INTEGRATING DESIGN PLANNING, SCHEDULING AND CONTROL WITH DEPLAN

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ABSTRACT

The planning and management of building design has historically been focused upon traditional methods of planning such as Critical Path Method (CPM). Little effort is made to understand the complexities of the design process; instead design managers focus on allocating work packages where the planned output is a set of deliverables. All too often there is no attempt to understand and control the flow of information that gives rise to these deliverables. This paper proposes the combined use of the Analytical Design Planning Technique (ADePT) and Last Planner methodology as a tool called DesPlan to improve the planning, scheduling and control of design. ADePT is applied during the early planning stages to provide the design team with an improved design programme that takes into account the complex relationships that exist between designers, and the information flows that flows between them. Then the Last Planner methodology is employed, through a program called ProPlan, to schedule and control the design environment.

KEY WORDS

Design Management, ADePT, ProPlan, Last Planner, Production Management, Planning, Schedule, Control, Dependency Structure Matrix.

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INTRODUCTION

The project programme drives the current design management practices, with limited consideration given to the management of the production of design information. This is a fundamental problem because the design process is information intensive, and the timing and delivery of design information is crucial to the successful delivery of the design solution. Current planning techniques also do not take into account the iterative nature of design (Austin *et al* 1996) with designers being expected to complete design as though it were a systematic and linear process. Jin et al. Also (1996) point out the reciprocal dependence as well as the precedence relations and the resource dependence in a construction project. In other words, information or produce of one activity could affect the decision made for another activity and vice versa. Thus, continuous communication among the involved parties is needed to insure that as many relevant information as possible is made available to the disciplines that requires it before a decision is made. Current planning methods force design teams to manage their work on a discipline basis, each working on achieving their deliverables as dictated by the design programme, with little regard of the relationship with other disciplines and organisations.

Design information tends to be formally distributed to all designers regardless of whether or not it is required, and the timing of information transfer is not properly controlled. All too often designers do not have the right information at the right time; therefore design tasks are undertaken with a risk of failure, and this leads to waste in the process due to unplanned rework (Huovila *et al* 1997).

The introduction of ADePT as a planning tool for design has seen improvements in building projects, providing practicing design managers with means to plan more effectively, concentrating on the flow of information between design tasks (Austin *et al* 1999a). The execution of design must also take advantage of this improved planning technique, so that designers are working in an environment that provides them with the means to identify what information is required, where that information resides, and who is responsible for providing it. Design programmes are also constantly being changed to reflect the intentions that are continually being defined by the project participants (Gurley & McManus 1998), which causes variability and uncertainty that is difficult to manage. As these variability and uncertainty manifest themselves as the design progresses, the activity definitions, the required information will need to be changed to reflect them.

In order to schedule the design programmes provided by ADePT, not only the activity sequence based on information relationships, but also the start/end dates, duration and resource requirement for each activity must be introduced. To assist in the scheduling and controlling of the design program, ProPlan, which systematically develops lookaheads and weekly work plan, has been developed. ProPlan which adopts the Last Planner concept (Ballard and Howell 1994a, 1994b) allows the scheduler to detail design activities, identify additional constraints, check constraint satisfaction, release work packages, and allocate resources; then at the end of the week, collect field progress data and reasons for plan failure. A similar methodology has already been applied in construction (Choo et al. 1998).

This paper introduces DePlan as a new approach to an integrated design planning, scheduling and control that combines the benefits of from the planning phase of design using ADePT to the scheduling and control phase with a production management tool called ProPlan, as shown in Figure 1:

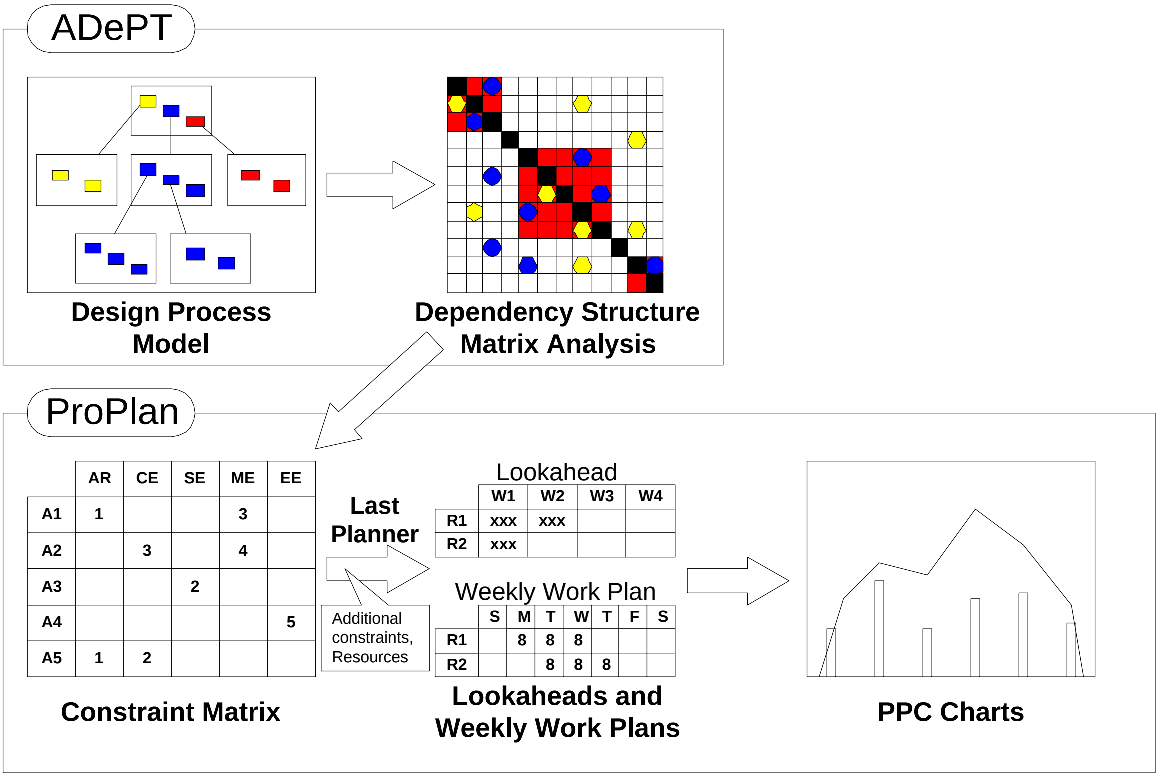


Figure 1. DePlan

ADEPT AS A PLANNING TOOL

The ADePT methodology has been developed to improve the planning and management of the design process. The first stage illustrated in Figure 2 is the production of a design process model for building design that defines the design activities and the information requirements that flow between them.

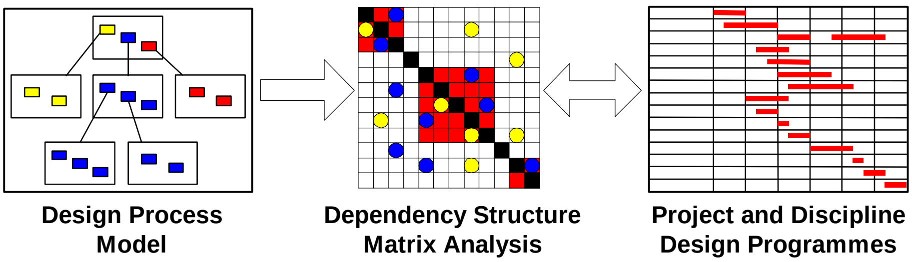


Figure 2. Analytical Design Planning Technique (ADePT)

The second stage imports the data from the design process model into the Dependency Structure Matrix (DSM) analysis tool. Iterations within the design process are identified and design activities are scheduled to provide an optimized order of tasks. The third stage of the ADePT methodology relates the matrix to a project programme, where the optimized order of tasks is reviewed, and resource is allocated. Other project constraints such as construction requirements will have an impact on the design programme; therefore there is iteration between the DSM and programming stages.

