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Published in:
Civil Engineering Systems

DOI:
[10.1080/02630259508970164](https://doi.org/10.1080/02630259508970164)

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Recommended citation(APA):
Ng, S. T., & Skitmore, R. M. (1995). CP-DSS: Decision support system for contractor prequalification. *Civil Engineering Systems*, 12(2), 133-159. <https://doi.org/10.1080/02630259508970164>

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**CP-DSS: DECISION SUPPORT SYSTEM FOR CONTRACTOR
PREQUALIFICATION**

Revised Paper for

CIVIL ENGINEERING SYSTEMS

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April 1994

CP-DSS: DECISION SUPPORT SYSTEM FOR CONTRACTOR PREQUALIFICATION

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ABSTRACT

A prototype decision support/expert system for contractor prequalification, CP-DSS, is described. The system firstly evaluates contractors' capabilities according to project specific criteria. It then identifies any risks that may be caused by contractors. Finally, contractors are appraised according to their likely performance, management capability, reputation, resources, progress, competitiveness and activeness and ranked in order of selection priority.

Keywords: Contractor prequalification, decision support systems, expert systems.

INTRODUCTION

Contractor selection is a critical aspect in the management of every construction project. Standard texts (eg., Ramus, 1989) advise clients' consultants to aim to find a contracting company:

- that is financially stable and has a good business record
- for which the size of a project is neither too small nor too large
- with a reputation for good quality workmanship and efficient organisation
- with a good industrial relations record.

Flanagan's (1990) view, elaborated by Drew and Skitmore (1993), of clients' basic requirements, is that consultants should select contractors who are likely to:

- be prepared to undertake and complete the work at a competitive **price**
- complete the work on **time**
- construct the work to the required **quality** standards
- execute the work without a significant **risk** of extra financial burden on the client.

Contractor prequalification is a widely used process to select competent contractors by assessing a candidate's competence or ability to meet the specific requirements for the performance of a task on these criteria. This usually involves screening by clients' consultants and the consideration of a wide range of factors. The information used, however, is often qualitative, subjective and imprecise (Russell and Skibniewski, 1988). As a result, prequalification is said to be largely an 'art form' where subjective judgment, based on the individual experience, is an essential part of the process (Nguyen, 1985). Consequently, bidders are occasionally selected who are unable

or unwilling to carry out the necessary construction work, and those who are genuinely able and willing are excluded from tendering.

It is argued that, in order to prequalify contractors on an impartial and objective basis, all previous and present data regarding potential contractors should be fully utilised and analysed. An ideal system would do this automatically. The only task for the client or consultant would then be to define the scope of work and other project criteria, with the system then suggesting the possible solutions for decision making. One possible way of achieving this is to integrate a decision support system with an expert system which contains all the relevant and reliable models and decision rules for the prequalification task. Although not totally objective, such a system should help rationalise the structure and systemize the prequalification decision process in addition to reducing the time and effort involved.

This paper describes a prototypical three-level decision support system for contractor prequalification, CP-DSS. It is claimed that the system offers an improvement to the existing prequalification practices through the quantitative and systematic evaluation of a wide range of data, the preclusion of any deterministic ratings or subjective human judgement, the generation of an objective short-list of tenderers to support decision-making, and ease of use by busy decision makers.

CONCEPTUAL FRAMEWORK

According to Russell and Skibniewski (1987), prequalification systems operate in two stages. Firstly, the scope of the work and contract type is defined, and secondly, a list of suitable bidders is identified. Russell and Skibniewski (1988) suggest that the following stages are involved in the contractor prequalification decision making process:

1. development of selection criteria,
2. gathering data on contractors' capabilities,
3. evaluating the data,
4. applying the data to criteria (from stage 1),
5. gathering more data for the decision if needed, and
6. making the decision.

Stages 2 to 6 should therefore be completed for each prospective contractor.

On this basis, a suitable conceptual framework was devised to capture the knowledge required for the system. Most of the knowledge was obtained by literature review and six structured interviews carried out in Hong Kong with relevant experts in this area (*cf.*, Ng, 1992). The interviewees consisted of architects, quantity surveyors and building surveyors. All had

extensive knowledge of both public and private sector prequalification systems. The interviewees were asked a series of questions relating to their background, current duties, decision criteria for prequalifying contractors, and decision rules for evaluating these criteria.

