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APPLICATION OF THE ANALYTICAL DESIGN PLANNING TECHNIQUE IN THE PROJECT PROCESS

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ABSTRACT

Traditionally, the building design process has been poorly understood and planned, and has been treated as completely separate from the construction process. This has resulted in a range of inefficiencies in the overall project process. This paper describes two related research projects which have produced techniques for planning and managing the design process, and improving the way the design and construction processes interface. These techniques are based around the use of process models and the application of dependency structure matrix (DSM) analysis, an optimisation tool, and have been developed through joint industry and UK government research. The research is being undertaken at Loughborough University in the UK, and the findings and techniques are being tested and applied in industry by designers and planners from the projects' collaborating organisations.

Keywords – Design, Construction, Processes, Integration, Planning.

1. INTRODUCTION

Previous research at Loughborough University has shown the successful application of the Analytical Design Planning Technique (ADePT) to simple design problems. This paper describes the development and testing of software tools to enable the ADePT methodology to be utilised on highly complex detailed building design problems. The research has proven the viability of ADePT as a technique to plan and manage the detailed building design process. Further research, modelling the interface between design and construction, giving an insight to the optimal timing of introduction of suppliers to the project process is being undertaken and is described.

2. FRAGMENTATION OF DESIGN AND CONSTRUCTION

The recently published Egan report⁽¹⁾, outlining approaches to improving the UK construction industry, identified the separation of design from the rest of the project process as a fundamental weakness in the construction industry: a significant re-balancing is required to integrate design with construction and performance and to ensure that issues such as flexibility of use, operating and maintenance costs and sustainability are considered in the design and planning stages of a project.

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The report identified the need for designers to work in close collaboration with the other participants in the project process. In current practice, tasks in different disciplines are not as well co-ordinated as those within a single discipline, because of a lack of understanding of the entire design process, and there is a lack of co-ordination of information exchange between the design and construction stages of a project due to fundamental differences in the nature of the stages and longstanding boundaries between the participants involved in them.

3. THE ANALYTICAL DESIGN PLANNING TECHNIQUE

The Analytical Design Planning Technique (ADePT), which has been developed over the last six years, consists of three main components, as indicated in figure 1: a model of the design process defining activities and their information requirements, the driving force behind design development ⁽²⁾; a Dependency Structure Matrix (DSM) analysis tool which is linked to the model via a database and identifies the optimal sequence of tasks and iteration within the design process ⁽³⁾; and a design programme which is integrated with the project plan through further DSM analysis ⁽⁴⁾.

