monthly basis by the contractor's Surveyor, held a large amount of data unused by the contractors except for the purpose of performance control. Examination of the data revealed that if processed and stored in a central database, it could provide invaluable source of information to contractors for analysing performance and initiating strategies both on the project level and the company level. A subsequent survey of fifteen other contractors revealed that substantially identical CVR procedures were in universal use. It was therefore decided to use a CVR format as a data capture facility for the system.

Actual CVR sheets used by different contractors were studied. The types of records used in these sheets were examined in terms of their usefulness to management for initiating future actions other than cost control. Results of this examination showed that if these performance "raw" data were processed they could form a set of variables that the contractor can use in the decision making process. Figure 1 shows a copy of a monthly CVR sheet.

A mathematical model was developed to process these monthly records into useful information subsequently called performance variables (i.e. variables used to measure the contractor's performance with respect to the project). These variables were perceived to be useful to contractors for the purpose of tendering, cash flow forecasting and also to forecast the data available in CVR sheets for future projects. This is done using a process that is essentially the reverse to that used when extracting these performance variables. These performance variables are listed below:

1- estimated profit margin vs. actual
2- estimated start date vs. actual
3- estimated completion date vs. actual
4- date of first valuation
5- number of days between valuations
6- retention
7- S-Curve determinants (alpha and beta) (see Kenely and Wilson 1986; Kaka and Price (1993))
8- estimated mark up on prelims vs. actual
9- percentage unbalance on prelims
10- under/over measure
11- maintenance period
12- unbalance of measured work
13- percentage break down of contract cost
14- payment delays to subcontractors and suppliers
15- payment delays from client
16- materials purchase strategies (time between purchase and installation)
17- percentage of materials on site which are included in valuations
18- percentage cash discounts
19- time limits in which discounts are available
20- sub contractors retention
21- method of prelims valuation and payment

Finally, further variables were introduced into the system in order to facilitate the sharing of information between different projects. These variables were called Contract Classification Variables (i.e. variables used to describe the project) and included nine criteria by which a contract is defined or grouped. These criteria were identified by contractors as the most important factors influencing contracts' characteristics and performance. The nine classification variables are listed below.

1. Location
2. Client
3. Construction Sector
4. Method of Procurement
5. Method of Tendering
6. Contract Type
7. Size of Work
8. Type of Work
9. Consultants Involved

The model was developed in such a way that when a contract is started, the contractor defines the project in terms of its classification variables. As the contract progresses and actual data become available, the contractor starts to fill in the CVR sheets on a monthly basis. When the contract is completed, the model processes the CVR sheets and as a result summarises the performance of the project in terms of the performance variables and the data (including contract classification variables) are sent to the central Database.

When a new contract is considered, the contractor defines the project in terms of its classification variables. The model queries the Database for the characteristics of past projects that match the same classification. Once the data is retrieved and processed a set of contract performance variables is predicted for that particular contract.

The above method will work as long as adequate similar past projects are found and retrieved from the Database. However, finding adequate data is not always possible, particularly in the early years of applying the proposed model. Also, certain classification variables are not finite in terms of the options available (such as the client for the contract). An Intelligent Data Retrieval system has therefore been developed to overcome this problem.

THE DATABASE RETRIEVAL SYSTEM

When starting a new contract, the user is asked to select the classification of the project the user is about to tender for (such as contract type, method of procurement and method of tendering). Once the user has entered the classifications the data retrieval system retrieves all the matching projects from the database. The model then calculates the maximum, minimum and the most frequently occurring values for each of the required input variables. These variables provide the contractor with more detailed information about the expected performance of the project under consideration.

If the retrieval system fails to find a match to all the classifications, the system has to be adjusted to find the best matching projects. The database retrieval system

(D.B.R.S.) removes the least important classification from the list and attempts to find a matching project again. If the D.B.R.S fails to find a match the second time, it removes the classification, which has the next lowest importance. This process continues until the minimum number of classifications, which is 3, is reached or a matching project is found.

