Personnel Scheduling Management System Investigation and Proposal

MARGARET E. BLAU

The focus of this study is the current state of personnel scheduling management systems in the Washington State Department of Transportation construction field offices. It is assumed that, although all of the field offices use some level of scheduling, there could be more effective and systematic and less reactive ways of doing personnel scheduling at this level. The study finds that the project engineers are scheduling under a variety of constraints and concerns that directly affect their ability to do long-range planning and respond quickly to short-range scheduling changes. In response to the findings, a unified personnel scheduling management system has been conceived, using patterns of scheduling already in existence at the field offices. Three design approaches are suggested that would fit into many of the field offices. Recommendations for implementation are also made, which are intended to ease the changeover into these proposed systems.

The Washington State Department of Transportation (WSDOT) is a state governmental agency that has been mandated to provide a multimodal transportation system that meets the social and economic needs of the state (*1*, p. 2). To fulfill the mandate, WSDOT designs, constructs, and maintains various facilities statewide, such as roadways and alternate transportation modes.

The department's construction section oversees the building of new facilities and the replacement of older facilities to the best known standards and specifications. The responsibility for maintaining these standards in construction lies in the on-site inspection of the various projects, which are handled through small units called construction field offices (also called project offices and field offices).

Headed by a project engineer, each field office is responsible for administering the contracts by ensuring that the contractors properly construct departmentally designed projects within a district. All aspects of construction management, including finances (to a certain degree), inspection, testing, and records are included within this office. As part of this, the project engineer must be able to balance all of the projects assigned to him or her with all of the resources given him or her in a cost-effective and timely manner. To do this, the project engineer must undertake what can be termed personnel management.

Personnel management at the construction field office level is, both currently and historically, a significant concern. No uniform personnel scheduling management system is available to the project offices, and personnel management methods as well as schedule controls are lacking. Project engineers need to handle constant schedule changes that involve altering or adjusting personnel schedules and that are generated by contractors, the public, the department, employees and others (see, for example, the internal document *Report to the Secretary of Transportation on the Construction Project Engineer Study*, WSDOT, January 1986).

Frequently, the project office develops a method of dealing with scheduling that resembles crisis management, here called reactive management. Scheduling is handled in immediate reaction to a situation rather than as an anticipated and planned response. When this type of method develops in an office, the project engineers appear to come to expect that they must operate in a reactive manner, neglecting planning.

This study was done to establish

- An understanding of the current state of personnel scheduling in the WSDOT construction field offices;
- An understanding of the problems that the construction field office project engineers face in personnel scheduling;
- An assessment of the methods used to deal with personnel scheduling; and
- Preliminary designs of systems that could help field office project engineers manage personnel scheduling in a more effective and systematic and less reactive manner.

The problems encountered by field offices will not disappear. Indications are that they will worsen with simultaneous shortages of funds and deteriorating highways. Response to these problems must be more effective, cost-conscious, and timely.

STUDY ASSUMPTIONS AND METHODOLOGY

To describe the study accurately, a listing of the assumptions on which it was based and a brief description of the methodology used are helpful. The following assumptions were formulated for the study:

- A more uniform personnel scheduling management system would be able to relieve the project engineer of some of the time-consuming aspects of personnel scheduling and, thus, free him or her for more direct contract administration.
- The personnel scheduling management system employs two types of scheduling: planning and operational, functioning simultaneously in the field office.
- The current state-of-the-art of personnel scheduling management at the construction field office level is based more on reactive management than on a treatment of the whole system based on foreknowledge and assessment.

Washington State Department of Transportation, District 1, Environmental Section—M.S. 138, 15325 S.E. 30th Place, Bellevue, Wash. 98007.

- The reactive response is one of the root causes for the lack of a personnel scheduling management system.
- It is possible to improve procedures and systems for planning and managing resources (personnel, time, equipment, and funds) so that an adequate response to scheduling changes can be formulated and acted on quickly and effectively.
- The system could be designed to fit into the current levels of scheduling found at the department.
- Systems currently in place, or simpler systems implemented from this study, can be upgraded as the construction field office gradually increases its sophistication in personnel scheduling.
- An improved system would increase productivity, decrease engineering cost overruns through earlier identification of them, and improve office morale and communications.

