WORKPLAN: DATABASE FOR
WORK PACKAGE PRODUCTION SCHEDULING

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ABSTRACT

A database program called WorkPlan has been created to systematically develop weekly work plans. WorkPlan adopts the Last Planner methodology, which implements several lean construction techniques. A week prior to conducting work, WorkPlan guides the user step by step through the process of spelling out work packages, identifying constraints, checking constraint satisfaction, releasing work packages, and allocating resources; then at the end of the week, collecting field progress data and reasons for plan failure. This systematic approach helps the user create quality work plans and learn from understanding reasons for failure. The functionality of WorkPlan is detailed in this paper. Various ways of displaying work package data are illustrated. WorkPlan is to our knowledge the first computer tool designed specifically to implement lean production philosophy in construction.

KEY WORDS

WorkPlan, weekly work plan, database, lean construction, production scheduling, screening, work package, constraint, percent of planned completed (PPC).

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INTRODUCTION

Scheduling of construction work is usually done with the support of computer tools that implement the critical-path method (CPM). These tools have served project managers well in their effort to plan and oversee construction projects in the process of administering contracts. They also have presented a common representation (based on activities of given duration and unit resources allocated to them, as well as predecessor relationships between activities) for different parties involved in a construction project to communicate with one another whom should be doing what work and when. However, these tools are inadequate in terms of use and expressiveness when it comes to supporting production planning and control, that is, supporting those who are performing construction work in the field.

The ability to actually get work done at the construction work face depends heavily on the availability of resources. CPM provides no mechanism for explicitly checking resource availability. Moreover, the resources that are relevant to field workers, namely erection drawings, materials, equipment and tools, and methods specifications, rarely—if ever—are explicitly described in CPM schedules. Not only is it tedious to do so, but it also requires a different mind set. Project management's schedules are therefore useless to those doing the work.

Accordingly, field workers have created their own, special-purpose planning systems to create weekly work plans. Although systems tend to differ from one company to the other, the information in them is usually work-to-be-done, assigned people and equipment, and assigned hours. Even though actual resource allocation and checking is done in preparation of the weekly work plan, resources do get cross-allocated or over-allocated, resulting in conflict. This occurs because there is no easy mechanism to verify resource assignment when the weekly work plan is spelled out on paper.

In this paper, we present ways to overcome this deficiency in current practice with regards to weekly work planning. More importantly, we have implemented lean construction techniques in a database application called WorkPlan. WorkPlan systematically guides the user through the steps required for creating a quality work plan. Its underlying data-checking mechanism helps maintain data consistency. WorkPlan allows the data to be organized in various ways to serve accounting purposes and display performance measures.

CURRENT PRACTICES IN FIELD LEVEL PLANNING

Weekly work planning is planning with the highest level of detail prior to having (skilled) laborers carry out the work. Actual resource allocation and checking is done in the preparation stage of the weekly work plan. Currently, most weekly work plans are drawn up by hand, using pen and paper. If a work package spans more than one week, its description will have to be rewritten each time a new plan is made, week after week. Also, information regarding laborers and equipment required in multiple work packages will have to be duplicated from one form to the next. Most paper-based weekly work plans are discarded after they have served their purpose: crew supervisors use them as 'cribsheets' to sequence work, assign work, and mobilize resources. Russell and Froese (1997) therefore referred to such plans as "throw-away" schedules. The opportunity for supervisor or management feedback and learning is thereby lost.

In addition, weekly work plans bear little relationship to the project's CPM. More surprisingly, they are not used to track labor hours spent (time cards) or the completion of work. Once construction has been carried out, progress is recorded in timesheets, which are used to pay for labor and track costs, which also requires paying attention to detail.

The irony of this practice is that weekly work plans and time sheets essentially pertain to the same information, namely work to be done for a given week, though one looks one week into the future and the other looks one week back. Nevertheless, two separate forms are typically used and there appears to be no explicit relationship between them. Tying the two together is the missing link between production and project management.

RELATED WORK

The application of lean production techniques in construction has been triggered by its success in manufacturing (Womack and Jones 1996). A number of studies were conducted to date in order to refine the thinking process and to develop appropriate methods to implement lean construction. However, to our knowledge, no computer tools have yet been developed for field-level use.