Based on the knowledge elicited at this stage, a questionnaire was developed to collect further information from a wider spectrum of construction professionals. This questionnaire comprised two parts. The first part required the respondents to give a rating to each decision factor and sub-factor. The second part of the questionnaire contained 11 questions for formulating the decision rules for the decision criteria.

A total of 100 questionnaire were sent to public sector clients and private consultants. 37 of these were completed and returned. The decision factors and sub-factors were then weighted as outlined in Russell and Skibniewski (1990). The results are given in Appendix A.

The knowledge elicited from the domain experts were then structured into a three-level model (see Fig 1) comprising a project specific module, a risk identification module, and final appraisal module.

Fig 1: *Three-level model*

The *project specific module* evaluates the competence of contractors in carrying out the project according to the project details as defined by client or consultant. This determines whether they can be qualified to enter the next stage or not.

The *risk identification module* examines the recent status and movement of contractors and helps to eliminate the possibility of any downside risks being passed onto the client after awarding the contract. Potentially risky contractors are screened off by the system in this stage.

The *final appraisal module* then evaluates the qualified contractors through a series of models and a score is assigned to each contractor to represent its relative merits. Based on these scores, each contractor is ranked in descending order and a short list of tenderers for the project is produced.

SYSTEM DESIGN

A prototype system, CP-DSS, was developed according to the above conceptual framework. It is implemented within DBase IV, Lotus 123 and KAPPA, an object-oriented expert system shell. The current working system runs on IBM PC and compatible DOS-base micro-computers.

Object-oriented Approach

The object-oriented approach was used for developing the system. This approach is particularly suitable for large domain problems of this kind (Ng, 1993), as it has the facility to allow for modularisation. Decision rules and facts are inherited from the parent objects to objects down in the hierarchy. This helps to avoid the repetitious process of having to allocate similar properties to related objects and greatly reduces the time required for system development while producing an easily maintainable system.

Fig 2: *Hierarchical tree structure of contractor*

Another advantage of the object-oriented approach is that it allows for future expansion. In its present state, the prototype can only deal with construction contractors. However, this programming approach enables the system to be extended to all other possible types of contractor. The various types of contractors incorporated into the system at the moment are civil engineering, maintenance, building services and specialist contractors. These are represented in a hierarchical form as shown in Fig 2. The structure of the hierarchical tree has been modelled in the prototype to facilitate future expansion.

Implementation of the System

The system was developed according to the architecture of DSS-ES integration, and the operation of the system is shown in Fig 3.

Project details are obtained from the client or consultant through the knowledge-based expert system. The knowledge-based expert system then communicates with the contractor database and collects information for intelligent analysis. The analysis is based on various decision criteria and decision rules kept in the knowledge-based expert system. It then determines whether a contractor is qualified or disqualified for further assessment.

The reasons for disqualification are reported by the expert system.

Fig 3: *The operation of CP-DSS*

The knowledge-based expert system then accesses the database of the qualified contractors. Again, the data is imported to the expert system for evaluation. The principle is similar to that of the previous stage, and the names of disqualified contractors with the reasons for failing are reported. The results at this stage are simply 'qualify' or 'disqualify', and these cannot be used to determine which contractors should be included in the short list.

The final appraisal process is carried out by a spreadsheet. An expert system is linked to the spreadsheet for advising whether a contractor is qualified for the final appraisal or not. The spreadsheet then obtains scores for the qualified contractors from various models. The inherent calculating capability of the spreadsheet enables a final score to be computed efficiently for each of the qualified contractors. Ranks are then given to the contractors according to their aggregate score, and a list of tenderers is then produced for the final decision.

DECISION CRITERIA, RULES AND MODELS

Project specific module

The results of interviews indicated that most clients and consultants prequalify contractors initially by project specific criteria, such as project type, project sum, etc. Normally, a number of contractors are screened off simply because they do not have adequate resources to undertake the project or sufficient experience in certain types of construction projects, e.g. hospitals. As a result, project specific contractor data is examined by the system first.

