# Design Decision Support from Informed Project Time-Cost Performance Simulation

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## ABSTRACT

The time performance of a construction project contributes significantly to overall project costs. The greatest potential for achieving better time and cost performance lies in the design stage of the project. This is when decisions which have the greatest impact on project performance are being made.

Designing for the best project time-cost solution involves a strategy of optimising project cost and time variables to find the best combination between these two parameters, such that project time and cost limits are not exceeded.

In practice, this optimization strategy will need to take into account the project objectives, the client's needs and limitations for the project, and the way the architect can assimilate relevant information in the design process. The obstacles which have prevented such a strategy being feasible include the separation of the design function from time and cost evaluation functions, and the information technology to provide decision support in a timely and affordable mode.

The paper describes the principles of time-cost planning and the conceptual framework for an expert system which can be informed of subjective factors particular to a project and simulate the construction time-cost performance of design alternatives.

The feasibility of designing for the optimal time-cost solution with support from this simulation approach is discussed.

Key Words

information technology; time-cost planning; design decision support; expert systems; simulation

## INTRODUCTION

The time required for the construction of a project is seldom accorded as much consideration during design as the construction cost of the project. Yet the time performance of a construction project contributes significantly to overall project costs.

In a study on 309 construction projects in Australia, Bromilow (1969, 1971) found that about 8.4% of the total end costs to clients were due to holding charges. This did not take into account other losses or opportunity



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costs caused by delays in the completion of building projects. He also reported that compared to building contract costs which were usually relatively well controlled, construction time was not and this had significant repercussions on the costs of the projects (Bromilow, 1972).

Many writers, including Dell 'Isola and Kirk (1981), Kelly (1982) and Flanagan and Norman (1983) have advocated that the greatest savings potential occurs in the early stages of a project life cycle, including the design phase of the project. A recent Royal Commission investigation into productivity in the building industry in New South Wales estimated that improvements of between 5% to 20% in time performance could be easily achieved by planning activities carried out before the construction stage, including designing for buildability, construction planning during design and higher quality design documentation (Gyles, 1992).

Most existing project planning and management techniques are tools for post-design application. When construction planning occurs after the design solution is finalised, the construction costs are treated as predetermined and programming usually focuses on arranging construction activities to minimise time project duration.

Considerable project benefits can be achieved through effective project time-cost planning during design. Time-cost planning may be defined as:

*"the process of bringing into consideration the effects of project construction cost and time relationships, so as to provide an information framework for better design decision making" (Chen, 1987).*

The objective of time-cost planning is to enable the solution with the optimal construction cost and time performance within project constraints to be identified during the design process.

Time-cost planning could be implemented as soon as there is sufficient commitment, to a particular conceptual design, to use time and cost information for the evaluation and development of the design. The later time-cost planning is implemented, the less effective the resulting measures will be. As with all decision processes, the more realistic and complete information that is available, the better will be the quality of decision making.

However, the compartmentalisation of functions in the overall project process creates barriers to information flow which degrade the quality of project decision making. The successful integration of time-cost planning with the design process needs to provide decision support which is relevant to specific project requirements, and compatible with design activities

This paper discusses the integration of time-cost planning into the design decision process and proposes a conceptual framework for an expert system which can formulate project specific decision rules and simulate the construction time-cost performance of design alternatives. The feasibility of such an approach in the light of existing information technology is examined.

**Decision Rules for Design Involving Time-Cost Planning**

In the design process, architects make decisions on behalf of the client, based on their understanding of project requirements. In order to function effectively as the design decision-making agents for the clients, they need to be able to evaluate choices with a project specific frame of reference which reflects the client's attitudes and preferences, the project objectives and the project constraints.

In terms of project time-cost planning, the strategy of optimising project cost and time variables can be stated as finding the best acceptable combination between these two variables such that project time and cost limits are not exceeded while achieving required project quality.

The decision rules for time-cost planning need to define:

1. a basis for comparison and trading off between project time and cost requirements,
2. acceptability criteria for design decisions, and
3. solution limits.

The four basic components of design decision rules involving time-cost planning may be described as:

1. time and cost decision limits,
2. project time utility and values,
3. client idiosyncrasies, and
4. conditions imposed by approving authorities.