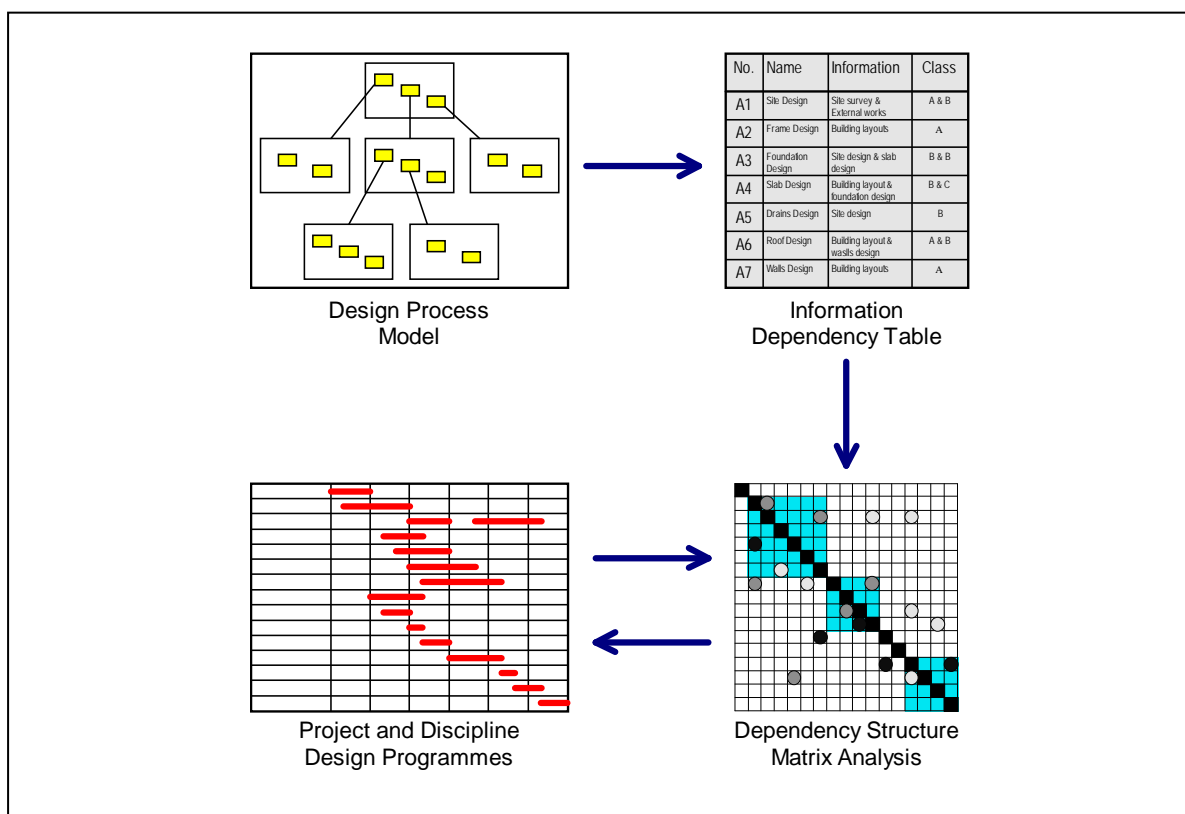


Fig. 1. The Analytical Design Planning Technique

3.1 Design Process Model

The model depicts the detailed design stage of a building project, although ADePT is applicable to other project stages and types of construction. The design process is represented hierarchically, the first level of which comprises the activities of the traditional design disciplines. This approach has been adopted because it reflects the way the industry currently works (and hence eased the compilation of the model), but the DSM stage of ADePT identifies a design sequence independent of the model hierarchy, which in turn can be used to structure multi-disciplinary design teams. The bottom level of the model's hierarchy represents elementary design activities and their associated information requirements and

outputs. Four types of information are distinguished at the detailed level of individual design tasks: intra-disciplinary; information from external sources; and cross-disciplinary information flows, which are regarded as more difficult to manage.

The model represents the design process at a generic level: that is to say it incorporates activities and information that can describe the design of a wide variety of buildings. Testing of ADePT has shown that over 90% of the necessary activities are included in the model to define the design of projects ranging from a £16M office development to a £160M hospital redevelopment ⁽²⁾, a finding in tune with the Egan report's view of the repeat nature of construction projects and the need for standardisation of processes as well as products.

3.2 Dependency Structure Matrix Analysis

A simple example of a Dependency Structure Matrix (DSM), the second part of ADePT, is demonstrated in figure 2. In figure 2(a) it can be seen that design tasks are listed arbitrarily in the rows of the matrix and that the order is mirrored in the columns. A mark in the matrix represents a dependency of the task in the row upon the task in the column. The dependencies are weighted on a three point scale (A, B, C) on the basis of the strength of dependency, sensitivity of the receiving task to changes in the information and the ease with which the information can be estimated. Dependencies weighted A or B are considered critical, while C is not essential to the task and does not contribute to iteration in the process. If design is undertaken in the order on the matrix from top-left to bottom-right, the shaded area indicates a need for iteration within the process. Figure 2(b) shows the matrix following analysis to determine the optimal sequence of tasks such that iteration is reduced to a minimum. It can be seen that the number of critical marks above the diagonal and the size of iteration within the process have been reduced. Testing of ADePT has shown that interdependent loops of design activity highlighted within the matrix correspond to areas of the design requiring careful co-ordination such as co-ordinated ceiling layouts or substructure and underground services. The activities in these loops are more often than not multi-disciplinary and hence co-ordination of work across the disciplines is required.