The factors outlined by McCanlis (1974) for selecting contractors, together with the expert knowledge in this area form the basis for defining these criteria. The decision criteria in this module include:

- size of project
- type of project
- complexity of the proposed construction work
- standard of quality required
- working capital
- capacity of work
- method of procurement to be used

- design liability
- level of technology required
- the need to build the work in a particular order
- work around dangerous substance
- the requirement for noise control
- location of work
- percentage of work to be sub-contracted

The decision rules are mainly derived from the relevant experts in Hong Kong. As a result, some of the rules may not necessarily apply to the peculiar environment or practice of other countries. It is important that these rules to be amended to tailor the decision making processes or customs of a particular country.

1. *Size of project* Most contractors tend to specialise in a particular size of work, and they may become inefficient once the project size is beyond their usual range. The expected project value should be within the contractor's minimum and maximum project amount.
2. *Type of project* Although a contractor may be more familiar with certain types of construction, it is unfair to assume that the contractor cannot build other types of work. The system compares the type, complexity and expected quality of the proposed project with the types of project undertaken previously by the contractor. Questionnaires are used to capture the knowledge for this criteria.
3. *Complexity* Contractors may not be able to complete a complex job if they do not have enough experience or resources to do it. It is important to ensure they should have completed a project of a similar or even higher level of complexity than the proposed one.
4. *Quality* Similarly, contractors may not be able to deliver the required quality of work without the required level of expertise. Therefore, they should have enough experience to handle the quality required for the proposed project.
5. *Working capital* Most experts believe that a contractor needs to have a working capital of at least twelve percent of the project sum in order to mobilise the work. Qualified contractors should therefore have an adequate amount of working capital to cover this aspect.
6. *Capacity of work* Contractors involved in many concurrent projects should not necessarily be deprived of tendering opportunities. If they have enough capital, the next task is to establish whether they have

sufficient time to organise the labour, plant and management expertise to carry out the project. Therefore, if a contractor's current workload is high, the time between tendering and actual commencement may determine contractor's eligibility to tender for the project or not.

7. *Procurement* The method of procurement for the proposed project should be one which is familiar to the contractor. This is particularly important for design and build or management type contracts.
8. *Design liability* Some contractor involvement in designing certain parts of the building is very common today. It is particularly important therefore to ensure qualified contractors have adequate experience and expertise to fulfil this design liability.
9. *Technology* The proposed project may require a new technology or method of construction to be employed. In this case, the contractor should have a high level of technology and good research and development capability available.
10. *Particular order of construction* Where the project is required to be built in a particular order of construction to meet the client's requirements for completion of some parts of work before others, it is important that the contractor has had some previous experiences of this nature.
11. *Work around dangerous substances* Qualified contractors should have experience in handling or working around dangerous substances.
12. *Noise control* Some projects require a strict control on noise levels. In this case the contractor should have enough equipment and experience to satisfy these requirements.
13. *Percentage of work to be sub-let* The proportion of sub-contracted work should be less than the maximum amount that the contractor can handle to avoid undue management problems.
14. *Location* Where the project is located in a special geographical location, such as outlying islands, the contractor should have experience in working in this area. This may reduce the risk of labour and material shortages and ensure the work is carried efficiently.

Risk Identification Module

In every construction project, clients are exposed to a number of risks which may cause substantial loss. The major risks which emanate from the contractor include:

- cost escalation
- delay
- non-completion
- sub-quality work

All these risks can be, and usually are, caused by the incompetence of contractors. However, these risks can be eliminated by careful choice of tenderers, taking into account knowledge of their past experience and performance and current workload (Flanagan and Norman, 1989).

It is very difficult to identify which contractor will least expose the client to any of the above risks. However, contractors belonging to any of the following category are more likely to be risky. These are the ones who have:

- not adopted a formal quality management policy
- recently been debarred from tendering
- failed to complete a contract
- committed a fraudulent activity
- insufficient local experience
- unstable company structure
- financially unsound

The decision rules in this module are based on knowledge elicited from the construction professionals and the results of the questionnaire survey.