The methodology used to develop the final personnel scheduling management system concept consisted of an investigation that included sending a questionnaire to and interviewing project engineers. This established an understanding of how personnel scheduling is done currently. As part of the investigation, the structural placement of projects, personnel, and the construction field office itself within the department was established; interrelationships were identified; and a model of scheduling for the construction field offices was developed. Then a comparison was made of current personnel scheduling management practices and the model. From this comparison, problems and constraints operating within the current system were identified.

Based on these investigations, a unified personnel scheduling management system was outlined. This system would need to include the ability to do both planning and operations scheduling (explained later in this paper), interconnecting the two. Three approaches to further design and implement this system were proposed, one manual and two computerized. All of the approaches used the steps to scheduling found in the conceptual exploration of the system, many of which were already in place in the construction field offices.

CONSTRUCTION FIELD OFFICES AND SCHEDULING ISSUES

Organizational Structure

WSDOT is organized as a hierarchical structure. Headquarters is concerned with the general administration of all aspects of the department, formulating policies for the department, and setting district goals. Districts, of which there are six, are concerned with specific project and personnel management issues. Construction field offices, which are also hierarchical, are a specific type of office in the district that administers assigned contracts through a variety of tasks including inspection, testing materials, and keeping records, using a variety of permanent and temporary staff members.

Project Cycles

Projects at WSDOT go through five phases from start to finish: conception, definition, production, operations, and divestment (*2*). Two distinct project subcycles exist within WSDOT. The first is exclusively a design cycle and encompasses the first three project phases, whereas the second is exclusively a construction cycle involving the last two project phases. The dividing point between the two phases is the ad date, which for design is the date the project is expected to be complete for advertisement and which for construction marks the beginning of contract administration.

Conception is a complex interaction between headquarters, the districts, the Transportation Commission, and the legislature, which results in the prioritization and programming of projects. After a project is programmed, the district defines it by creating the Design Report, which includes the design concept, recommendations for design alternatives, and various special studies required by the project's scope. After the Design Report is completed and headquarters has approved it, the district produces the plans, specifications, and estimates (PS&E), which include the drawings and other information used by the contractors to construct the project. The construction field office is not expected to be involved in these phases, although PS&E theoretically would be reviewed by a construction field office beginning about 2 months before the ad dates.

The construction phase begins with operations, which is project inspection as construction is done; staffing levels for each project change in response to contractor needs as construction progresses. The final phase, divestment, is the completion of the final estimates (required at headquarters 45 days after the contractor finishes) and final records (required as soon as possible after the project closes).

Personnel Scheduling

Most projects are ready to construct when the field office receives them, and personnel with a variety of skills in inspection are available to ensure timely construction to specifications. To match the personnel and projects required for construction requires the generation of a balanced personnel schedule. Here, a generic model of scheduling is developed and is used as a focal point for discussion.

Elements of Scheduling

Scheduling combines and balances three elements: personnel, projects, and time. The typical approach to creating a complete personnel schedule includes

- Projects fixed in time based on ad date and duration;
- Office personnel assigned to projects; and
- Combining these to assess how personnel are used over time.

Optimizing the schedule is done by controlling the occurrence of projects in time and the assignment of personnel to projects.

Model of Personnel Scheduling

Figure 1 illustrates the concepts presented as elements of scheduling. Projects and human resources are apportioned to the field office from other departmental levels. The project engineer assigns his or her available resources to the office's projects, resulting in a personnel schedule.