Several lean production techniques (after Womack and Jones 1996) have been implemented in our system, namely:

1. Clearly documenting, updating, and constantly reporting the status of all process flows to all involved, so each person knows what others do and understands the implications of quality of their own work on the quality of the process output.

WorkPlan stores all work planning information in a database and generates relative information from it.

2. Synchronizing and physically aligning all steps in the production process so there is little wait time for people or machines, and virtually no staging of partially completed products.

WorkPlan tries to eliminate unnecessary wait time on site by helping its users screen work packages (Ballard and Howell 1997). Releasing work packages only when all the resources are ready allows the construction to be carried out with minimum chance of being interrupted. As a result, fewer partially-completed work packages are being assigned to crews on site.

3. Stopping the assembly line to immediately repair quality defects. While this usually is very disruptive for the process as a whole, there are several advantages to doing so: (1) the flawed processing step can be corrected right away, before numerous other assemblies have undergone the same treatment, resulting in additional defects; (2) it is substantially easier and less costly to discover and repair a quality defect early on in a process rather than at the end, after an assembly has been completed.

Our implementation makes it possible to identify defects every week (i.e., reasons for deviation from the schedule) so that the scheduling process can be rectified immediately in other to prevent the same defect from happening again.

APPLICATION OF LEAN CONSTRUCTION TECHNIQUES TO WEEKLY WORK PLANNING

Weekly work plans can be developed as valuable tools for production planning and control through the application of lean construction techniques. In the application we developed, weekly work plans are generated using a database. This database comprises information about work packages to be assigned and resources that can be used, i.e., the laborers and equipment available to a company to conduct its work. Resource information often already exists in electronic format in the company, possibly in the form spreadsheets or word processor files, but it may not be readily available for use throughout the project. One technique for reengineering the information process is to "capture information once and at the source" (Hammer 1990), and this has been achieved in WorkPlan.

Preparing a weekly work plan is the process of assigning specific laborers and equipment to work packages that need to be carried out. In order to determine the required amount of time and resources, the scope of each work package needs to be defined clearly. Traditionally speaking, from a project management viewpoint, a work package is a sub-element of a construction project on which both cost and time data are collected for project status reporting. The set of work packages for a project constitutes its work breakdown structure (Halpin 1985). The literature is vague on exactly how one is to clearly define a work package's scope. Therefore, it is even harder to define what resources are needed to meet those scope requirements.

Our definition of work package is that it defines a definite amount of work to be done using specific design information, material, labor, and equipment, and with prerequisite work completed. These requirements therefore act as constraints that must be satisfied in order for a work package to be carried out successfully, productively and without interruptions. These constraints are categorized in five types, as constraints on contract, engineering, material, labor, equipment, and prerequisite work.

Contract
- Is this work package in the contract? Is it the result of a newly-issued change order?
- Has all coordination information been confirmed?
- Has the subcontract been issued?

Engineering
- Have all submittals been turned in? Have they all been approved?
- Have all shop drawings been turned in? Have they all been approved?
- Are there any outstanding requests for information (RFIs)?
- Have all methods and procedures been decided?
- Have assembly drawings been received?

Materials
- Have all fabrication drawings been produced?
- Have all material requirements and sources for procurement been established?
- Have all requests for quotation (RFQs) been sent?
- Have all materials been purchased? Have they all been fabricated?
- Have all materials been delivered? Have they all been allocated?

Labor and equipment
- Has the work package been scheduled?
- Are the required laborers available for the duration of the work?
- Is the required equipment available for the duration of the work?

Prerequisite work
- Has all prerequisite physical work been completed?
- Have all work areas been cleared so that the work package can begin?

Even though a specific work package may require constraints in addition to those provided here, at least the most frequently recurring constraints have been listed. If any of these constraints is not met for a specific work package, that work package should not be started or its execution will likely be slowed down or interrupted during construction.

Once all constraints on a work package have been satisfied or are expected to be met before the work is executed, the work package can be released for construction. Specific laborers and equipment can then be assigned.