1. *Quality management* The contractor should be able to prove his observance to the requirements of ISO 9000 by obtaining a certificate in quality assurance.
2. *Debarment* The contractor should not be recently debarred from tendering due to problems in cash flow, resources, management or fraudulent activities.
3. *Failed contract* The contractor should not be invited for tender if he has a failed contract due to inadequate resources, management capability, bankruptcy or problems with work permits.
4. *Fraudulent activity* A contractor who has been involved in fraudulent activities, such as the provision of false financial data, false organisation, sub-standard quality, illegal labour or payment overclaim, are to be avoided.
5. *Length of business* To ensure the contractor is familiar with the local practice and construction environment, the length of business should be not less than two

years (in Hong Kong).

6. *Stability of firm* Unusual senior personnel movement, recent strikes, and a high proportion of redundancy and resignation may be a sign of a financially unhealthy company. Contractors with any of the above problems are temporarily suspended from tendering.

7. *Financial stability* Subsidiary companies who rely heavily on the parent company's capital, contractors who do not satisfy a ratio analysis, such as quick ratio, profit ratio, etc. (cf., Calvert, 1981), and those who do not have enough capital to finance the project are disqualified.

Final Appraisal Module

Contractor prequalification usually requires an appraisal of the contractor's past performance, reputation, resources, etc. to enabling a short-list of tenderers to be produced. Very often, clients and consultants overlook the importance of this process by simply giving a subjective rating to the contractor. These ratings may only reflect their overall impression on a contractor according to their performance of a particular project in a particular time. A more objective and scientific approach is to utilise all the available data of contractors, and put them to the relevant models for evaluation. The outcomes of these models should be given a weighting to indicate the degree of importance in the overall evaluation. The weighting for various decision factors and sub-factors has been developed from the results of questionnaires. This weighting has been built into various models to ensure an objective assessment is achieved.

Seven separate models perform the evaluation tasks. These models evaluate the contractors'

- performance
- management capability
- reputation
- resources
- progress
- competitiveness
- activeness

The *Performance Model* measures contractor's performance directly against definite standards. The Performance Assessment Scoring System (PASS) has been the principle source of reference (Hong Kong Housing Authority, 1992a). The system classifies a building's construction in terms of four main aspects: structural work; architectural works, other obligations and external works. Each of these factors is, in turn, sub-divided into a number of items (see Fig 4). Performance on each item is

assessed according to the predetermined standard at various sample locations.

Fig 4: *Decision factors of performance model*

A matrix has been designed by the Hong Kong Housing Department to model the evaluation process (see Fig 5). At a particular sampling location, the construction work is judged as complying or not complying with the stated standards. The results in the matrix should indicate whether or not a contractor has passed the factor in that particular spot. The score for each factor is calculated by multiplying the percentage of items complying with the standard (ticks) with the percentage of passed factor spots (P) and the weighting. The individual scores are then added up to give a total (see Appendix B.1).

Fig 5: *Matrix for evaluation of performance in PASS*
(Source: *PASS Manual, Hong Kong Housing Authority*)

However, the weighting allocated to each item in the PASS are mainly based on the designer's perception and are, therefore, the same for each item. They do not take into account the possibility that some items are more important than others and should therefore carry a higher weighting. Hence, this weighting has been reallocated according to the questionnaire's findings.

The *Management Capability Model* was developed from the management capability module of the PASS (Hong Kong Housing Authority, 1992a). Five aspects are assessed by this model, they are management organisation, resources, organisation of works, documentation and general obligations. Again each of them has a number of items to be evaluated (see Fig 6).

Fig 6: *Decision factors of management capability model*

The assessment is made by giving a grading A, B, C or D, in some cases A or D, for each of the items being assessed. The grading is based on objective standards of attainment. In order to obtain a score, the attainment levels are given a numerical value. The total numbers of each grade are then multiplied by a multiplying factor (i.e. 3, 2 and 1 for A, B and C respectively). The score for each decision factor is then divided by the total numbers of possible grades for that factor (Appendix B.2).

The weighting obtained from the questionnaires is also applied to the decision factors and their associated items to ensure an objective result is achieved.

A matrix similar to that of the PASS has been developed for the *Reputation Model* (Appendix B.3). Four main decision factors were determined, they are integrity, co-operative outlook, financial credit rating and claims record. Under each heading, a number of items are assessed (see Fig 7). The assessment is carried out over several different projects to eliminate the likelihood of bias. The results are recorded in the matrix for evaluation. The basic principle of the evaluation is the same as that of the PASS.

