed system as a means of engendering wider academic debate; and
3. to compare the differences between the proposed and existing systems.

PILOT STUDY

To provide a system that is an improvement upon those currently utilized, it is first necessary to ascertain the shortcomings inherent within existing systems. A pilot study was therefore undertaken with the aim of identifying such shortcomings and also determining the needs of construction plant managers. 60 top UK plant hire companies and contractors were selected using random numbers tables. This selection was based on sources such as the "Where Hire?" plant directory and the National Association of Demolition Contractors (Anon 2000b); the Scottish Plant Owners Association and the Contractors Mechanical Plant Engineers also provided some assistance. The survey was administered through semi-structured questionnaire letters, telephone interviews, site visits and formal meetings. Information collected from selected case studies of the Construction Federation's Information Technology Construction Best Practice (ITCBP) also enriched the survey findings. Essentially, the survey served to excoriate information on: current plant history data capture mechanisms and existing plant information management systems utilized.

32 responses were received from the pilot study, which represents a high response rate of 50%. Interestingly, a high proportion (61%) of respondents failed to maintain any meaningful 'formal' plant history data capture mechanisms. 25% kept an informal paper-based documentation of plant history records such as inventory details and maintenance records.

The remaining 14% had some form of electronic information management system (either PC or network based) for plant documentation. Practitioners proffered various reasons as to why only a minor proportion of plant users adopt formal paper or electronic plant information management systems. These range from the limitations of paper documentation already highlighted to the prohibitive cost of purchasing and operating software and associated hardware requirements (and also the investment in personnel to administer such systems employed). Furthermore, most respondents also stated that existing static electronic database systems do not provide a dynamic decision support capability. Hence, whether the system is paper or electronic based, users are confronted with an inability to interpret reports generated by such systems; unless of course, lengthy manual mathematical manipulation of the data is employed.

An interesting finding, however, is the fact that over 97% of the plant companies surveyed have access to the Internet and, in almost all cases their personal web sites also. This is particularly encouraging and suggests that the World Wide Web is already appreciated as a tool for information dissemination/management by the construction industry.

INHERENT POTENTIAL OF THE PROPOSED INTERNET SYSTEM

The Internet is simply a densely woven fabric of computers, interconnected through various Internet Service Providers (ISP), yet the potential for business is enormous (Pavlinusic *et al.*, 1998). Essentially, the 'net' has engendered greater generalization and globalization of communication, commerce and information management as a result of near instantaneous information transfer (Rowley, 1998). It provides a simplistic mechanism for processing queries on a central machine whilst simultaneously, implementing a graphical interface to that data on a remote machine. The 'Web' also offers a mechanism whereby changes to applications are instantly delivered to all users (Garvey, M *et al.*, 2000). These features make the Internet a suitable platform for implementing the proposed intelligent system.

AN INTELLIGENT PLANT INFORMATION MANAGEMENT SYSTEM: A DESCRIPTION AND STATUS OF RESEARCH

In order to ensure that the intelligent system overcomes the inherent limitations of existing systems, it will be designed as a three-tier web based client-server architecture (Liang *et al.*, 2000). This will enable the system to provide accessibility from remote plant sites in addition to providing intelligent decision support. Details of the client-server architecture are illustrated in Figure 1. The first tier will host the user interface and run on the client's machine. The second tier will be designed as either a Java, Hypertext Mark-up Language (HTML) or Common Gateway Interface (CGI) Script-enabled Open Source Database Connectivity (ODBC) broker server. This will be resident on the web server and will enable communications between the first and third tiers. The 'intelligent' components will be resident on the third tier of the system. This tier comprises of a web-enabled Relational Database Management System (RDBMS), a Model Base Management System (MBMS) and a Knowledge Base Management System (KBMS). A brief description of each of the components and the research methodology being adopted for their design now follows.