To be able to remove the least important classification the importance of each classification has to be assessed. In order to investigate the importance of each classification a survey was devised to assess how the industry ranked the classifications.

THE SURVEY

The aim of the survey was to allow contractors to indicate which classification variables had the greatest effect on different characteristics of construction projects. Table 1 shows some of the characteristics and the classifications that were used in the survey.

Table 1. The characteristics and classifications used.

Characteristics	**Classifications**
1. Profit	1. Location
2. Retention	2. Client
3. Maintenance period	3. Construction Sector
4. Completion Date	4. Method of Procurement
5. Delay of Client payments	5. Method of Tendering
6. Delay of Sub Con. payments	6. Contract Type
7. Risk	7. Size of Work
8. Percentage of Sub Con.	8. Type of Work
9. Over measurement	9. Consultants Involved
10. Front End Loading	
11. Materials Purchased	

The survey was conducted by post with the questionnaires being sent along with a stamped, addressed envelope in an attempt to increase the return rate. The questionnaire was sent out to a number of randomly selected construction companies with a range of sizes, to ensure a broad view of the industry. More than 70 questionnaires were issued and 17 usable responses were returned, indicating a response rate of about 25%.

A scoring system was used to assess the importance of each classification. The scoring system worked by assigning the highest value, in this case 9, to the classification that has the most influence, descending to 1, for the classification that has the least effect. The scoring process was carried out on each of the characteristics for each of the companies. Table 2 below shows the calculated averages of the order of the classifications as specified by each company.

Table 2. The individual company average classification orders from most important to least important classifications

Company	**Most Important** →					**Least Important**			
1	3	2	4	6	5	8	9	7	1
2	2	3	9	6	8	4	7	5	1
3	2	6	9	4	8	5	7	3	1
4	9	2	4	6	7	5	8	3	1
5	2	6	8	3	4	7	9	5	1
6	2	8	3	6	7	4	9	5	1
7	6	4	3	5	8	2	9	7	1
8	2	9	6	4	5	8	3	7	1
9	3	9	4	2	6	8	7	5	1
10	9	2	4	6	3	5	7	8	1
11	2	9	4	8	6	5	7	3	1
12	6	2	7	4	8	3	1	5	9
13	2	1	4	6	9	3	8	5	7
14	6	2	4	8	3	9	5	7	1
15	2	7	3	6	8	9	5	4	1
16	4	9	6	2	7	8	3	5	1
17	4	2	8	7	9	5	6	3	1

It can be seen from Table 2 that different companies place different classification factors as the most important, in terms of their affect on the overall characteristics of projects. Eight out of the seventeen companies placed number 2, “the client” as the most important. The next most frequently occurring classification was number 6, “the contract type”, with 3 occurrences. Table 2 does indicate clearly that the majority of companies place number 1, "the project location" as the least important of the classifications.

Table 3. Overall companies order of the classifications

Classification	**Score**
1	26
2	132
3	85
4	108
5	56
6	112
7	64
8	83
9	95

Having found the overall order for the survey (see Table 3), each characteristic was then investigated separately to find out which classification had the greatest effect on each of the characteristic variables. Table 4, below indicates each characteristic and the order of the various classification factors, which influence it.

Table 4. Individual characteristic overall calculated orders

Characteristic	**Most frequent**			→			**Least frequent**		
1. Profit	2	4	5	8	9	3	7	6	1
2. Retention	6	2	4	3	8	7	5	9	1
3. Maintenance period	2	6	3	4	7	8	9	5	1
4. Comp Date	2	9	6	4	8	5	3	7	1
5. Delay of Client	2	9	6	4	3	5	8	7	1
6. Delay Sub Contractor	2	3	6	9	4	5	7	8	1
7. Risk	2	9	6	4	8	7	5	3	1
8. Percentage Sub. Con.	8	6	3	7	4	5	2	9	1
9. Over measurement	9	8	4	3	7	6	5	2	1
10. Front End Loading	6	4	3	5	8	9	2	7	1
11. Materials Purchased	6	4	8	3	7	2	9	5	1

The overall calculated order for each characteristic indicates that in 6 out of the 11 characteristics, the client, (number 2) was deemed to be the most important classification variable. Once again it can clearly be seen that the location of the project has little effect on the characteristics. The overall average order for the companies was then compared with each individual company in an attempt to find a trend. The analysis found that although there was no conclusive match, the companies taking part have constantly placed the same classification variables at the top.