Fig 7: *Decision factors of reputation model*

The *Resources Model* is based on the short-form questionnaire designed by the Hong Kong Housing Authority for obtaining data on contractor resources (Hong Kong Housing Authority, 1992b). The model consists of four factors - capital, experience of staff, plant and premises.

Various tables (see Fig 8) with factors and sub-factors have been developed for collecting data. They can be saved on the diskettes and distributed to the contractors for completion (Russell, 1992).

Fig 8: *Decision factors of resources model*

The data collected from the contractors are analysed by the model. For instance, in assessing the experience of staff, various personnel are listed and a weighting is given to each of them. Multiplying factors are also given to adjust the differences in staff input between full-time and part-time staff, and experienced and inexperienced personnel. An initial score is computed for each item according to its status (i.e. full-time or part-time) and experience. The contractor's score

on that item is then compared with that of the others, and the score is divided by the highest score amongst the contractors to produce a relative score. Contractor who score highest in that particular item can get a relative score of 1.00, whereas the others can only get a lower score. Relative scores for other items are calculated under the same principle. The relative score is multiplied by the weighting to give a weighted score for that item. The weighted scores for all items are totalled, and a total score for the experience of staff is computed.

Scores for other factors are calculated on the same basis. Finally, the total score for contractor resources is calculated by adding up all the weighted scores of the four decision factors in the model (see Appendix B.4).

Various progress monitoring systems, such as critical path method (CPM) and programme evaluation and review technique (PERT), have been developed to indicate whether a project is likely to deviate from the original goals and objectives in terms of time and cost. These systems are included in the *Progress Model* to give an objective evaluation on contractor's progress. The PERT approach to contractor prequalification has been proposed by Russell and Irtishad (1990). In this model, contractors' progress on their projects is evaluated according to their work done. The programme status is derived from the 'time so far' x 100 x 'percent of completion'. For instance, if the percentage of completion is 40, and the time now is 6 weeks, the activity will require 15 weeks to finish. This can be compared with the planned time to find out the expected overrun. This evaluation technique has been modelled in a relational database. Five database files have been created, including builder, project, activity, projects carrying out by each contractor, and activities in each project. They are linked together to produce a progress report. The total time overrun actually determines the score of each contractor. The longer the delay, the lower is the score.

Competitiveness Model. Every client wants to obtain genuine competitive bids from the tenderers. Contractors who persistently submit uncompetitive bids should be avoided. Information on previously returned bids are used for the evaluation purpose. The basic principle is that the higher the tendered price is relative to the lowest accepted bid, the lower the score. The final figure is computed from an average of 50 previous projects (Appendix B.5).

The *Activeness Model* is, in fact, an integral component of the competitiveness model (Appendix B.5). During inputting the tendered prices of various contractors, an option is available to indicate if a contractor has not returned his tender for that project. A score is calculated by comparing this with the number of projects for which the contractor has been invited to tender. The more a contractor has returned a priced bill, the

higher is the score.

The above models are linked to the final scoring model for summarising and reporting. Real-time scores are collected from these models simultaneously. These are adjusted by the weighting to represent their importance. The weighting is derived from the questionnaires mentioned above. The total of these weighted scores constitute the overall scores for the contractors (Appendix B.6).

CONTRACTOR DATABASE

In order for the prequalification system to arrive at a decision, data must be gathered on each contractor. These include:

- name of contractor
- types of projects executed in the past five years
- amount of project executed in the past five years
- complexity of work executed
- quality of work executed
- experience in handling dangerous substances
- experience in noise controlling
- experience to work in a particular order of construction
- maximum percentage of subletting
- level of research and development
- level of technology
- expertise in design
- location of work executed
- methods of procurement adopted
- has he got the quality assurance certificate
- reasons for recent debarment (if any)
- reasons for failed contract (if any)
- reasons for fraudulent activity (if any)
- length of time in business
- capacity of work
- company's stability
- financial details

According to Russell and Skibniewski (1988), this data can be derived from internal and external sources. Internal data is interpreted as coming from past projects that a contractor has performed for the decision maker. This information provides an in-depth look at how contractors conduct their business and perform under the job conditions. It is, therefore, likely to be the most reliable. Internal data includes monthly progress reports, contractor performance evaluation reports, and input from client personnel who have had contact with the contractor on past projects.