Generating a weekly work plan on a computer is not only timesaving, the process can also be made error-proof. A real-time cost generation function can be used to compare alternative resource allocations. A cross-allocation checking function can detect resource conflicts (assignment of the same resource to different work packages at the same time) before they arise on the site.

Once a work package has been completed, the actual schedule can be input into the database and compared with the original schedule. The update can be used to generate timesheets when needed for accounting purposes. However, tracking this information provides not only the basis for the cost calculation but also important measurement of the reliability of the current scheduling system.

Plan reliability can be measured by PPC (Percent of Planned Complete). PPC is calculated by dividing the number of completed assignments by the total number of assignments each week (Ballard and Howell 1997). To enable continuous leaning, each work-package's completion status must be accompanied by reasons for failing to meet the schedule. The identified reasons can then be studied and possibly remedied in order to prevent them from recurring in subsequent construction work.

Every time a modification is made to the schedule, the scheduler has the option of updating the estimate of the remaining work. In WorkPlan, this information is not generated within the database itself. It has to be based on the estimates made by the scheduler based on the amount of work left. By each week having to estimate the total cost of work remaining to complete a work package, a realistic target cost can be set. This approach contrasts sharply with traditional project control practice, where forecast-to-complete is usually based on actual-cost-to-date. Accordingly, the forecast to complete is either an extrapolation of the average throughout the project or the average over a certain number of weeks. In our system, neither the budget nor actual-cost-to-date is a factor in determining the target cost. Much emphasis is placed on the planner's expectation and forecast of how work will be executed and progress. Comparison of actual cost incurred or estimated against budget is done separately.

IMPLEMENTATION OF WORKPLAN

Since construction information presents itself in groupings of similar data that are tightly inter-linked, a database provided a perfect platform for developing the application. From

the variety of database management systems on the market, Microsoft Access 7.0 was chosen because it can be easily programmed through VBA (Visual Basic for Applications). It was also chosen because the program can be distributed with the runtime version of Access so that the user does not have to purchase Access to just run the WorkPlan database. Since we expect that specialty contractors will be the main users of this application, affordability was one criteria for software platform selection.

Figures 1, 2, 4, and 5 give actual screen dumps from the WorkPlan database system. Figures 3 and 4 show reports generated by WorkPlan. The Work Package Entry Form allows the user to enter information about the work package's number, project number, description, duration, and budget cost (Figure 1). In the same manner, information about labor and equipment is input (Figure 2).

Figure 1: Work Package Input Screen

Figure 2: Laborer Information Input Screen

For each work package that is input by the user, WorkPlan generates five categories of constraints by default to refer to (1) contract, (2) engineering, (3) materials, (4) labor and

Figure 3: Work Package Constraints Input Screen

equipment, and (5) prerequisite work. Figure 6 shows how the program user can detail the problems and solutions for each category. The problems may be selected from the preloaded list (see section "Application of Lean Construction Techniques to Weekly Work Planning") or be typed in by the user if items need to be added or other wording is found to be more appropriate. At the bottom of this screen are problems that are still outstanding; at the top those that have been solved. Once an outstanding problem has been solved (checked), it automatically moves up to the top. Solved problems are not deleted from the database even though they require no further attention. Keeping them displayed confirms they have been attended to. The list of solved problems can also be used to construct a knowledge base of constraints to help anticipate future problems with related work. Once all constraints on a work package have been met, the work package can be released for construction. Only work packages that have been released can be assigned and scheduled for execution.

Once all constraints for a work package are satisfied, the work package can be released for construction. Figure 4 shows this process. By pressing the down-arrow button, an unreleased work package can be released; by pressing the up-arrow, a released work package can be unreleased. The latter should occur in exceptional circumstances only, if a previously unidentified constraint crops up at the last minute or a constraint is not satisfied to the extent it was anticipated.