This indicates that all companies felt that certain classifications are important influences on certain characteristics. This led to the need to investigate whether a single overall order can be used or there is a need to use a calculated order for each characteristic. The results from the companies point to a combination whereby an overall order is used. With certain characteristics however requiring their own specific order. Therefore, a solution would require the classifications to be omitted in different orders for different characteristics. To clarify, it means that when "profit" is being used to search for matching projects, the order in which classifications may be omitted is 1, then 6, then 7, then 3 etc. However, when "retention" is used to search the order is 1, then 9, then 5, then 7 etc.

In order to identify which of the characteristics required their own specific retrieval system, the survey results were analysed further. The individual characteristics for each company were used to find which companies had placed the same classifications in the same order. Firstly, the first two classifications with the highest overall scores were used to find matching companies. Secondly, the top three classifications were used to find a match and thirdly the top four classifications were used to find a match. Table 5 indicates that for one or more matches to the individual characteristic order, five characteristics have over 50% of the companies placing the same classifications in the same order, indicating a trend. The table also shows that three characteristics

have over 50% of the companies placing two or more classifications in order, while none had over 50% placing three or more in order.

Having tested the individual characteristics above it can been seen that when looking for one or more matches in the classification order, five of the characteristics have 50% or more of the companies placing them in the same order. This indicates that the criteria were not stringent enough. When looking for three or more classifications in a row, none of the characteristics had over 50% of the companies placing them in the same order.

Table 5. Percentage of companies with matching classification orders

	Characteristic	**1 or more**	**2 or more**	**3 or more**
1	Profit	52.9	64.7	23.52
2	Retention	47.1	64.7	23.52
3	Maintenance	11.8	35.29	17.64
4	Complete	82.4	47.05	35.29
5	Delay of client	100	94.11	35.29
6	Delay of sub	35.29	35.29	11.76
7	Risk	70.6	41.17	29.41
8	% sub-con	50	37.5	37.5
9	Over measure	37.5	25	6
10	Front end Load	18.8	12.5	6
11	Mats on site	25	25	6
	no of passes	**5**	**3**	**0**

When looking for two or more of the classifications in order, three characteristics were found to have 50% or more of the companies placing the classifications in the same order. It can also be seen that there is a considerable gap between the three and the other characteristics. This confirms that it is necessary to have specific classification orders for specific characteristics.

CONCLUSIONS

A Management Information System has been developed that uses historical information stored in a database to assist contractors in their decision making. The MIS uses a retrieval system to retrieve information from the database. The system uses a series of classifications to find matching projects. The system removes the least important classifications one at a time until it finds a match. In order for the retrieval system to work correctly, the importance of the different classifications had to be investigated. In order to investigate the importance a survey was devised.

A survey document was created and then validated and approved by the collaborating contractor. The survey document was sent out to contractors of various sizes and in various locations. The returned surveys were then scored to find which classification was felt to be the most important.

Having scored all the classifications for each of the companies, an overall order was created for the companies. An overall order was created for each of the classifications. The overall order for the companies was then used to investigate whether there was a trend in the order. The investigation failed to find any trend in the company orders.

The overall orders for each of the classifications was then used to investigate whether a trend existed within any of the characteristics. The investigation found that in several cases companies had placed the classifications in the same order. The investigation found that three characteristics had a higher percentage of companies placing the same classifications in the order, these where, 'profit', 'retention' and 'client delay'. The results of the analysis indicated that using one order of importance for the retrieval of the data was not the best solution. The results indicated that a system using individual orders for the retrieval of information for the characteristics 'profit', 'percentage retention' and the 'client delay' and an overall order for the other characteristics would provide the most accurate results.

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