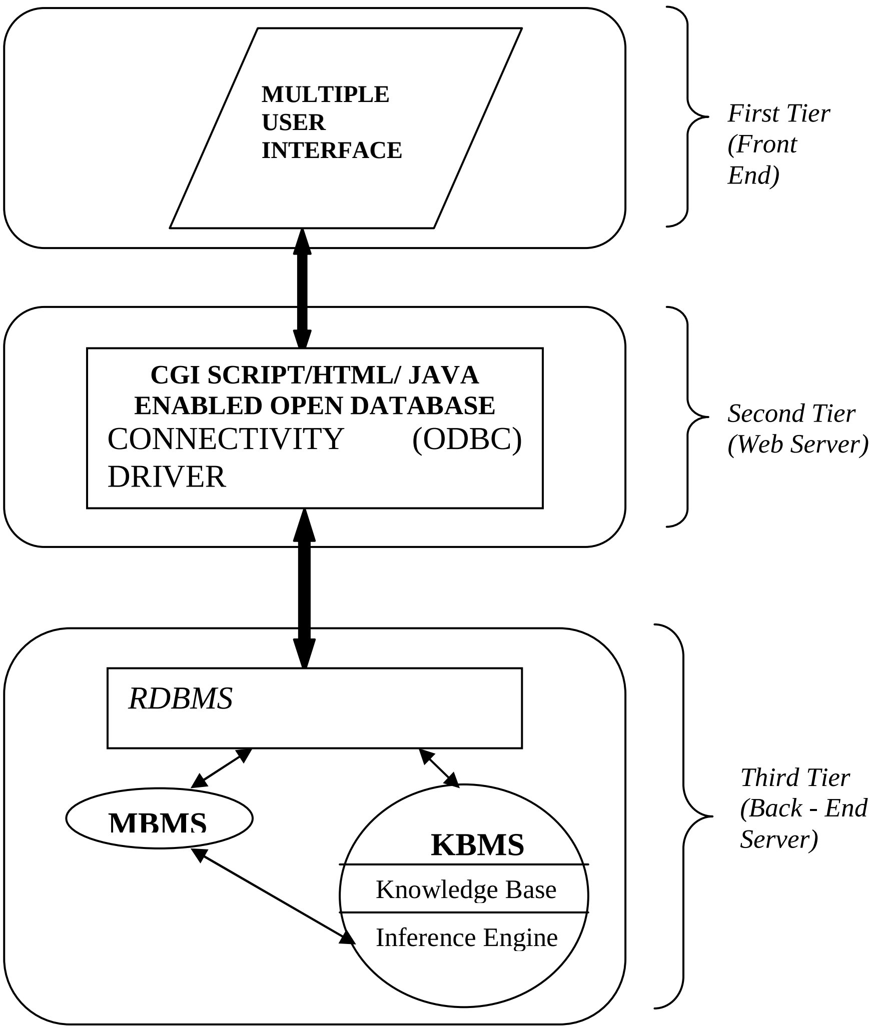


Figure 1: The Proposed Three-Tier Client-Server Architecture

The Web-Enabled RDBMS

A relational database structure will be adopted due to the nature and inter-relationship of plant history data (Zhang, 1999). The model has a unique advantage over the hierarchical and network database systems as it greatly facilitates the dynamic modelling of a non-static database (Pavlinusic, *et al.* 1999). Hence, the RDBMS will enable the overall system to possess intelligent functionality.

The system design has commenced with the collation of the data capture formats for plant history data and their translation into relational tables using Microsoft Access 2000 software. Relations between record forms are also being normalized in order to eliminate all duplicate entries. Entity-relationships are being formulated from these normalized relationships as a precursor to finalizing the RDBMS design. A typical data flow structure for construction plant information management is presented in Figure 2; this Figure serves as a basis for formulating the RDBMS. The dataflow structure indicates that plant identification codes and machine types are common to all the relations of the database. Hence in the RDBMS, these codes (attributes) will be treated as component keys in each of the tables (relations).

The MBMS

The MBMS is proposed as an intelligent platform, based on deterministic time series or neural network models for predicting plant maintenance costs. These techniques have been selected for their enhanced predictive capabilities over the traditional statistical techniques and also their ability to update key model parameters (i.e. variables and model coefficients) as a result of changes in machine usage (Famili *et al.*, 1996, Edwards, *et al.* 2001).