DESIGN PROCESS MODEL

ADePT generic design process model (Austin *et al* 1999b) used to develop DesPlan has been applied on a range of building projects varying in value between £15M and £180M. The process is represented graphically by a modified version of IDEF0 (Figure 3) and a project-specific model created for each building.

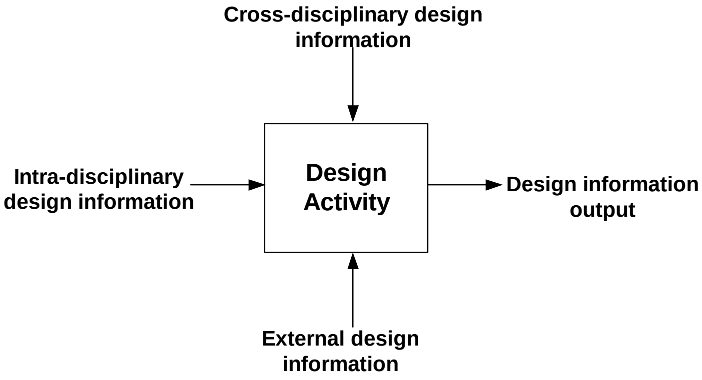


Figure 3. IDEF0v Notation

This figure could be omitted if we are short of space

The hierarchical design process model is based on the five major building design disciplines: architecture and civil, structural, mechanical and electrical engineering. Each discipline's activity is decomposed to reveal systems, subsystems and individual design tasks and the information requirements and output.

DEPENDENCY STRUCTURE MATRIX ANALYSIS

Dependency (Design) Structure Matrix analysis was developed by Steward (1981) to improve the efficiency of solving complex problems. By using a matrix to represent the interrelationships between activities, Steward found that a problem could be divided into contributing sub-problems. DSM has since been used by a number of researchers. Rogers (1989) improved the scheduling of problems with up to 50 activities at the conceptual design stage. Huovila (1995) applied DSM to building design problems and McCord & Eppinger (1993) to various engineering problems, including semi-conductor design and automotive engineering design. ADePT model represents one of the biggest applications of DSM, with 350 to over 800 activities and 2,400 to 10,000 information dependencies.

Figure 4 is an example of a dependency structure matrix with ten design tasks listed vertically from Task A to Task J. The same tasks are horizontally listed in the same order as the vertical order. Each cross in the matrix illustrates a dependency on the vertical task from the corresponding horizontal task, where crosses below the diagonal represent required design information that is available, and crosses above the diagonal is information that originates from design tasks that have not yet been undertaken. For example from Figure 4 it can be seen that Task D requires information from Task C and Task F. Task C information is available since it has already been completed; however Task F information is not available because Task F is not scheduled to start until later.