*Time and Cost Decision Limits*

These decision limits define the area within which an acceptable design solution would be found. Project time limits are decided by the objectives of the project and the relationship with external events which affect the achievement of these objectives.

Project cost constraints may be in the form of a budget determined by the client or limits imposed on the client by available funding for the project. Flexibility in cost constraints contributes to the range of time-cost alternatives which may be acceptable within decision limits. Project budgets should take into consideration considerable savings in holding costs and the benefits of early completion which can be achieved through time cost planning.

*Project Time Utility and Value*

There is economic incentive to change a project duration as long as there is an anticipated net gain in benefits. This applies to both expediting project completion if the cost of project expedition is less that the expected increase in project returns, as well as extending a project program which had been unnecessarily restrictive and costly.

The reasons and incentives for expediting a project include:

1. earlier and more certain financial returns,
2. economic advantages (competitive edge, market share, etc),
3. social needs and demands,
4 political advantages, and
5. avoidance of problems or disadvantageous situations.

The value which the client perceives for the timing of a project's completion is subjective. The concept of "time-utility" may be used to describe the value which the client places on the timing of project completion, taking into account all considerations.

Project time-value is the value, in money terms, to the client, of a change in the timing of project completion from the original completion date. The time-value of a project is a function of the financial benefits of early project completion represented by reduced holding costs and earlier returns (project time-cost), as well as the utility which the client perceives the timing of the project completion taking into account all other subjective considerations (project time-utility). The concept of project time-value provides a common basis for trading-off between construction costs and the value of construction time.

*Client Idiosyncrasies*

Client idiosyncrasies described as the preferences of the client for things to be done in certain ways. In the organizational context, the idiosyncrasies may reflect corporate or institutional attitudes, policies and standards.

Client idiosyncrasies generate additional design decision constraints. They may be reflected in the formal requirements of the project brief. Even as informal requirements, they could create strong design constraints if the client is insistent on particular design directions.

The effects which client idiosyncrasies have on the design decision process needs to be identified and accounted for in the decision rules.

*Conditions and Constraints Imposed by Approving Parties*

All building projects are subjected to constraints and conditions imposed by parties outside the project decision-making team. The parties whose conditions affect the acceptability of the design solution include:

a) planning and building control authorities,

b) other authorities with special concerns affecting the project (eg. environmental protection, health and safety, licensing authorities, etc), and

c) non-statutory special interest groups (eg. financiers, trade unions, competitors, shareholders, end-users, neighbours, etc).

Figure 1 illustrates the sources and relationship of the components which determine the design decision rules involving time-cost planning.