Work Package Release

Unreleased Work Packages

WP No	Description	Con	Eng	Mat	L&E	Pre
97-309-C-200	Louvers: Get HP release to fabricate	2	1	1	0	0
97-309-C-300	PH Roof-Area A: Rough-In Roof Drains	2	0	0	0	0

Released Work Packages

WP No	Description	Con	Eng	Mat	L&E	Pre
97-309-C-110	PH Roof-Area A: Metal Deck Installation	0	0	0	0	0
97-309-C-1000	PH Roof-Area B: Rough-In Roof Drains	0	0	0	0	0

Figure 4: Work Package Release Screen

Resource Assignment

Work Package No 97-309-C-1000

Assignment PH Roof-Area B: Rough-In Roof Drains

		This Week							Next Week					
		28	29	30	1	2	3	4	5	6	7	8	9	10	11
Laborer ID	**Work Desc.**	S	M	T	W	T	F	S	S	M	T	W	T	F	S
Gilbert Atlas	Sheet Metal	0.00	0.00	0.00	4.50	8.00	5.50	8.00	0.00	0.00	0.00	8.00	8.00	0.00	0.00
Gilbert Atlas		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Patterson Andy
Downey Earl
Diaz Joe
Jones Kenneth
Downey Willard

Laborer Cost: 968.24 | 595.84

Equipment ID	**Status**	S	M	T	W	T	F	S	S	M	T	W	T	F	S
Wheel loader	Rented	0.00	0.00	0.00	0.00	8.00	8.00	0.00	0.00	0.00	0.00	8.00	8.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Equipment Cost: 2640 | 2640

Total Cost: 3608.24 | 3235.84

Remaining Work

	Unit Cost	Amount	Extended Price
Laborer	$15.00	900	13,500.00
Equipment	$25.00	700	17,500.00
Total			31,000.00

Re-Calc   Commit

Figure 5: Resource Assignment Screen

The Resource Assignment Screen (Figure 5) allows the actual scheduling of a released work package. Each available resource can be assigned to a specific work package. As shown in this screen capture, the names of laborers and equipment are selected from a drop-down list using data stored in the database. The hours represent the time each resource will work on the specific work package. Once the schedule is set, the total number of hours committed for each resource is checked. The WorkPlan user, i.e., the Last Planner, is notified if any resource is assigned for more than eight hours per day. "Remaining work" is used in estimating the total cost of the work package based on the expected unit cost and quantity of work. The Last Planner has the option of changing the expected amount whenever the plan is updated.

Figure 6 shows a weekly work plan generated from this screen. This plan can be printed out and handed to the field crew. In turn, the crew is expected to fill out the actual number of hours they worked on each specific assignment, and check whether or not their assignment was completed as planned. If not, they must provide reasons for variance. This data is then entered into the computer by means of the Resource Assignment Update Screen.

Date Prepared :															Monday, July 13, 1998		
Weekly Work Plan														**Construction Group**			
Project No	Project Name	Name	(Jun)			This Week								Next Week		(Jul)		Plan Percent Complete		
Cost Code	Assignment	Desc	28	29	30	1	2	3	4	5	6	7	8	9	10	11	Yes	No	Reasons For Variance
97-309-C	AREA A																		
1000	PH Roof-Area B: Rough-In Roof Drains																		
		Gilbert Atlas				4.5	8	5.5	8				8	8					
		Sheet Metal																	
		Wheel loader					8	8					8	8					
		Rented																	
97-309-C	AREA A																		
110	PH Roof-Area A: Metal Deck Installation																		
		Gilbert Atlas		8	8														
		Waterproofing																	

Figure 6: Sample Weekly Work Plan

The left side of the resource assignment update screen (Figure 7) represents the "scheduled" work and the right side is used in inputting the actual schedule. The default value of the right side is "as scheduled". Changes can easily be made by selecting resources and typing numbers. The "Remaining Work" section appears as it did on the Resource Assignment Screen. The option button to record the completion of the work package lets the planner specify that the work package for the whole project is complete therefore can be removed from the workable backlog.

Once all information has been recorded, the reasons for the variance (difference between "scheduled" and "actual") are input. This is shown in Figure 8. These reasons are divided into seven categories, namely (1) Contract, (2) Engineering, (3) Material, (4) Labor and Equipment, (5) Prerequisite work, (6) Weather, and (7) Accident.

In turn, WorkPlan uses this data to create the PPC Report that represents the reliability of the current planning system (Figure 9). The vertical axis on the left is for PPC whereas the vertical axis on the right is for the number of occurrences for each category. The solid line represents PPC and the bar chart corresponds to the number of occurrences. The occurrences can be used for deciding where to focus management attention in order to improve the reliability of the current planning system.