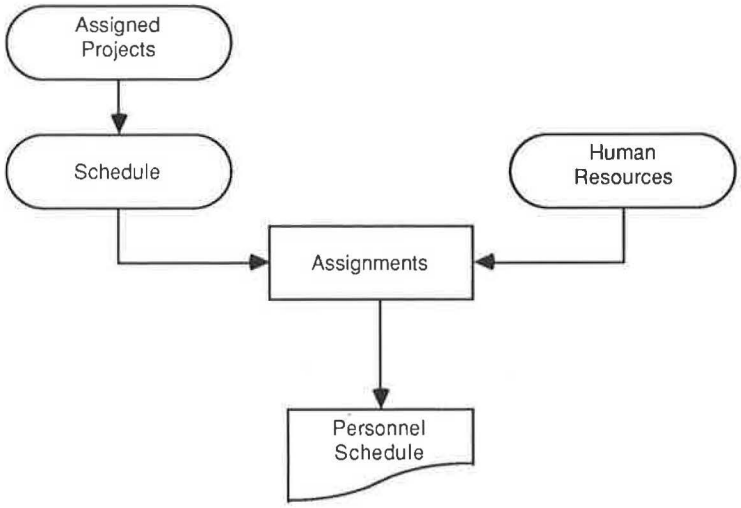

FIGURE 1 General diagram of personnel scheduling within field office.

Figure 2 presents a more refined picture of the project office process, which reflects both planning and operational considerations. In planning, expected future projects and anticipated human resources are assigned together over a range of time and balanced with the use of available information. If a balance is not achieved on the first iteration, all the elements are open to alteration. The expected final result is the preliminary personnel schedule.

Operations scheduling is used when projects are under way and is a dynamic, constant balancing of personnel assignments. Continual reassessment is necessary as project schedules and available personnel change over the short term. During this assessment, or monitoring, the type of change taking place is established, and appropriate adjustments are made.

Methods for Creating a Personnel Schedule

On the basis of these dimensional elements, the two phases of personnel scheduling and what the project engineer perceives as his or her need for a personnel schedule, the project engineer chooses one of four general levels of "scheduling" identified by Shawcroft (*3*) to create the best balanced match between people, projects, and time. The following descriptions are based on how each level characteristically handles the phases and the elements of personnel scheduling. Whether the first two levels (informal and "to do" lists) can truly be scheduling is questionable because they do not use all three elements of scheduling.

- *Informal*—mental. The project engineer associates personnel and projects in his or her mind to generate the field office's personnel work load. Written forms of schedules of any kind are rare and reliance is placed on the project engineer's memory. Formalized longer-range scheduling is rare.
- *"To do" list*—formalized list of projects or tasks. Listed items are usually unrelated to each other. Key personnel may be assigned to a project or task. Time may be involved, but only informally.
- *Bar chart*—time added to the list of projects or tasks. Time is considered essential to the schedule, and projects and personnel are assigned on a time line. The charts created are generally static and cover fairly long periods. Project tasks are not related to each other, and updating is difficult.
- *Network*—relationships between tasks added. The effects of changes on one task can automatically propagate changes in following tasks related to the first task. Resource demand, because it is interconnected with tasks, also changes automatically as tasks change. Time is dynamic, so that both longer- and shorter-range scheduling are important. Updating is one of the keys to maintaining this level of scheduling.

CURRENT FIELD OFFICE PRACTICES

Data Collection Methodology

The methodology used to examine the issues of personnel scheduling management in construction field offices involved, first, a literature search to discover what previous experience might have been. This search unearthed much indirectly related material, but nothing that could direct the research.

Second, the methodology involved sending a questionnaire to and interviewing the field office project engineers. The objectives of the questionnaire and interviews were to

- Determine existing personnel scheduling practices and procedures;
- Identify scheduling problems and constraints; and
- Obtain suggestions for what would be useful in a personnel scheduling management system.

Other states were also interviewed to compare WSDOT's personnel scheduling management techniques to theirs and possibly gain suggestions for potential solutions to the problems encountered. Detailed information was included in a technical report.