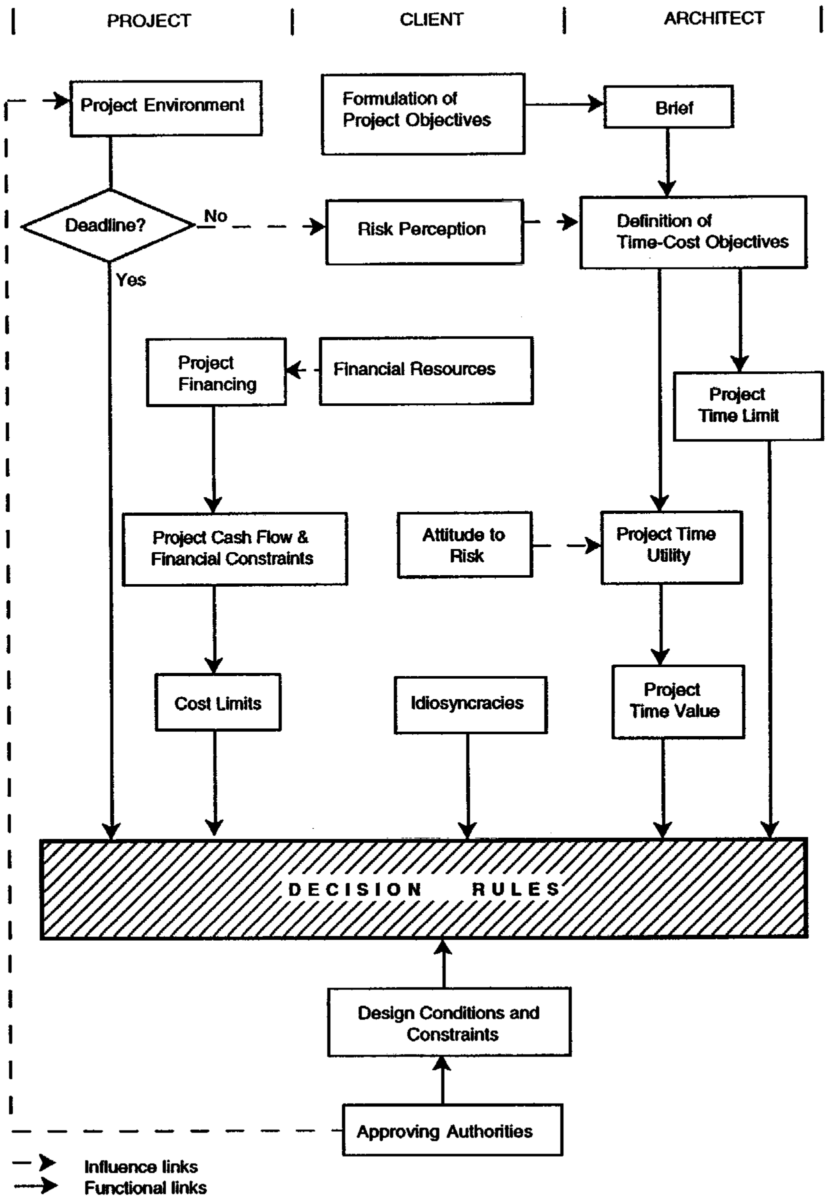


**Figure 1.** The Time-Cost Decision Rules Model

**Integrating Time-Cost Planning with the Design Process**

A major practical problem to the effective implementation of construction time-cost planning during the design process is the need to reconcile the requirements of an optimizing strategy with the efficient operation of the design process.

The design strategies used by architects vary considerably and reflect subjective approaches to solving complex problems. However, a characteristic which can be observed in architectural design strategies is the top-down development sequence from the conceptual to the schematic to the detailed. Each step of the development considers the solution in more detail.

Maver (1970) described a model of design activity, illustrated at Figure 2 which allows relevant decision support to be integrated at the activities of each stage of the design process and each level of the design morphology.

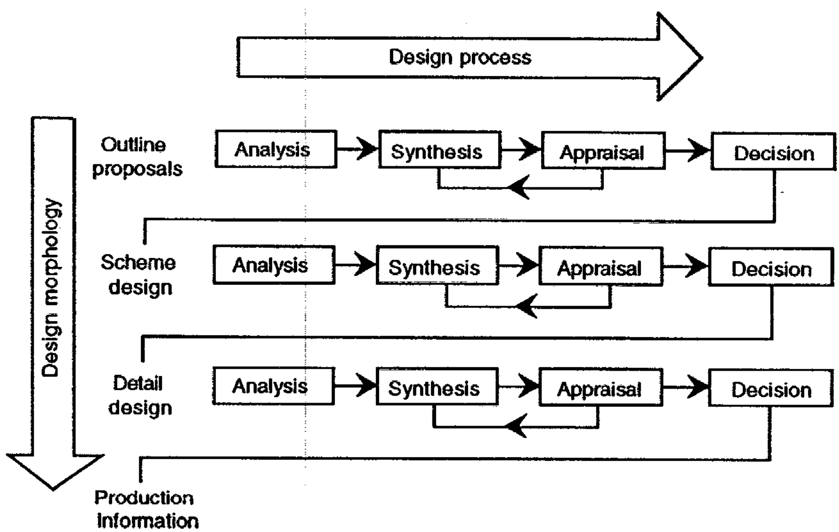


**Figure 2.** Model of Design Activity (after Maver, 1970)

**Simulating Project Time-Cost Performance During Design**

A practical strategy is to implement project time-cost planning at different levels of the design morphology, commensurate with the progress and information needs of the design process. Time-cost planning during design would involve the generation of time-cost information at the various levels to facilitate appraisal of design alternatives and refinement of solutions.