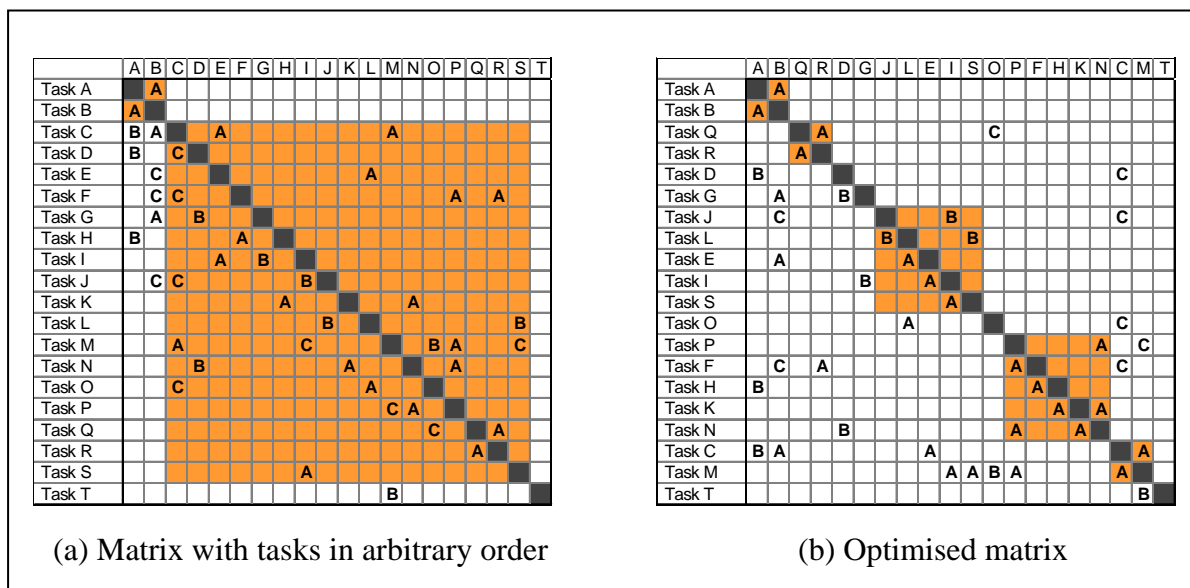


Fig. 2. A simple example of Dependency Structure Matrix analysis

Where the design team are required to achieve co-ordination in their solution, they may be co-located or expected to develop the design through a series of workshops, suggesting a change to the way complex co-ordination is approached, which to be effectively undertaken, must be tackled differently from areas of design where co-ordination is not such a serious issue. The blocks of interdependent design activity require a concerted management effort, rigorous review strategy and a strong link to the client's decision making and approval processes. They also highlight where a concurrent, collaborative working strategy is appropriate for the design team members, who must liaise closely in all decisions, understand each others' design requirements and constraints, and have confidence in each others' commitment to the achievement of a common aim. The fulfilment of these ambitions can be encouraged through the co-location of members of the design team or, where this is impractical, via the implementation of effective electronic communication techniques.

Testing and assessment of the technique has required the development of prototype software tools, particularly for the matrix analysis and data transfer, the process modelling and programming being carried out with proprietary products.

3.3 Programming

In the final part of ADePT, the sequence of tasks in the DSM is transferred to a project management program to create a programme of the design process by addition of resources and duration. The 'loops' of iterative work can be programmed to ensure the design is developed efficiently and the optimal programme provides a starting point for the integration of design within the project process, an operation that involves further analysis of the DSM.

4. INTEGRATING DESIGN AND CONSTRUCTION

Historically, design and construction have been viewed as two separate systems, with different resources, programmes and budgets. This has led to the development of two entirely different cultural entities, i.e. the design team and the site team. In order to integrate the two, it is necessary to explore and gain a good understanding of the processes by which design and construction teams operate and how they relate and depend upon each other.

4.1 Programming the Processes

In order to integrate the processes of design and construction, it is important to develop a project programme that represents both an optimised design, and construction period. By this it is meant that it is no longer acceptable to rely upon a programme which is largely focused on construction activities alone. Instead, a greater understanding of both design and construction processes will lead to the elimination of waste caused by over-design, iterative design and co-ordination problems through the use of optimised planning techniques.

Scheduling the design process with ADePT identifies the optimal sequence of tasks to satisfy the development of a design solution. This means that the programme produced in the final stage of the technique's implementation represents this optimal design process. In practice, it is highly unlikely that this sequence will be realistic because of the constraints put on the process by the need to deliver a building in a short a timescale as possible: the design, procurement and construction processes overlap and therefore design information must be released to contractors before the ideal time. A knowledge of the optimal design sequence, when combined with a view of the ideal construction sequence (which is relatively easy to determine with the use of readily available project planning tools), provides a good starting point to integrate design within the wider project process. Figure 3 depicts the philosophy of integrating design and construction processes and programmes. This integration is not straight-forward, as the two processes do not fit together

comfortably. In order that they are integrated, the constraints that each process puts on the other must be considered. For example, foundations are one of the last building components to be designed (ideally), but they are one of the first to be required on site which means there is usually a need to design them out of the optimal order i.e. the construction process imposes a constraint upon design. In figure 4 it can be seen that moving a task (M) in the optimised DSM results in some critical information placed above the diagonal. In order that this does not create interdependencies within a large proportion of the design process, the information must be dealt with in a way that ensures it does not need to be revisited at a point later in the process, by fixing or conservatively estimating the information.