Levels of Scheduling

According to the information from the questionnaires and interviews, almost all the responding engineers and members of their staff were involved in some form of preliminary per-

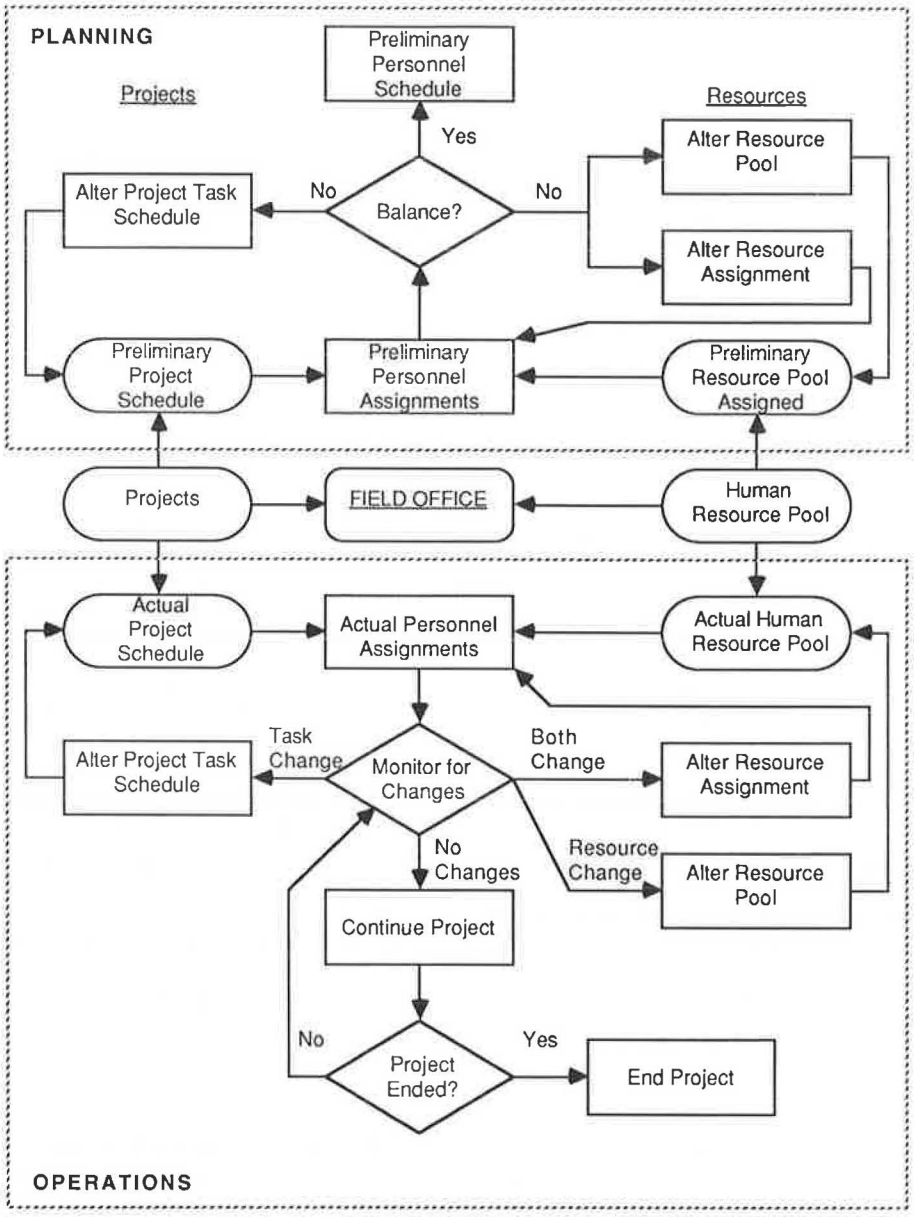

FIGURE 2 Flowchart of planning and operations personnel scheduling.

sonnel scheduling (or planning), and virtually all of them attempted some form of operational personnel scheduling. Though usually informal, the operations phase also included some type of monitoring. Of the four levels of scheduling, 13 percent of the project engineers use informal levels, 44 percent use "to do" lists, 37 percent use bar charts, and 6 percent use networks.

