Process modelling for planning, managing and control of collaborative design

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Introduction

Process modelling has become an established tool whereby the information requirements of the design team may be identified, mapped, modelled and then reviewed to ensure that the final design and the design process take cognisance of all the stakeholders involved within the project. Over the last decade several techniques and products based on this approach have emerged. The ADePT technique developed from initial research at Loughborough University has been used for the management of the design of a range of infrastructure projects and engineering products. The methodology that has subsequently evolved has helped to: ensure the rigorous planning of design; control design deliverables; manage customer expectations, assist with change management; and ensure the development of robust process and control systems.

Over this period the approach described in this chapter has been implemented on over 40 projects in the UK and worldwide, with a total contract value of over £4Bn. Evidence of the overall impact of ADePT implementations has been gathered by ongoing research undertaken by the writers, feedback from individual project teams and by independent assessment. The writers’ close association with the initial research that led to the ADePT technique, and the subsequent methodology and its implementation have enabled them to fully monitor and review not only the development of the methodology but also its adoption and use for collaborative design across project teams.

This chapter considers collaborative design to be project based design involving multi-disciplinary teams. It outlines both the ADePT technique, the original method, the subsequently developed methodology, the body of methods that have been produced, and their adoption within a collaborative design environment. Three case studies are introduced to highlight the use of process mapping, the repeatable nature of design, and the control of workflow. Lessons learned for the transfer of innovations are also discussed.

The ADePT Technique

The development of the Analytical Design Planning Technique, ADePT has been widely reported. Full details of the technique may be found in Austin et al, 1999, 2000, 2002. The following text taken from Baldwin et al, 2007, provides a summary of the technique.

“ADePT enables the planning of building design to be approached in a more systematic manner through the use of process modelling to produce a model of the information required, analysis of the models by a technique known as the Dependency Structure Matrix, and the production of design programmes. It provides a way to understand the entire design process by taking a systems view to design. The technique improves the efficiency of the design process by reducing the level of iteration in design tasks, providing an understanding of the effects of change and reducing abortive work. It enables the constraints of earlier design and subsequent construction processes to be managed.
The technique may be viewed as a four stage technique. The first stage involves the production of a model of the design process which identifies the design tasks involved and the information requirements for each of these tasks. (To assist with this task a generic model of the information required at the detailed design stage of a building design comprising some 106 tasks and 104 information flows is available.) The second stage transfers the data into a matrix form, (the Dependency Structure Matrix, DSM), which is used to identify loops within the iteration process. The third stage is the re-arrangement of the task order to break down the iteration block producing an optimised DSM. This enables the programme for the design of the building to be revised based on the optimized design process. The fourth stage enables the output from the DSM matrix to be input into a conventional project planning software package. Figure 1 shows an example from the model. Figure 2 shows the four stages of the Analytical Design Planning Technique in diagrammatic form.”

**From Technique to Methodology**

ADePT has been used across a range of projects and disciplines under different forms of procurement. The ‘generic model’ developed to provide the basis for building construction has also formed the basis for modelling the information requirements of other civil engineering and construction works. The predominance of Public Private Partnership programmes for the National Health sector of government has led to a range of successful Hospital and Health Care commissions. Similarly the methodology has been adopted by those responsible for a number of new Schools and Ministry of Defence, (MOD), projects. All these projects have been characterised by their multi-disciplinary nature and the need to identify, understand, and manage the interfaces between design disciplines and management processes. Experience gained in using the technique has led to a broader methodology for Design Management.

Use of the technique in a commercial environment highlighted the need for improved management of the design deliverables as ‘packages’ of work. In addition to the constituent parts of the ADePT technique shown in Fig 2 additional tools and techniques based upon spreadsheet methods have been developed to enable the monitoring of this ‘work flow’, a process integral to the production of design deliverables. The resulting methodology is shown in Fig 3. This includes: defining the design process; optimising the design process; producing the project and departmental schedule; and performance measuring and reporting.

Adept Management, a ‘spin-off company’ formed in 2002 to provide design management consultancy, market the software and associated software products has developed templates of design activities for use on typical building design projects. These templates contain all the necessary logic and information flows within the design process and may be quickly amended to suit the specific requirements of the project and the procurement activities included to produce co-ordinated design and procurement programmes.

Using the methodology has highlighted the need for not only managing the design process at the early stages of the design but the need to continually monitor the design process through to the completion of the design. The importance of planning the design process has to be supported by the management of the design process. The ADePT methodology provides a level of detail previously unavailable to senior management, a basis to understand a range of different design solutions and detailed analysis of the information needs of the design and construction teams. Whilst those
involved in the production of design deliverables may recognise the benefits of the technique this does not mean that these organisations readily change existing work patterns and fully commit to providing updated production information. An inability to contribute fully may be due to resource availability, contractual restrictions and/or a reluctance to provide information because of commercial sensitivity. Collaborative tools and techniques do not automatically overcome existing business culture.