In the initial stages of design, when broad concepts are being explored, time and cost information would need only be indicative estimates. As the development of the design progresses, increasingly detailed time-cost planning information at activity level is required to enable realistic project time and cost parameters to be predicted.

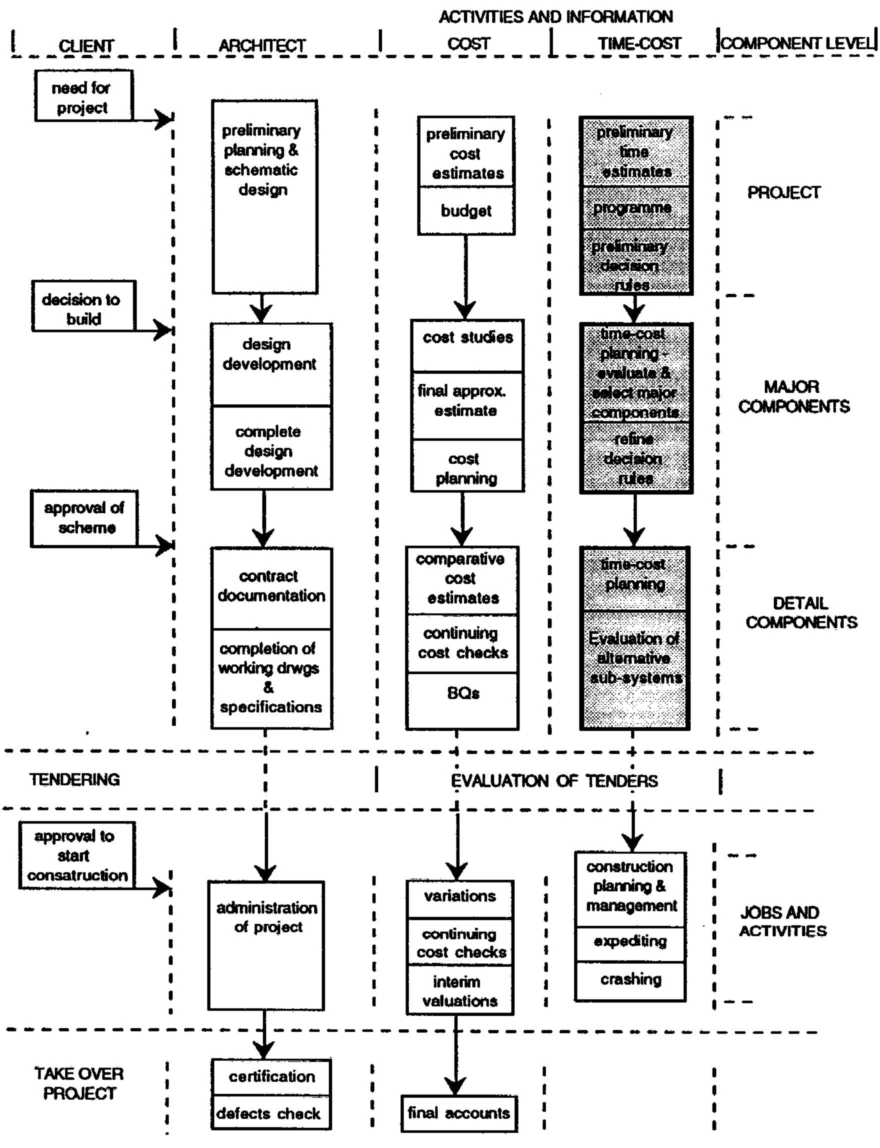


**Figure 3.** Project Activity Flow and Information Requirements

Figure 3 illustrates a typical project process with the corresponding time and cost information needs.

During the design process of a project, three different levels of time-cost information and planning activities may be identified. These occur at:

1. the schematic design stage,
2. the design development stage, and
3. the contract documentation stage.