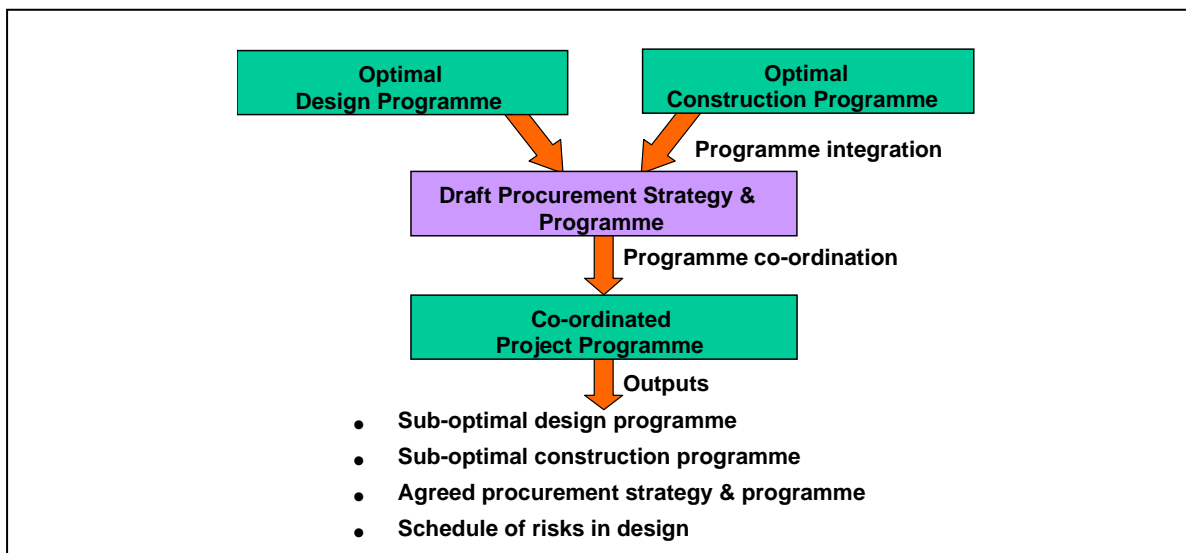


Fig. 3. A schematic of the integration of design and construction processes

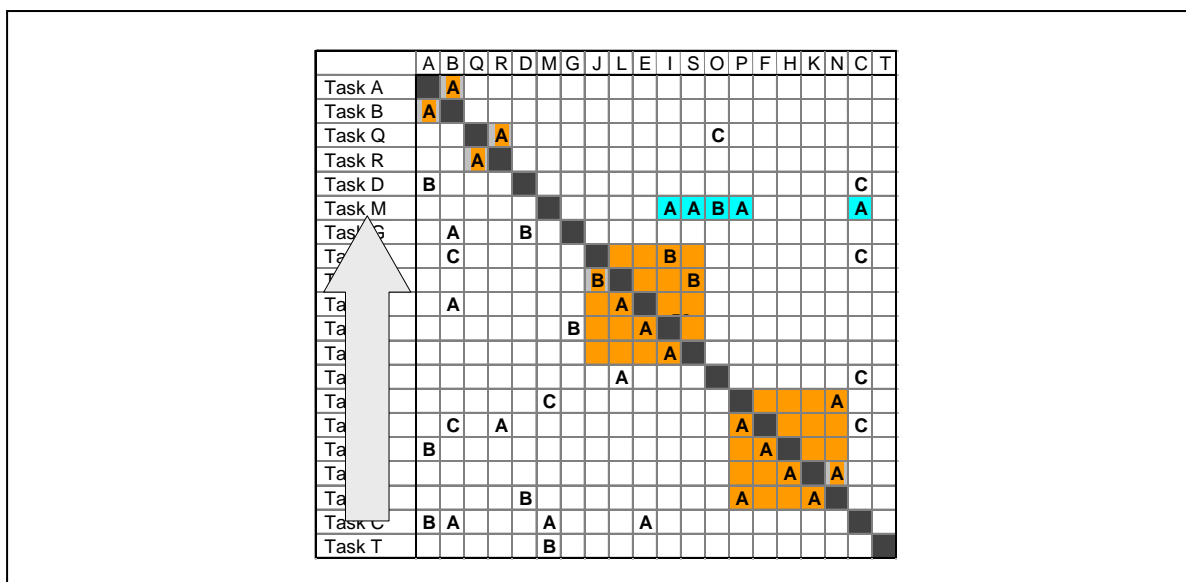


Fig. 4. The effect of constraining the design process to suit construction

Figure 3 indicates the outcome of integrating the two processes: constrained (or sub-optimal) design and construction processes (with corresponding programmes); a procurement strategy that is mutually agreed by consultants and contractors following objective decisions about the impact of incorporating constraints; and a schedule of the risks in the design. This schedule is

produced through the analysis of the constraints on the design process: the cost of fixing or estimating information within the design can be compared against the risk of not doing so, thereby allowing the engineering economics in design to be assessed and logged in a risk register. As such, ADePT can act as a tool to compliment risk management. It identifies areas of design where risks are present, illustrates the scale of risk in the design process itself and contributes to the development of a legacy risk register for use in future projects.

4.2 Introduction of Contractors and Suppliers

The integration of the project process allows the participants to engage in a timely manner. Having established an approach to undertaking the design and an agreed procurement strategy, the design associated with each contract can be examined to determine whether it is best undertaken by a consultant, contractor or sub-contractor, and selecting and matching the individuals involved in this process becomes an important step in successfully managing the design process⁽⁵⁾. In some cases, it may appear logical that the contractor is not involved in design until a late stage in the process, however it could prove beneficial to introduce their expertise earlier if the design of the relevant systems and elements require full co-ordination with other contracts (either in the design itself, or on site). Alternatively, it may seem sensible to introduce contractors early in the process (to encourage as much of an integrated project as possible), although this may result in an uneven design workload while they wait for consultants or other contractors to develop their own design. This can result in money being paid in the form of a retainer while no work is being undertaken in return, and increased costs associated with contractual arrangements such as two-stage tendering. Therefore, it might prove beneficial to delay the introduction of the contractor.