ADePT has been particularly successful when linked with the approach to planning identified as ‘Last Planner’, see Ballard and Howell, (1994), Ballard, (2000). Planning that adopts the ‘Last Planner’ philosophy ‘follows a production management philosophy that includes reliability scheduling and controlling design activities.’ Combined together, ‘Last Planner’ and ‘ADePT’ have been termed ‘DePlan’. This methodology “helps planners to generate quality plans, that is, plans that express what is ready for execution; by sequencing activities in the right order; by identifying informational and resource requirements ahead of design execution; by sequencing activities in the right order; by identifying informational and resource requirements ahead of design execution; and by scheduling only those activities that have met these requirements.” Choo et al, (2004). It focuses on what can be achieved with the resources currently available whilst highlighting the design tasks that are unable to be commenced. The overall ADePT approach, incorporating DePlan, is summarised in Table 1.

This way of working and its benefits may be summarised as follows:

- it identifies and removes turbulence from the project process;
- it provides greater certainty of design co-ordination;
- it offers the ability to better prioritise design work;
- it integrates sub-contractor design with consultant design in an effective way;
- it makes management of design change is more effective than is typically the case;
- it improves collaboration between design team members; and
- it focuses the team through workflow control to task completion.

To achieve these benefits it has been found essential to adopt a facilitated approach to planning whereby a facilitator, “defines the high level structure of a design plan; involves the design team members at appropriate times in defining the design scope and identifies issues around the interfaces between design, procurement and construction- and enables a consistent and meaningful programme to be produced.” Choo et al, (2004). One party has to take responsibility for the control and production of the design information. This role of Design Manager, responsible for the modelling, analysis and subsequent monitoring of the design deliverables may be allocated to one of the organisations involved in the project or may be undertaken by an outside consultant.

Case Study Examples

Case Study 1 – Process Mapping

The Highways Agency introduced their Early Contractor Involvement (ECI) form of contract to gain benefit from contractors’ input at the early stages of design on new highway schemes. This early
input would ensure the design solution could be built safely and efficiently, was maintainable, and was sustainable. Having to introduce their Project Managers into the design teams at an earlier stage meant that the roles of the contractor’s Project Manager and the consultant’s Design Manager, and the interfaces between these roles, needed to be defined.

Adept Management worked with a major civil engineering contractor and their five design partners to develop process maps of the early stages of the highway design process and of the corresponding management processes. The design process maps covered six key disciplines: traffic and economic analysis; structures design; highways design; geotechnical design; environmental analysis and design; and statutory procedures. It was clear from the maps produced that the highways design process was the central element of the overall design process since a high proportion of the information exchanges between design team members passed through this design discipline. The design process maps were developed with input from all five design consultancies. There was a very high level of commonality of approach between the companies, with only minor differences around terminology and no fundamental variations. This reinforces one of the basic premises behind the ADePT approach: that generic templates can be produced and implemented on a range of projects because, whilst the product may vary, the design process is largely generic.

The management process maps covered eighteen aspects of the Project Management, such as Risk Management, Value Management, and team communication. All cross disciplinary information dependencies were identified, whether they were across the design disciplines or between design and Project Management. Of course these were based on the team’s current understanding of projects rather than any experience under the ECI contract. So, as expected there were interfaces between designers and the contractor’s Project Manager where the direction and timing of information exchange was unclear. However the integrated set of process maps provided valuable insights to the team over where the Project Manager should intervene in the design process and the division of responsibilities between Project Manager and consultant’s Design Manager.

In this study, as is often the case where process mapping is seen as a useful tool, the motivation is to introduce a new or improved process. However the new process is something of an unknown and so an existing process is what is mapped, thus allowing waste to be identified and removed and the new process to emerge. Adept Management used Dependency Structure Matrix analysis to identify interdependence in the integrated highway design process which had been mapped. Key decision points could then be identified and the timing of information exchange between designers and the Project Manager could be clarified. This analysis was, in effect, the first step in redesigning the process to suit the ECI contract.

The civil engineering contractor and their design partners now have the process map available as a template, thus enabling robust integrated action plans to be put in place on future ECI contracts.