Planning

Generally, if the project engineers plan, they do so to determine the adequacy of personnel and equipment and to schedule people with projects. Planning schedules were done mostly at grosser detail levels, such as months or no time periods, gross task schedules, and key personnel assignments only.

Problems they encountered that they perceive as limiting the effectiveness of planning included the uncertainty of start dates, uncertainty of when project tasks would actually occur, and lack of detailed project schedules. These problems all focus on the project dimension of scheduling, and the data required to alleviate them must come from outside the field office. Areas such as lack of procedures for scheduling were not considered problems because the project engineers feel they can control them.

Operations

Like planning, operations schedules were done at a fairly gross level of detail, with less documentation (only about a third write down an operations schedule). Those who document, however, used a greater level of time (weeks and months). About two-thirds of the project engineers also monitored all projects, usually to update schedules.

As with planning, problems such as lack of detailed, updated, and reliable contractors' schedules, uncertainty of project activities' timing; and lack of response time were important

in limiting the use of personnel evenly over a year. Much of the data for these concerns are not under the project engineer's control. Those that the project engineer could control were not considered problems.

To solve the problems encountered in operations, project engineers generally use solutions that alter the resource pool (such as adding temporary employees, instituting overtime, or borrowing crew) or the assignments. Fewer than half of the project engineers ask the contractor to adjust his or her schedule, the only nonresource-altering solution mentioned.

CURRENT STATE OF PERSONNEL SCHEDULING MANAGEMENT

Systems of Scheduling at WSDOT

The project engineers do carry out purposeful personnel scheduling management at WSDOT. Characteristics common to all the systems found at the department include the

- Delegation of day-to-day scheduling to the chief inspector or the project inspector, unless a crew change is required, at which point the project engineer becomes directly involved in the process;
- High level of distrust of the contractor's progress schedule and the written updates received; and
- Reluctance of almost all project engineers to ask the contractor to alter his or her schedule.

Table 1 compares the typical system features and characteristics of the four systems mentioned as they are found at WSDOT (note that CPM is "Critical Path Method").

Limitations of Current Systems

Two major restrictions limit the project engineer's ability to do personnel scheduling management. The first, and most important, restriction is that the project engineer is severely limited in his or her ability to balance the system. As illustrated by Figure 3, the project engineer cannot take advantage of the balancing techniques offered by the left side of the scheduling model, which concerns the ability to alter project

TABLE 1 ELEMENTS OF PERSONNEL SCHEDULING SYSTEMS AT WSDOT

Typical System Features / Type of System	Attitudes	Planning	Operations	Treatment of Elements (time, people, projects)	System Advantages	System Disadvantages
Informal	Lack of interest in • time • paper • planning Don't need to plan Personnel most important "Gut feel" scheduling	Reluctant to plan No balancing Considered unreliable Mental	Started after contractor begins work Reactive to situations Informal monitoring Mental	Mental process Attention on personnel Assignments fluid Operational timeline a mental process	Little paperwork Project Engineer available to solve problems Project completion is goal	Less flexible as design centralization comes in Lack of historic records Difficult for anyone to take over Not true scheduling (unwritten)
"To do" List	Unconcerned about "missing pieces" in schedule Some mistrust of computers "Gut feel" scheduling with a little planning	Done readily Some balancing attempted Not connected to operations No timeline Update by adding project to list	No time line People and projects matched Monitoring by verbal update and personal visit	Time missing Projects, people in list at gross level (whole projects, key people)	Documentation exists Simplicity Anyone can understand lists Secondary task list possible	Not true scheduling (no time element) Inability to anticipate change
Bar Chart	Challenged to control problems	At least a season to a calendar year is planned Balancing is integral part Time line with some project divisions Updating useful and common	Highly detailed (if on computer) Contractors' progress is monitored and connected to office schedule Use computer programs: • Microsoft Project • Lotus 1-2-3	Chart covers all elements Engineering costs tracked often Project tracking done Procedures tailored to office needs	Able to do resource leveling (histograms available) Realistic attitude toward planning All elements involved Computer easily incorporated	Lack of time for update Information may be missing Manual chart slow to update System set up is time consuming and complex
Network	Planning key to operations Crew needs as much information as possible as soon possible Prefer contractors to hand in CPM	Essential Key to operations Preliminary schedule leads to operations schedule	Daily schedule Use several computer programs: • Microsoft Project • Lotus 1-2-3 • SPF	Detailed preliminary schedule Detailed operations schedule Engineering costs tracking essential	Resource leveling, balancing Combines planning and operations (unified system) Track contractor easily System enhanced easily Updates more easily Schedule available quickly	Setup time is long Level of detail and accuracy is affected by uncertainty of activity start dates