The matrix analysis stage of ADePT provides a means of assessing the impact of each package of work upon the others, and the need for co-ordination between them. In response to Egan's call for integration within the project supply chain, incorporating techniques and approaches from other sectors, such as the automotive industry, the application of ADePT to the fabrication design stage of a project is being examined as part of the Integrated Collaborative Design research project. This will determine strategies for integrating contractors and suppliers into the consultants' design process in a manner that is both timely and that allow the design co-ordination and contracts to be effectively managed. The key to this approach is that participants should be introduced into the project early enough to allow their design to be co-ordinated with other parts of the project, and as late as possible such that their design is not constrained by decisions made by the consultant. This concept is beginning to be termed the 'last responsible moment' and applies to the design process in general where delaying decisions helps to maintain flexibility in the design for as long as possible.

4.2 Integrating Processes

The identification and improvement of design and construction processes can only eliminate part of the wasted time and effort from the construction project process if they are controlled and integrated. Following on from the need to develop a project programme to suit design and construction, a further key issue associated with the integration of design and construction is the effective translation of design information into installation and fabrication information, and ultimately material flow⁽⁶⁾.

The translation of detailed design information into construction information relies upon the effective communication of information from the designer to the sub-contractors, fabricators

and installers. At this transition the relationship between designer and constructor is probably at its most critical, and there is obvious scope for waste due to:

- Poor quality of the design information passed on from the designer to the supplier⁽⁷⁾.
- Ambiguous definitions of scope of service and roles and responsibilities.
- Contractual terms and conditions applied by the main contractor on the supplier.

Discussions with consultants, contractors and suppliers within the industry has also highlighted further issues leading to waste and inefficiencies within the process:

- Poor understanding of the suppliers' skills and capabilities.
- Inefficient administrative procedures, which inhibit the development of a closer working relationship between supplier and main contractor.
- A misunderstanding of each others' business operations.

The process represented in figure 5 illustrates the way in which design information is converted into co-ordinated installation information, fabrication information and material flow. The designer passes on detailed design information to the appointed supplier who then finalises the design and co-ordinates all production information with other suppliers. This finalised design information is fed back to the designer for checking and once approved is used to develop fabrication information.