**Case Study 2 – The Repeatable Nature of Design**

When the MOD commissioned the redevelopment of one of their largest garrisons, the challenge facing the design team was significant. The site was to incorporate around 130 buildings in total and, whilst the overall project timescales did not present a major problem, some of the design deadlines...
were extremely tight, being dictated by the MOD’s design check procedures and timescales. In addition, with so much design information to be produced, managing the resource requirement on the design team was a critical element.

The consultant was developing a range of standard solutions to be rolled out across the buildings. With such a wide (and fast) roll-out it was imperative that the design solutions were fully co-ordinated first time as any problem would need to be dealt with as many times as the design had been rolled out.

The multi-disciplinary design consultant wanted to put in place design programmes for each of the buildings. Rather than plan each building’s design independently, Adept Management worked with the consultant to identify a small number of ‘generic’ building types, such as training buildings, accommodation, office space, etc. Then Adept Management’s generic building design templates were used to develop templates for each building type, which could then be tailored quickly to suit each individual building.

The templates produced were used to develop design programmes using the Dependency Structure Matrix stage of the ADePT approach. This then gave the consultant a suite of design programmes, each incorporating activities associated with key co-ordination points and integrated with the MOD’s design check and sign-off processes. Developing this overall suite so that the consultant’s resources could be moved seamlessly across buildings was a major challenge. One of the difficult aspects of this was in understanding the timescales needed for the design of each building where later buildings were, in some cases, largely a roll-out of a previous design with only the building’s interface with the ground requiring any real new design information. The temptation was to slash timescales but any error in estimating timescales could lead to a large delay as a proportion of the overall time allowed for the design. The consultant monitored the time required for design as solutions were rolled out across the project and could very quickly gauge what reduction in time they could expect on future buildings.

This case study showed the highly repeatable nature of the design process not just because on this project design solutions were being rolled out but because a small number of design processes were able to be applied to a large number of buildings. The overall project was planned with effort that did not extend significantly beyond that expected for a single large building.

**Case Study 3 – Work Flow Control**

Adept Management was commissioned to develop a suite of design programmes on a major healthcare development in the north of England, comprising two new hospitals. The buildings were commissioned by the Government under a PFI contract and so the sign-off and approval processes that are involved in that form of contract had to be built into the design process models. The result was that the highly detailed programmes highlighted not only the cross-disciplinary co-ordination issues but also the contractor and client cost checks, review meetings and approval points. Ultimately the programmes featured contractor and client activities as heavily as some of the design team consultants, showing the importance of their roles in an integrated design process.
The fourth stage of ADePT, control and monitoring of work flow, was implemented on the project. Periodically, typically each month, a schedule of activities was distributed to each of the design team members, including contractor and client. This highlighted the activities which were due for completion in that period, those which were due to be progressed, and those due in the following period so that priorities could be assigned. The team members reported back at the end of each period the progress against each activity, any reasons why activities due for completion had not been completed, and any known constraints affecting forthcoming activities. Based on this feedback, the programmes could be updated and any delays or constraints could be actioned.

The progress across the team can give an overall indication of progress, identified by combining all progress on the programme. However the management team on the project were also interested in seeing the performance of team members individually. This is measured as the ratio of activities due for completion in a given period versus the activities which were actually completed; called percentage planned complete (PPC) in the Last Planner technique.

This measure is used since it is only upon the completion of a design activity when all of its outputs can be said to be fully co-ordinated and complete. The measure focuses the team upon fully completing activities since a report that all activities are 90% complete scores a PPC of zero. So, the scenario where an activity’s progress develops over time by 0, 50, 85, 90, 95% can be replaced by 0, 50, 100%. Feedback collected from the project’s Design Director has confirmed that the approach had the desired effect, focusing the team on completion of tasks.

Lessons learned

The ADePT methodology has become a proven technique for improving the management of the design process. The methodology has shown how process modelling supplemented by use of the Dependency Structure Matrix, (DSM), technique when linked to traditional project planning software can provide a comprehensive tool-kit for design management. Presentation of the output from ADePT to traditional project planning software enables the impact of design decisions on the design and construction process to be fully evaluated. The output of ADePT is best linked to planning software applications, e.g. MS Project, Primavera, Power Project etc. as it is then possible to produce the detailed level of analysis required for effective planning. The adoption of the ‘Last Planner’ philosophy has been found particularly appropriate in the effective management of the design process.