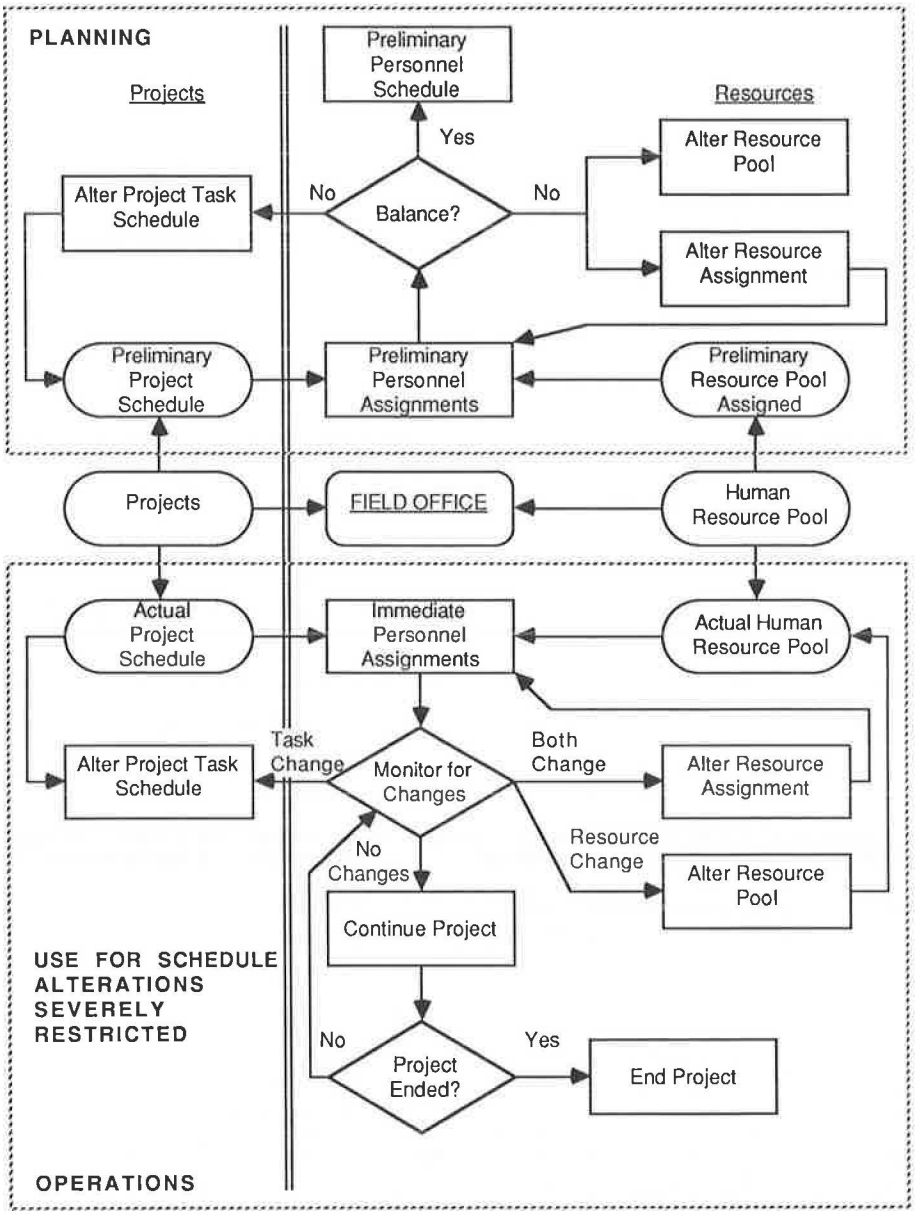

FIGURE 3 Model of scheduling: limitations on the construction field office.