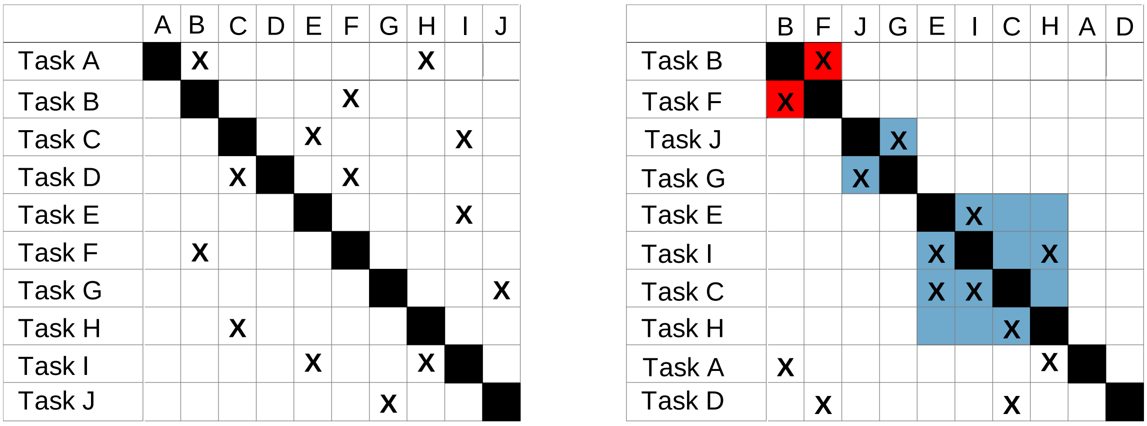


Figure 4. Example of DSM Analysis before and after partitioning

Special considerations need to be given to the situation when the dependency requires information from an activity that has not been undertaken. This information will have to be estimated so that the design task depending upon it can be enabled. This means that the design task may have to be re-visited to update the estimated design information to check whether or not the original estimate was satisfactory. This iteration is characteristic of the design process; therefore by using the DSM analysis the design planner can begin to allocate necessary resource and planning strategies to manage the iteration.

The estimation of information is not always an acceptable solution therefore some design task information dependencies will need to be treated differently. The DSM software can partition the matrix by re-ordering the sequence of design tasks to maximise the number of design tasks below the diagonal, as shown in Figure 4. The profile of the matrix has changed and now shows smaller blocks of inter-related design tasks that are easier to plan and manage.

DESIGN PROGRAMMING

The partitioned matrix is linked to a planning tool to generate a programme for the design activities by the addition of resources and durations. The sequence of design work is defined by the output from the DSM, however where there are blocks of interrelated tasks the project planner will need a strategy that will enable the de-coupling of the design tasks. This may involve planning the tasks within the block concurrently so that iteration can be achieved and a design solution delivered efficiently. Figure 5 shows an example of planning a block of interrelated tasks concurrently. The block has a finite duration, and the constituents of the block are planned to start and finish so that the flow of information maximizes the opportunity to complete the design iteration and yield a design solution. Other strategies are described in Austin et al. (1999a).

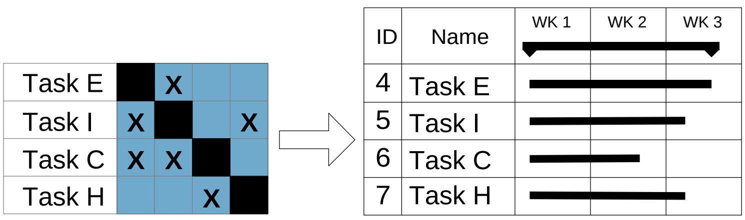


Figure 5. Programming Iterative Blocks of Tasks

PROPLAN AS A PRODUCTION MANAGEMENT TOOL

ProPlan has been developed to support scheduling and control of design process according to the Last Planner concept. ProPlan is allows the user to generate project data from the start but is also capable of importing the ADePT output matrix (Figure 6), i.e., the list of activities, the responsible disciplines for each activity, and the informational dependencies.