At the schematic design stage, time-cost planning activities will be aimed at providing information at the project level. The estimation of cost and time requirements at this level may be derived from historical comparative data. Preliminary cost estimates may be calculated using volume or square metre rates from comparable projects for instance. Time requirements may be estimated using empirically measured time-cost functions such as the method proposed by Bromilow and Henderson (1977).

The information required to establish preliminary time-cost decision rules would also be available at this stage. As the work description at this stage is less defined, these rules should have potential for refinement as the design process proceeds.

At the design development stage, the conceptual solution needs to be defined in terms of the major components. Architectural, engineering and services systems need to be evaluated and selected. In terms of optimising time-cost options, this is the first level of evaluation. An appropriate strategy at this stage is to identify the combination of major components, in an acceptable design solution, which produces the optimal time-cost solution.

This range of major components would in the first instance be limited by what is acceptable within design constraints already established in the design decision rules. As decisions on the combination of major components are made, additional design constraints will be generated and applicable to subsequent stages of design development.

Figure 4 proposes an algorithm to identify an optimal time-cost solution at the major component level.

The first step in the sequence is to identify the boundaries of the major components which the project can be divided into. This could vary depending on the design approach of the architect. During the design development process, alternatives for these major components are considered and tested for acceptability against the design criteria which the architect has formulated at the conceptual stage. These could include subjective preferences, the influences of client idiosyncrasies, as well as requirements of approving authorities.

Only the alternatives acceptable by the applied design criteria need to be considered in time-cost planning. The alternatives of each component can be considered to form sets (A1, A2,...Ai; B1, B2,...Bi; ...N1, N2,...Ni). Each