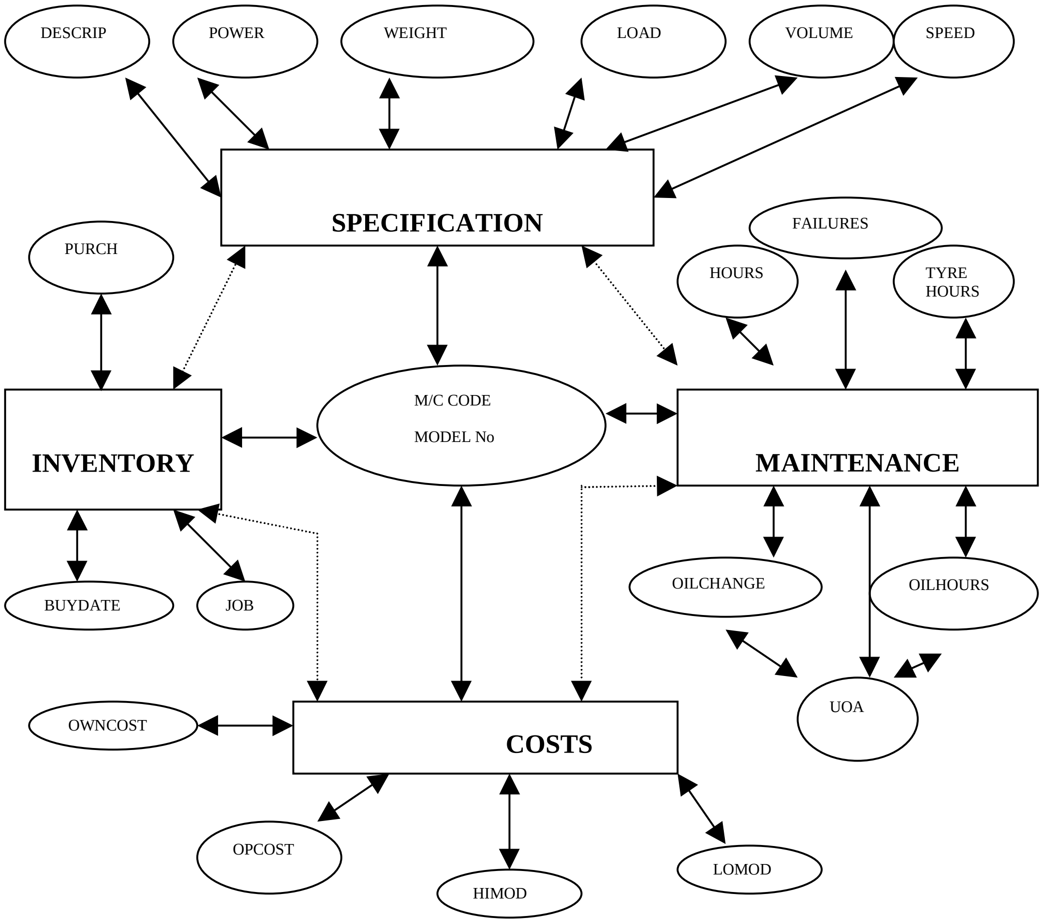
The KBMS

A KBMS is a computer programme containing organized knowledge, both factual and heuristic. It concerns some specific areas of human expertise and is able to produce inference for the user (Zhang, 1999, Liang *et al.*, 2000); in this case plant maintenance scheduling, component or complete plant replacement and projected maintenance costs. The KBMS will be constantly upgraded as the RDBMS is updated with the most current plant data. Hence, it will be designed to contain a user interface, knowledge base and an inference engine.

BENEFICIARIES AND CHALLENGES OF THE PROPOSED SYSTEM

A comparative analysis between the proposed and existing plant information management systems based on various application criteria, has revealed potential to greatly enhance plant history information management. Key benefits are enumerated in Table 1.

Generally, the system will eliminate the burdens associated with paper documentation, provide better plant information management decision support and enhance system accessibility from numerous remote locations. This implies a more efficient and effective means of managing plant history records. Furthermore, wider profit margins will be assured, as the often huge financial losses associated with plant management decisions (based on the existing systems) will be minimized. The construction industry and its associated off-highway plant sector will therefore benefit immensely from the implementation of the proposed system. Specifically, the system will be most useful to plant hire companies and construction companies; who either own, operate or maintain a substantially large fleet of plant.