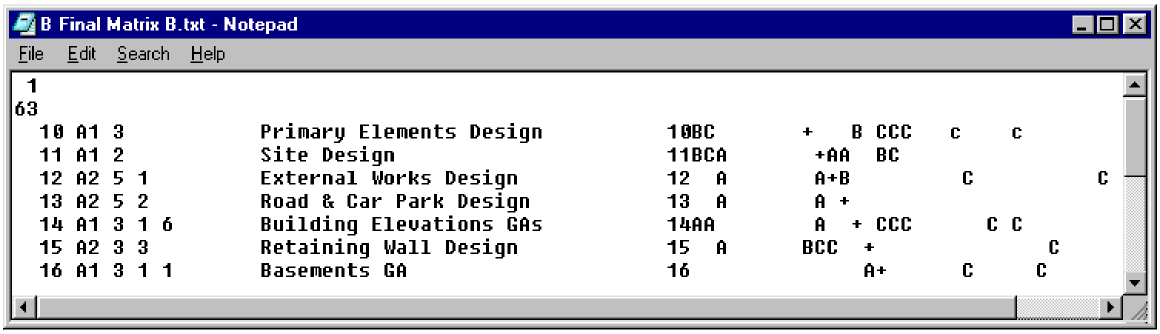
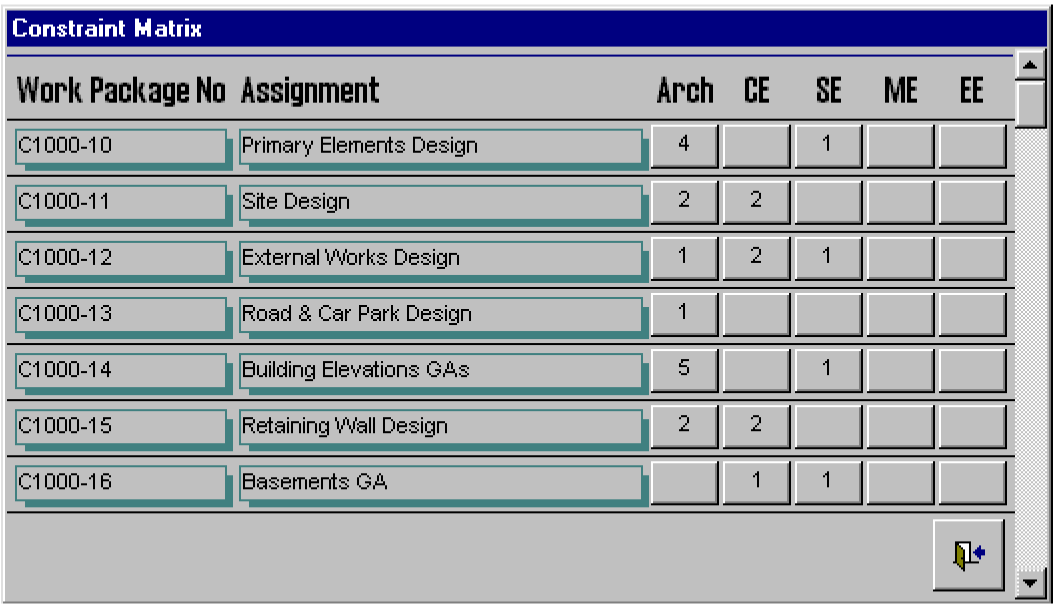


Figure 6. Sample matrix generated from ADePT

The imported information is then automatically restructured to generate the constraint matrix (Figure 7). Each design activity corresponds to a work package in ProPlan. The constraint matrix shows the number of design activities that belong to each responsible discipline. These activities are informational constraints that must be attained in order for each activity to be carried out successfully. By categorizing the constraints by disciplines, the planner can determine which discipline is most critical to the release each design activities.



Constraint Matrix

Work Package No	Assignment	Arch	CE	SE	ME	EE
C1000-10	Primary Elements Design	4		1		
C1000-11	Site Design	2	2			
C1000-12	External Works Design	1	2	1		
C1000-13	Road & Car Park Design	1				
C1000-14	Building Elevations GAs	5		1		
C1000-15	Retaining Wall Design	2	2			
C1000-16	Basements GA		1	1		

Figure 7. Constraint matrix based on Figure 6

By clicking on any number in the matrix, details of each constraint can be seen. For example, detailed description for “1” in the civil engineering discipline (CE) for work package C1000-16 (Figure 8) can be seen by clicking that number. Figure 8 shows two sections of constraints. The top section refers to the constraints that have been met and the bottom section refers to the constraints that have not been met. The number "1" corresponds to the bottom section of the screen. By keeping track of what has been done, document trail for all constraints are maintained. The planner can also add additional constraints if they manifest themselves during project execution.