Experience of using the technique in a business environment has highlighted a number of changes in methods of working form those developed in the pilot testing during the research. The use of the Information Dependency Table, (see Figure 2), found to be a good working tool to record experts’ decisions in a research environment, has not proved efficient in a commercial environment, members of the design team preferring to move swiftly as possible to the project planning software environment to review the results of the analysis. The generic building model developed to form the process model required for all individual projects is not always the most suitable basis for new model developments. In many cases the design team prefer to use models already produced for previous projects as this results as an initial model for use by the design team.
The primary focus of ADePT is the management of the information flows between designers, not just design deliverables. However the production of design deliverables to agreed time schedules remains the primary concern of Design Managers. The workflow tools and techniques developed to assist the Design Manager in this task have been important in supplementing the basic technique which utilises DSM to investigate and optimise design solutions. The use of ADePT is important in enabling Design Managers to fully understand the implications of incomplete information or assumed information. From the feedback obtained from the projects where the software has been used it has been necessary to continually develop the software to meet the changing needs of users. At the time of writing two commercial software tools are in development to enable the planning and control aspects of ADePT, named ‘ADePT Design Builder’ and ‘ADePT Design Manager’ respectively.

Conclusions

In 1998 the Rethinking Construction Report highlighted that the separation of design from the other phases of a project was a fundamental weakness in the construction industry, (Egan, 1998). During the subsequent period the continued utilisation of PFI and Design and Build as preferred forms of project finance and procurement has highlighted the need for improved management of the design process. Despite this focus the problem of late delivery of design information and its subsequent impact on construction schedules persists. Process modelling can help to overcome these problems. Adoption of the process modelling and related techniques on construction projects has now been shown to provide significant, measurable cost savings.

The introduction of these new tools and techniques is considered by the writers to be imperative for new forms of procurement that bring together teams that are required to embrace the challenges of projects in new ways. The current availability of such systems and the cost of the related technologies is not an obstacle to their adoption. The challenges, as with the majority of systems implementation are human and organisational. Traditional software systems particularly Project Planning Systems remain the preferred communication platform of business organisations because of the familiarity with input requirements, the output produced and the existing ‘ways of working’ that have been developed around them. The adoption of new techniques on the projects that have adopted process modelling to date has been almost exclusively based on the use of consultants with a record of design management experience. This directly reflects the evolution and introduction of critical path planning methods, the forerunner of current Project Management software, in the late 1960’s and early 1970’s. These Critical Path Planning Techniques initially developed in the late 1950’s took some 20 years to evolve, mature, and to become widely accepted as the pan industry approach to project monitoring and control. Process modelling techniques for the management of design have now become accepted practice for some construction and engineering organisations. The next decade will show how widely they become adopted across the industry.

Acknowledgements

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References


Figures and Tables

Fig 1 – An example of the design tasks and information requirements within an information model
Figure 2 - The four stages of the Analytical Design Planning Technique in diagrammatic form

Process Model

Information Dependency Table

Project Programmes

Dependency Structure Matrix

Figure 3 – The further developed ADePT methodology

Model of design process (template)

Matrix analysis to identify optimal design sequence

Project & departmental schedules

Performance measurement & reporting
<table>
<thead>
<tr>
<th>Step</th>
<th>Description of ADePT Work</th>
<th>Features of Approach</th>
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</table>
| 1    | Modify design templates to suit requirements of the project, incorporate the Contractor’s procurement activities & start on site milestones. | • All design tasks fully integrated with similar levels of detail;  
• All undertaken within same planning environment;  
• All logic inherent across disciplines & with procurement included. |
| 2    | Undertake an initial streamlining of design & procurement process by considering initial design compromises to unlock the design process | • Design activities co-ordinated across the disciplines & procurement;  
• Areas of collaboration needed to deliver an efficient design highlighted (interdependent blocks);  
• Initial design risks and design assumptions were produced to deliver initial design programme. |
| 3    | Export the initial ADePT model into planning tool, add & level resources and impose procurement and start on site deadlines | • Resource design activities to give a levelled programme, coherent for design disciplines and project as a whole;  
• Highlights pinch points in the project process;  
• Release of design info streamlined to suit construction sequence. |
| 4    | Effect of undertaking design sub-optimally considered and pinch points resolved | • Procurement dates for work packages identified  
• Change to suit design or procurement programme, whichever takes priority;  
• Realistic release of information from the design team produced. |
| 5    | Production of single, co-ordinated and realistic multi-disciplinary design and procurement programme | • Potential to reduce the number of work packages issued identified;  
• Release of design information for construction streamlined into natural clusters. |
| 6    | Issue Work Plan to design team covering short-term look-ahead period | • Design team can focus on a ‘to-do list’ rather than programme;  
• Constrained activities identified and action plans put in place;  
• Scheduled activities only cover those free from constraints. |
| 7    | Capture progress, update programme and report performance | • Programme updated regularly;  
• Design team performance against programme reported;  
• Impacts of delay between team members highlighted. |