Source: Boyd, 1995

Legend:

MODEL No.	Manufacturer's model number
DESCRIP	Description of machine
POWER	Combined engine power in KW
WEIGHT	Empty weight in KG
LOAD	Load capacity in KG
VOLUME	Volume capacity in cum.
SPEED	Maximum speed in KM/hour
M/C CODE	Alphanumeric machine ID code
BUYDATE	Date of machine purchase (y/m/d)
PURCH	Initial purchase cost
JOB	Job codes where machine is located
OWNCOST	Hourly ownership (average)
OPCOST	Hourly operating cost
HIMOD	Cost multiplier for severe conditions
LOMOD	Cost multiplier for easy conditions
HOURS	Current engine hours
OILFREQ	Freq. of need for oil change (hrs)
OILHRS	Engine hours at the last oil change
UOA	Used oil analysis result
TYREHRS	Engine hours after installing new tyres
FAILURES	Cumulative number of in-service b/downs

Figure 2: Typical Construction Plant Dataflow Structure

Some challenges are anticipated before the aforementioned benefits are fully realized. It is evident, for example, that technology transfer into the construction industry is notoriously problematic (Edwards, *et al.* 1998). Specifically, practitioners are slow to accept new and innovative technologies (Lundegard, 1998). However, the attraction of this system can be found in the attractiveness, ease and widespread utilization of web applications within current plant management practice.

Table 1: The Proposed System Vs. Existing Systems

S/No.	Property	Paper-based Methods	PC or Local Network Methods	Proposed Web-based System
1	Paper Work	High	Low	Very Low
2	Difficulties of accessibility to the System	High	Relatively High	Very Low
3	Software and hardware requirements	Not Applicable	Very High	Moderate
4	Level of decision support that can be offered	Low	Moderate	Very High
5	Ease of database upgrade in line with day-to-day plant utilization, maintenance and stock records	Low	Moderate	Very High
6	Capacity to automatically update model base with changes in database trends	Not Applicable	Nil	Very High
7	Ease with which knowledge base can be upgraded	Not Applicable	Low	Very High
8	Ease of upgrading the system with newer software	Not Applicable	Low	High
9	Security of data	Moderate	High	High

The pilot study also revealed that practitioners prefer to keep plant performance data a corporate secret. This is obviously from the point of view of rival competition. Therefore, other factors such as data security and integrity and associated technical support will be carefully considered a priori to system development. Security issues to be considered include authentication and permissions validation. These issues represent a user's access to the server and the permissible scope of activities within a particular database.

Future Work

The research is currently at the stage of designing the RDBMS. The process involves extensive collaboration with participating practitioners; the fundamental purpose being to create a user-friendly system in conjunction with industry for industry. Future work will entail the generation and validation of intelligent models that could be used for predicting construction plant maintenance costs. The system's MBMS will be developed from these models. A key research element at that stage of the research will be the selection of the most suitable time series models and the transformation of the 'static' models into 'dynamic' models. Finally, the KBMS will be designed to contain information required to emulate human expertise. This will be facilitated through the compilation of facts or data and special rules, which express how the facts can be manipulated and evaluated.   Further work, past this initial research, will apply methodologies presented to additional plant items and other areas of plant performance (e.g. plant utilization, breakdown and so forth).

CONCLUSION

The importance of construction plant information management has been identified, and understood, for some time. However, existing techniques have a number of inherent disadvantages. These have hindered a significant number of plant users from actually implementing formal information management practices over the years. As a result of this, huge financial deficits have been incurred on a wide range of plant applications.

The new system proposed will consist of a three tier web-enabled architecture. A front-end user interface, a middle ware web-server sub-system and a back-end RDBMS, MBMS and KBMS.

The implementation of this system will have a multi-faceted effect on the construction industry. Generally, construction plant information management will become more efficient and effective, whilst plant management decision support will be extensively enhanced. The artificial intelligent capabilities of the proposed system will enable it to constantly adapt itself to 'understand' the particular circumstances within which a plant item is operating. Existing systems, lend decision support, based on fixed historical databases and assumed operating conditions. Hence, the new system will be a major advancement over such systems.

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