Information flow is the key to the success of the integration of the two processes. In most cases the transition from design to construction involves a shift of responsibility from one organisation to another, therefore, the quality of information and its timely exchange is critical.

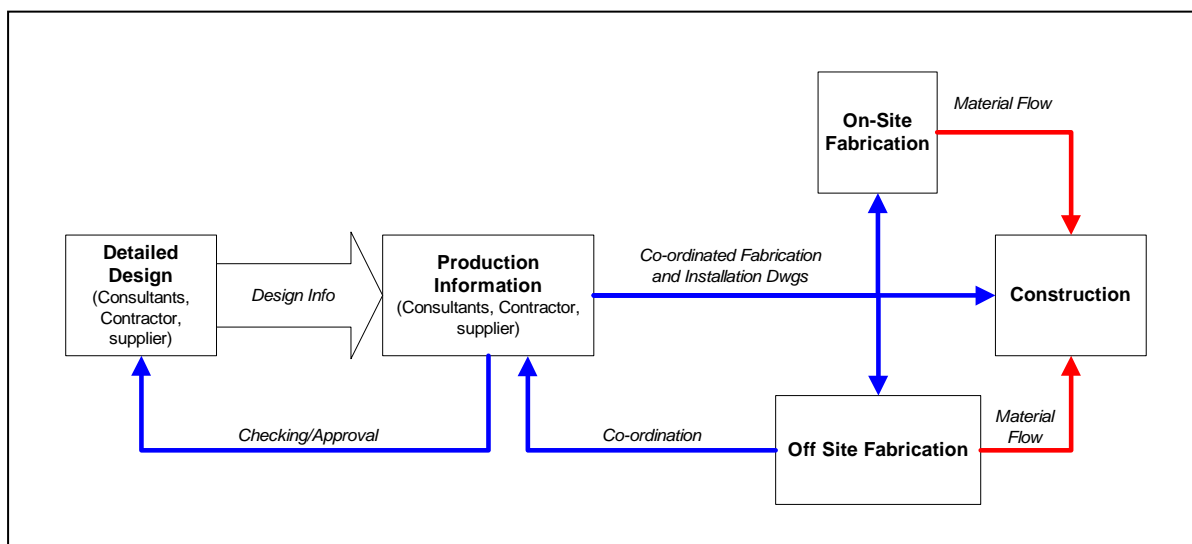


Fig. 5. The relationship between Design and Construction

The detailed design model described in section 3.1 is being extended to the production information stage (as defined in the RIBA Plan of Work⁽⁸⁾) to enable designers and constructors to successfully plan and integrate their work by identifying what activities need to be done, who is best placed to do them, and when they should be done to optimise the order of site activities and material flow. This will mean that not only will there be a better understanding of the processes involved in the transition between project stages, but also that

improved quality of information is passed between the stages, by the right people, at the right time.

The extended model will also identify what information is needed to progress the production information stage, creating an *Information Pull* from the supplier rather than an *Information Push* from the designer. This will help to lead to:

- Clearer definition of the scope of service and the roles and responsibilities within the design and construction teams.
- Identification of the information requirements of all team members.
- Improved understanding of the optimal integration of suppliers.

These benefits will help to overcome the problems commonly experienced when information is transferred from design consultants to contractors, such as the inappropriate timing of information exchange, and an inappropriate quantity or completeness of information at the time it is exchanged.

The research project ultimately aims to develop a supply chain framework based on the model of detailed design and production information stages that will overcome the problems discussed earlier.

5. CONCLUSIONS

Through the use of process modelling, DSM analysis and the production of design programmes, the planning of building design can be approached in a more systematic manner compared to that that is widely adopted at present. The application of developed software has given an indication of the full benefits to be gained from the ADePT methodology, including:

- The technique acknowledges the iterative nature of design.
- It identifies and accurately programmes crucial multi-disciplinary co-ordination activities that require a collaborative working environment to be undertaken effectively.
- It allows key information estimates and fixity requirements to be identified.
- It can help to identify effective design and procurement strategies.

The extension of the ADePT model from detailed design to the production information stage of a project will identify supplier design activities and co-ordination issues and therefore highlight waste in the design process. This will enable the optimisation of activities in the process and the timely introduction of suppliers, which will in turn help to eliminate this waste.

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