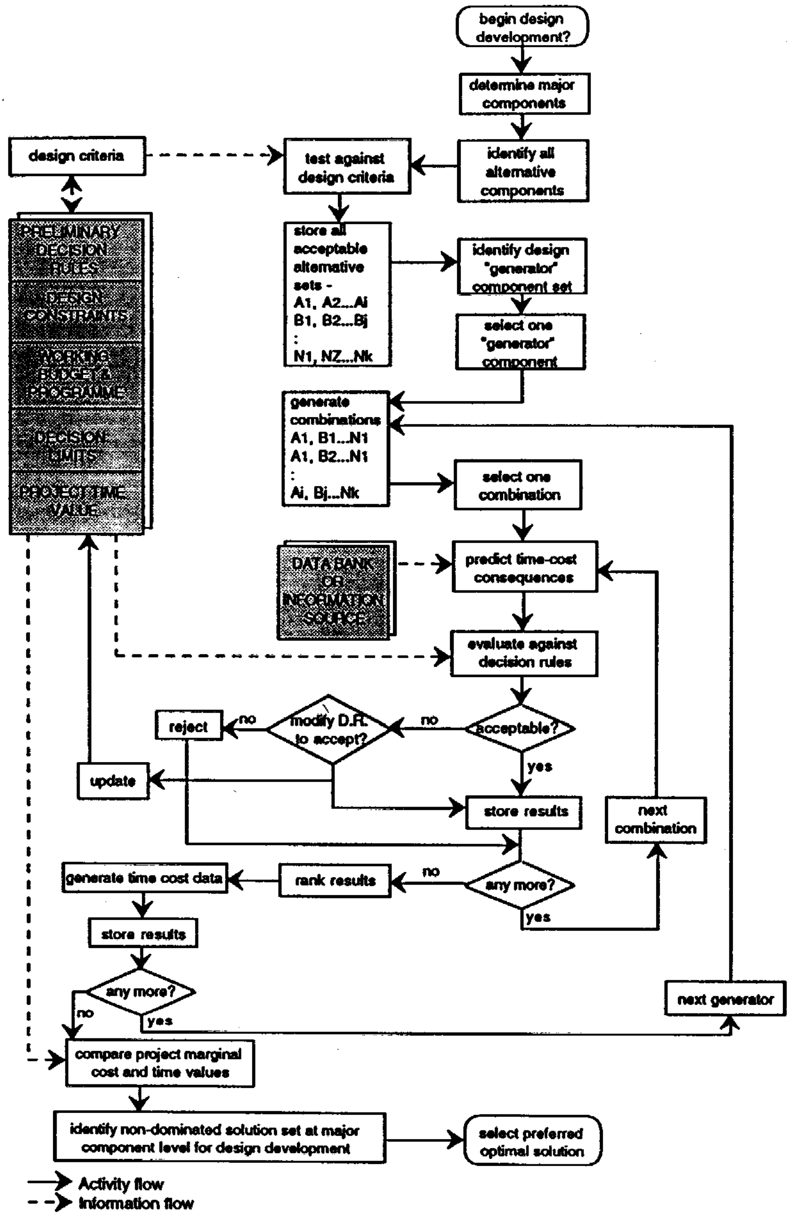


**Figure 4.** Algorithm to Identify Optimal Time-Cost Solution at Design Development Stage

alternative solution then consists of a unique and acceptable combination of components drawn from each set.

The development of alternative design solutions may be considered to begin with a selected "generator". This is usually a conceptually important aspect of the project which determines the nature and character of the whole assembly. Examples of "generators" include the structural system of a high rise building, the external envelope, the planning arrangement, sculptural form and so on. The "generator" component provides the starting point from which constructionally feasible solutions are developed. Alternative "generators" may also be used to explore a wider range of solutions.

All the acceptable alternative solutions generated provide information from which a set of non-dominated alternative solutions can be identified. A non-dominated solution is one which is not more expensive and requires more time than another.

In some cases, a solution inferior in time and cost performance may be considered to have other desirable qualities. In such situations, the architect may choose to intervene to alter the time-cost performance of the solution by reducing the cost requirements of that solution by an equivalent value of its desirable qualities.

The architect then can choose a preferred solution from the non-dominated set for detail design development and contract documentation. At this stage alternative detail components, which are compatible subsystems of the major components already committed to, are considered.

Figure 5 proposes an algorithm for identifying optimal time-cost solutions at detail component level.

The object of time-cost planning at this level is to select subsystems which improve the time-cost performance of the major components so that overall project time-cost performance is optimised.

The first step in this process is to establish an arbitrary "standard" project which will allow potential areas of expedition to be identified and to which the performance of alternative subsystems can be compared. Maver (1970), Radford (1981) and others support the approach that a design intuitively synthesised by the architect is an effective way of arriving at a first approximation from which the iterative process of appraisal and modification can converge towards an optimal solution.

Areas with potential for expediting the overall project progress can be identified from critical path analysis of the standard project. Strategies can be formulated to explore the areas in the major components which have been identified as having potential for expedition. Alternative detail components or subsystems can be substituted for the "standard" detail components in these areas. Sometimes the use of a time or cost saving subsystem on a critical path may open up other areas of potential expedition. These may be followed up as part of the overall strategy.