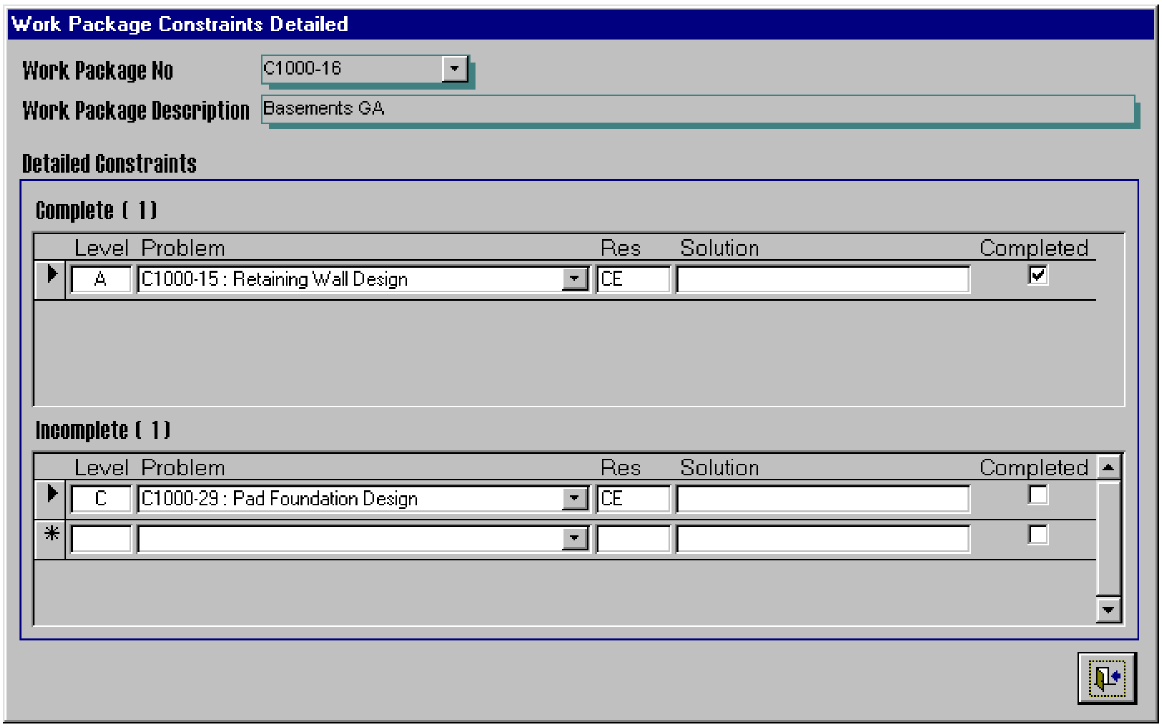


Figure 8. Detailed design constraints for C1000-16.

Other types of constraints can also be specified. These constraints are divided into five categories; contract, engineering, samples, resources, and design constraints (Figure 9). Contract category refers to constraints regarding contractual finalization, commercial constraints, permits, subcontracting, etc. Engineering refers to constraints from other engineering functions such as construction management and planning supervisors. Samples refer to instances where design is constrained by the agreement to use of samples or mock-ups. Resources refer to constraints regarding planning and management of resources, including designers and supporting services**.** Design Constraints are the information provided by ADePT. Design constraints for all discipline can be seen from this screen.

When constraints for a design activity are satisfied or are expected to be satisfied, this activity can be released for scheduling. In the scheduling phase, explicit resources such as designers and supporting services (accounting, administration, drafting department, etc.) are assigned to generate weekly work plans (Figure 10). To keep track of constraints that are expected to be met, those constraints are automatically printed in the "make ready" section. Ballard and Howell (1994a) refer to weekly work planning as "commitment planning" because, at this stage, the specific resource assignments need to be made so that work can actually be performed. The scheduling window for weekly work plans is one week. The design activities in the weeks beyond one week are scheduled using the lookahead window (not shown). Since it is hard to precisely determine specific designers and corresponding supporting services that needs to be assigned to each design activity, the planner can denote with a simple “yes/no” to show whether each design activity will need to be carried out each week. Ballard (1997) describes the purposes for lookahead planning as:

1. Shape work flow in the best achievable sequence and rate for achieving project objectives that are within the power of the organization at each point in time.
2. Match labor and related resources to work flow.
3. Produce and maintain a backlog of assignments for each frontline supervisor and crew, screened for design, materials, and completion of prerequisite work at the CPM level.
4. Group together work that is highly interdependent, so the work method can be planned for the whole operation.
5. Identify operations to be planned jointly by multiple trades.

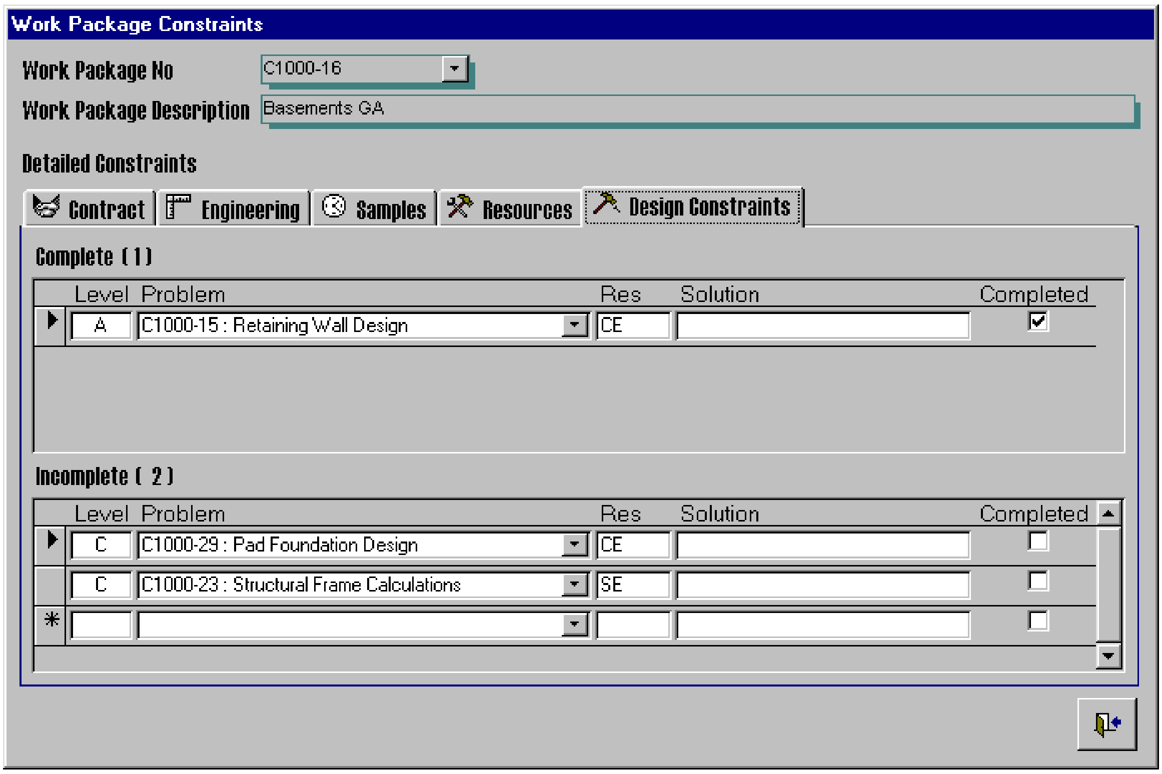
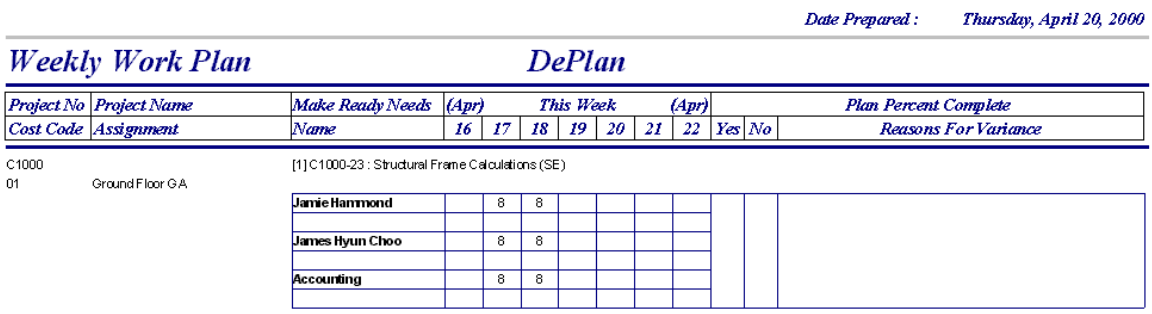