Data from external sources is obtained via questionnaires returned by contractors. It is recommended that the questionnaire requests information on company organisation,

listing of past projects performed, current balance sheet, listing of current projects under construction, experience of key personnel and references. Additionally, other external sources to which questionnaires can be sent include previous clients, project managers and banks.

To permit more timely, accurate, and comprehensive data to be collected, Russell (1992) proposes the use of an automated real-time data collection technology. The contractor is given a previously formatted diskette where the data necessary for the evaluation is outlined and input using a computer keyboard. Contractor data is stored on the diskette and sent back to the evaluation entity to facilitate easy access.

All these data are stored in the contractor's database. To protect the evaluation entity against fraudulent or incorrect input of contractor data, Russell (1992) suggests the development of an expert system to test the validity of submitted data. The verified data can then be used for the evaluation.

REPORTING

Various reports are produced to support the clients and consultants in decision making. These contain all the essential information necessary to make a correct decision, including:

- project details
- list of top-ten contractors
- status of contractors and reasons for failing
- bar chart of the top-ten contractors

Decision makers can base their decision on the top ten contractor list and other information to draw up a short-list of bidders straight away. In addition, the status of contractors and reasons for failing to prequalify can give the decision makers some idea why a contractor has not been prequalified. Sometimes, decision makers might want to reconsider a contractor for inclusion on the list if it is thought that the problem is just a trivial one. Reports on project details enable decision makers to check whether or not these details have been entered correctly. A simple mistake in the project data can cause a completely different result and a different list of bidders to emerge.

TESTING AND VALIDATION

All the above modules were tested and debugged as they are written. However, due to the difficulties in obtaining the real data from clients and contractors, experimental data was used for testing purpose. These data were input into the spreadsheet models to test the formula, conditional statements and macro

commands. In addition, experimental records were used in the databases to test the linkages between various relational database files and the output of the final report. The 'IF-THEN' statements in the knowledge-based expert system were tested with both positive and negative assumptions to ensure that they produced accurate conclusions.

After all the modules were individually tested and debugged, they were integrated and tested as a system. To enable the tests to be carried out, a contractor database was set up to provide data to the system. Project details, such as those in Table 5, were then entered into the system. In this particular example, the system successfully spotted DEF Construction Co had been recently debarred to tender. As a result, this contractor was disqualified. Those who passed the first two modules were successfully transferred to the final evaluation stage. Scores were then drawn from various models (according to the experimental data mentioned above) to produce a final score league. Depending on the scores, each contractor was given a rank and a top-ten list of contractors were produced to support decision-making.

The conceptual framework, decision criteria and decision rules were presented to some of the interviewees for validation. The concept and emphasis, the criteria and requirement of the prototype system were found to be sound and applicable to the actual prequalification process. They also found CP-DSS to be user-friendly, as the system only requires the users to define the project details by simply entering the value or selecting from the pull-down menu, and the evaluation process is then carried out by the system automatically.

The results of the above testing and validation studies indicate that the prototype is a very promising system for improving the objectiveness, quality and reliability of current prequalification practices.

CONCLUSIONS

A three-level decision support system for contractor prequalification, CP-DSS, is described. The system offers certain improvement to the existing prequalification practices:

- a wide range of data is evaluated quantitatively and systematically,
- no deterministic rating or subjective judgment is required,
- an objective short-list of tenderers is produced to support decision-making, and
- ease of use by busy decision makers.

These benefits were justified in the testing and validation studies. Users were prompted to input the project details. The system then evaluated all the available data of contractors

according to the decision rules and various models to produce an objective list of bidders for decision-making. Insufficient or inappropriate contractors were disqualified during the test to eliminate the possibility of employing an inappropriate contractor to carry out the project.