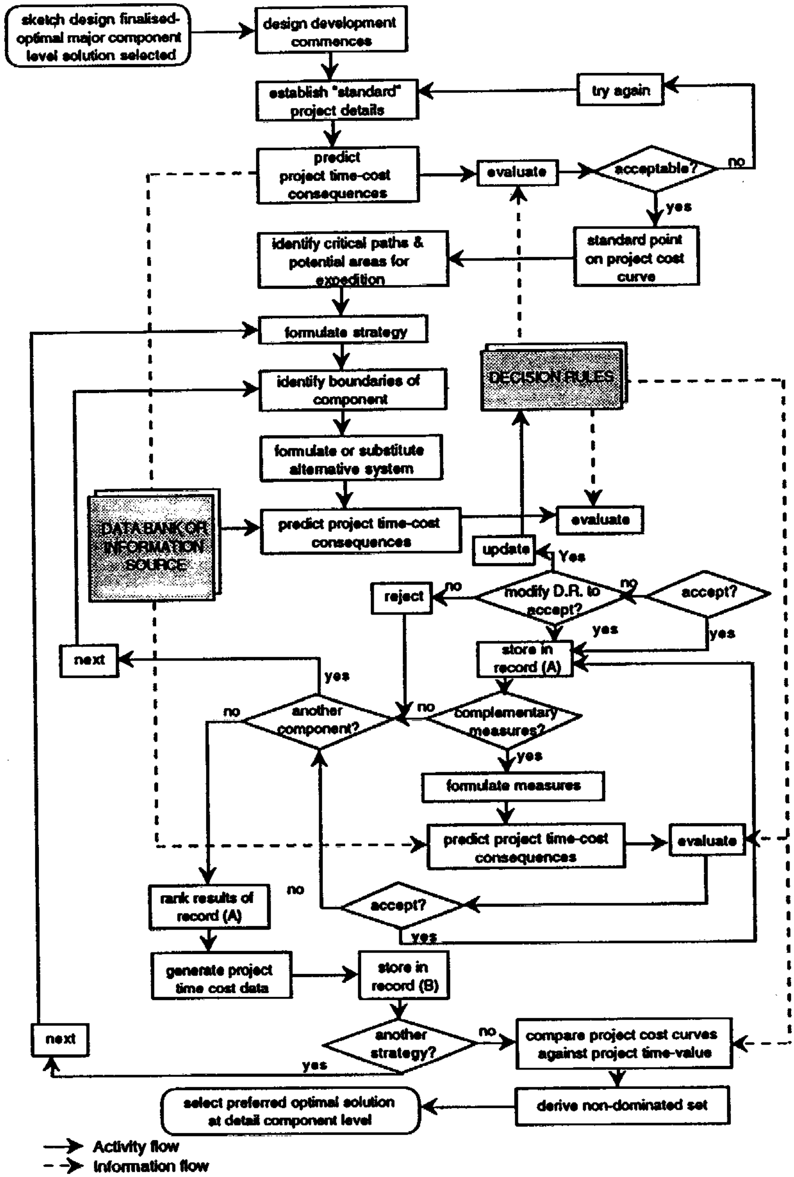


**Figure 5.** Algorithm for Identifying Optimal Time-cost Solutions at Detail Component Level

Each complete strategy would result in the generation of a number of expediting measures which will change the overall project time and cost requirements. These measures are evaluated for their acceptability against design criteria, constraints and other decision limits. The acceptable measures may then be ranked according to their cost requirements and a set of non-dominated solutions selected.

The procedure can be repeated for as many unique strategies as can be formulated by the architect. As for the previous level of time-cost planning, a non-dominated set of solutions may be identified. The preferred optimal solution at detail component level can then be chosen from this set of solutions by comparing the marginal cost of expedition against the project marginal time value.

**Discussion**

The concept of time-cost planning or optimising construction cost and time during the design process is one which has only become feasible with the availability of powerful computer technology.

The decision support model for time-cost planning described in this paper integrates tools which interact with users and extensive databanks, and apply the knowledge and heuristics of experts. It provides the framework for a project decision expert system and the development of an "intelligent" computerised decision support system. Such a system is consistent with the development towards computer guidance tools for the construction industry envisaged by writers such as Warsawski (1985) and Mathur(1988).

Other recent developments have enhanced the feasibility of the proposed approach. The realisation of the potential of Information Technology for the construction industry have initiated the development of standards for coordinating building project information and data exchange. The Association for the Coordination of Building Information in New Zealand (ACBINZ) is working to obtain consensus on a standard building information system (Doherty, 1993). The National Committee on Rationalised Building (NCRB) in Australia recently proposed a strategic model for an information and decision support system for the building industry in Australia (Leslie, 1992). These developments will be eventually enable industry knowledge and data bases to be constructed and facilitate electronic data availability to all participants in the industry.

The proposed approach also embodies two major changes from traditional practice in the construction industry. These are :

1. the generation and assessment of a large number of alternative design solutions for a single project to facilitate the optimization search, and
2. the application of multidisciplinary information during the design process.

The first function requires powerful, inexpensive and convenient information processing capabilities which did not exist until recent times. The second requires integrative communication links which overcomes the space and time barriers between various disciplinary experts and the client during the project design process. The technology to enable these functions are now readily available.

These changes are necessary if the construction industry is to challenge some of the productivity barriers that have limited the conventional practices of design and construction management.

## CONCLUSION

The development of management tools which harness the potential of information technology is important to drive the necessary changes in the construction industry towards more productive practices.

The provision of design decision support by informed project time-cost performance simulation is one approach which will facilitate a quantum improvement in construction productivity.

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