Figure 7: Resource Assignment Update Screen

Figure 8: Reasons for Incomplete Screen

Figure 10 shows a sample timesheet generated by WorkPlan. By grouping the actual work completed by each laborer, the timesheet can be created automatically. The cost for each work package is also provided.

Figure 11 shows one of many useful reports that can be generated from the data that resides in WorkPlan. The report shown provides a high-level view of what the project entails.
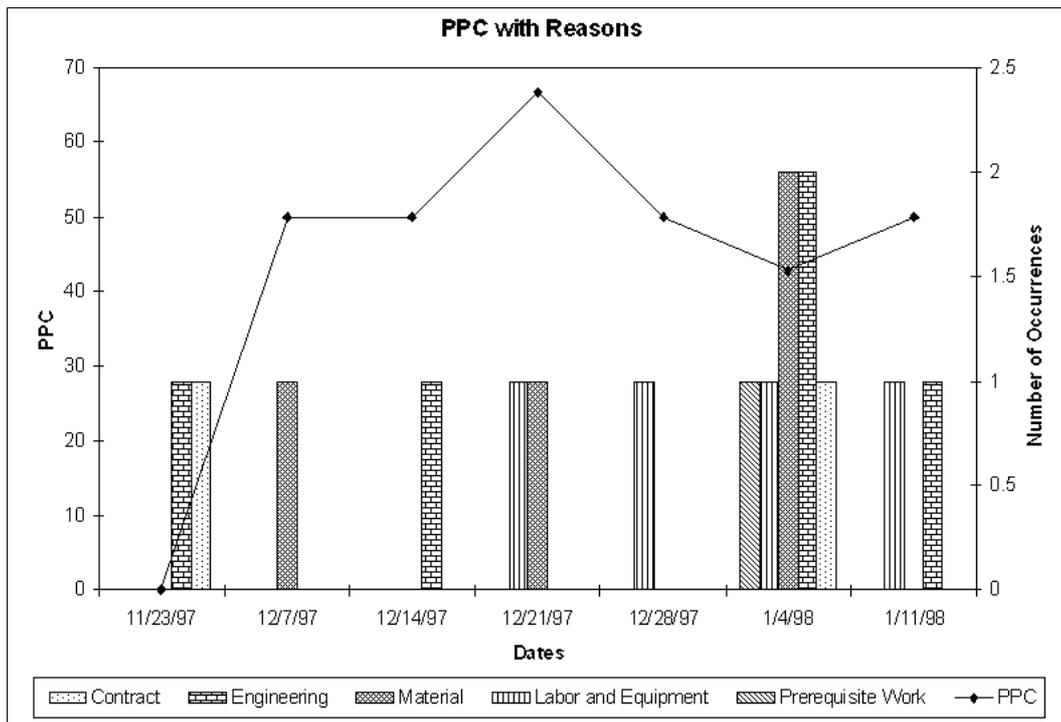
Figure 9: PPC Report

Figure 10: Sample Timesheet

Figure 11: Work Package Listing

SUMMARY

Existing CPM-based project management tools used in construction do not appropriately support production scheduling. As an alternative, we have presented a computer tool that assists schedulers with detailed production scheduling. By allowing the reuse of relevant information and the automatic checking of cross allocation of resources, the scheduler is able to work more accurately and save time as compared to developing work plans using pen and paper. WorkPlan not only allows detailed scheduling of work packages, it also integrates various kinds of construction data so that the relationships between them are easier to see.

Most important, however, is that the WorkPlan system adopts the Last Planner methodology. WorkPlan guides the user step by step through the process of spelling out work packages, identifying constraints, checking constraint satisfaction, releasing work packages, and allocating resources; then at the end of the week, collecting field progress data and reasons for plan failure. This systematic approach helps the user create quality work plans and learn from understanding reasons for failure.

The WorkPlan system is straightforward in concept and implementation. Nonetheless, it is an extremely valuable tool for keeping track of a large amount of tedious details describing resources, that, when not available, could seriously hamper the productivity of field crews.

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