In the next stage of the research, the following improvements to the system are intended:

- the elicitation of heuristics from a wider spectrum of professionals and experts in this domain
- the employment of more knowledge elicitation techniques and an increase in the number of structured interviews and the sample size of the questionnaire
- testing the system by relevant experts with real data in order to calibrate the tolerance of disqualification
- refinement of the modelling techniques for appraising contractors and more models to be tested and included in the system to improve the quality and accuracy of appraisal to contractors
- the development of a large database for contractors in the database management system (DBMS) and linked to the expert system and a proper decision support system (DSS) package with various models being set up to evaluate this data
- more research on the methods of checking and testing contractor's data to ensure the data is accurate and consistent to be used for the evaluation purpose
- expansion of the concept to other types of contractors to develop a global but flexible decision support system for contractor prequalification

It is anticipated that an objective and well structured prequalification system, such as CP-DSS, can help to improve the objectiveness, quality and reliability of construction prequalification. In Russell's (1992) words *"reducing contractor failures and increasing the efficiency of the construction industry ... [which will] result in reduced construction costs and enhance the competitiveness in both domestic and internal markets"*.

ACKNOWLEDGEMENTS

Many thanks are owed to Mustafa Alshawi of Salford University, Vongue Coffey, Mike Lamont, Lawrence Chung, Helen Mak, of the Hong Kong Housing Authority, S F Kao of the Hong Kong Government Secretariat, Andy Wong of Vigers (HK) Ltd, Greg Keefe of Manchester Metropolitan University, and Scarlett Yim, K W Wong,

K K Siu, H W Law, K H Fung, S L Choi and Y M Yew. We are also indebted to the two anonymous reviewers for their kind and constructive comments.

REFERENCES

Calvert, R., *Introduction to Building Management*, Butterworths, 1986.

Drew, D.S. and Skitmore, R.M., *Prequalification and C Competitiveness*, Omega, 1993.

Flanagan, R., *Making International Comparisons in the Global Construction Market*, *Transactions*, The International Council for Construction Research Studies and Documentation W-65, Sydney, Australia, 1990.

Flanagan, R. and Norman, G., *Pricing Policy*, *The Management of Construction Firms*, ed. by P.M. Hillebrandt and J. Cannon, 1989.

Hong Kong Housing Authority, *Performance Assessment Scoring System (PASS) Manual*, Hong Kong Housing Authority, 1992a.

Hong Kong Housing Authority, *Short Form Questionnaire to Update Information on Companies Included on the Housing Authority List of Building Contractors*, Hong Kong Housing Authority, June, 1992b.

McCanlis, E.W., *Tendering Procedures and Contractual Arrangements*, RICS, 1974.

Ng, S.T., *Decision Support System for Contractor Prequalification*, Thesis Presented to the University of Salford in Partial Fulfilment of the Requirement for the Master Degree in Information Technology in Property and Construction, 1992.

Ng, S.T., *Using Object-oriented Techniques for Developing Integrative Expert Systems in Building Defect Diagnosis*, *Proceedings*, International Symposium on Economic Evaluation and the Built Environment, CIB W55 & W95, Laboratorio Nacional de Engenharia Civil, Lisboa, Portugal, Vol. 1, 1993.

Nguyen, V.U., *Tender Evaluation by Fuzzy Sets*, *Journal of Construction Engineering and Management*, ASCE, 111(3), 1985.

Ramus, J W., *Contract Practice for Quantity Surveyors*, Heinemann Newnes, 1989.

Russell, J.S., *Decision Models for Analysis and Evaluation of Construction Contractors*, *Construction Management and Economics*, May, 1992.

Russell, J.S. and Irtishad, A., *A PERT Approach to Contractor*

Prequalification Analysis, *Transactions*, American Association of Cost Engineers, 34th Annual Meeting, Boston, Mass., 1990.

Russell, J.S. and Skibniewski, M.J., A Structured Approach to the Contractor Prequalification Process in the U.S.A., *Transactions*, The International Council for Construction Research Studies and Documentation CIB W-55, Copenhagen, Denmark, 1987.

Russell, J.S. and Skibniewski, M.J., Decision Criteria in Contractor Prequalification, *Journal of Management in Engineering*, ASCE, 4(2), 1988.

Russell, J.S. and Skibniewski, M.J., QUALIFIER-1: Contractor Prequalification Model, *Computing in Civil Engineering*, ASCE, January, 1990.