Figure 9. Detailed constraints for C1000-16.



Date Prepared : Thursday, April 20, 2000

Weekly Work Plan DePlan

Project No / Cost Code	Project Name / Assignment	Make Ready Needs / Name	(Apr) 16	17	18	This Week 19	20	21	(Apr) 22	Yes	No	Plan Percent Complete / Reasons For Variance
C1000		[1] C1000-23 : Structural Frame Calculations (SE)										
01	Ground Floor GA											
		Jamie Hammond		8	8							
		James Hyun Choo		8	8							
		Accounting		8	8							

Figure 10. Weekly work plan generated from ProPlan

The lookaheads act as an interface between the overall project schedule and the weekly work plan (production schedule). The production activities (design activities) need to be executed according to the overall project schedule since there are milestone dates (meetings, inspection, due dates) that determine the latest finish dates for certain activities. Therefore, it is important to note that the main objective of the lookahead is to determine which activities need to be carried out in which week and to make it ready according to the project schedule. Figure 11 is an example of lookahead generated from ProPlan.

Lookahead

		Apr.								May					
WP No	Assignment	23	24	25	26	27	28	29	30	1	2	3	4	5	6
C1000-10	Primary Elements Design														
C1000-11	Site Design														
C1000-12	External Works Design		Yes	Yes	Yes	Yes	Yes								
C1000-13	Road & Car Park Design		Yes	Yes	Yes					Yes	Yes	Yes			
C1000-14	Building Elevations GAs									Yes	Yes	Yes	Yes		
C1000-15	Retaining Wall Design														
C1000-16	Basements GA														

Figure 11. Lookahead generated from ProPlan

After each week, the designers need to fill out the actual number of hours they worked on each design activity and check whether or not their assignment was completed as planned. If not, they must provide reasons for variance. This data is used to calculate PPC to measure the reliability of the planning system. PPC can be calculated by dividing the number of completed assignments by the total number of assignments each week. Recording completion status of design activities for PPC calculation is important, but elaborating on reasons for failure is more valuable because it enables learning thereby preventing the same mistakes in the future.

DEPLAN CHARACTERISTICS AND FUTURE WORK

The concept of DePlan is therefore relatively straight forward: define the design process from a generic model and produce an integrated project plan by DSM analysis; then schedule and control design production with lookahead and weekly work plans that assign design activities as the required information and resources become available. Design is thus planned and managed on the generation of information not deliverable production, with realistic and achievable task setting. The effects of change can be managed by further matrix analysis and process reliability monitored by measurement of PPC.

The ProPlan is ready for test projects. Three candidate projects are identified in US which is expected to start in May 2000. Some candidate projects are being negotiated in UK as well. The main purpose of the test projects is to determine the merits and demerits of DePlan, integrated application of ADePT and ProPlan. ProPlan will also be modified according to the findings from the project as well.

Since the input design model is developed based on UK industry, UC Berkeley is working to creating a model based on US industry. The data generated from ProPlan will facilitate the creation of model because it will reflect the actual practices of description of activities and the relationships between them.

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