task schedules. Control of the schedules used by the project engineer for planning and operations is in the hands of the design section of the department and the contractor. The second restriction, affecting the resource pool, consists of difficulties in communication and perceptions about departmental policies.

Project Schedule Limitations

Resource Leveling For the field office, resource leveling, an important aspect of scheduling, is essential for two reasons:

- Highs and lows caused by the seasonality of the construction process for contractors also affect the construction field office schedules; and
- The department limits each field office to a certain level of permanent staff somewhere between the peaks and valleys.

The following major limitations affect resource leveling for projects:

- The construction field office does not know for certain about a project's assignment until 2 months (maximum, frequently less) before the ad date, leaving little time for the leveling, which begins to be required at least a year in advance.
- The field office does not control the ad or start date, both of which change frequently, quickly, and with little prior notice, making resource leveling for more than in-house projects a futile exercise.
- Project engineers do not control contractors' progress schedules and so only guess the task schedule for resource leveling.

To partially solve this problem, the focus must shift from a concentration on projects to the resource pool. Also, a secondary task schedule not necessarily dependent on particular projects can be planned for slack times.

Lack of Communication The construction field office is seldom fully informed about the project it will be inspecting until approximately 2 months before the ad date. This tends to limit the project office's planning to notifying headquarters of what the field office believes (guesses) it needs in the way of personnel and equipment for the next season. Many of the project engineers limit their view of planning deliberately to avoid having to deal with as many changes as are expected.

The solution to this problem may lie in a greater attention to the valid concerns of construction inspectors by design teams. The design team must become aware of the advantages of involving the construction personnel much earlier in the design process, perhaps at the Design Report stage.

The Contractor's Progress Schedule Project schedules for operations within the field office are often partially based on the contractor's progress schedule. The contractor's progress schedule is supposed to tell what the contractor intends to do, approximately when in work days, and what the critical work items are. However, many contractors' progress schedules are not detailed or accurate, and updates are infrequent. The inaccuracy of these schedules limits the field office's ability to create reliable schedules and the techniques available for adjusting the personnel schedule.

The solution to this problem will include holding more strictly to the contractor's progress schedule specifications, which require accuracy and weekly updates. Enforcement of these specifications will require support from upper-level construction personnel.

Resource Pool Limitations

Resource pool limitations are generally caused by two problems: communication difficulties between district construction organizations and perceptions about departmental policies. The communication difficulties were not found statewide and were generally influenced by rivalries, egocentricities, and position-protection attitudes. Policies perceived as restricting the project engineer's ability to schedule include design centralization (which takes away work during slower seasons), cutbacks in permanent staff (which cause lower inspection standards), and contractor accommodation as the main purpose for scheduling (which can strain the resource pool).

Solutions to these problems most likely lie outside the field office, through reestablishment of trust by greater communication at all levels. The initial movement would come from upper levels of management.

PRELIMINARY DESIGN CONCEPTS

System Objectives

Five major objectives for improving personnel scheduling management surface when the scheduling model is used to explore the current personnel scheduling systems of the construction field office:

- *Improve personnel needs projects* by upgrading planning scheduling by incorporating minimal levels of project detail and personnel demand while keeping the system relatively easy to use and maintain.
- *Minimize reactive management* by upgrading operations scheduling by incorporating ways to see clearly the complete day-to-day tasks and available personnel in the short term.
- *Maintain efficient use of resources* by upgrading resource scheduling to eliminate unnecessary resource peaks and valleys.
- *Improve documentation* by maintaining records that chronicle the relationship between project progress and personnel assignments and use.
- *Create ease of use* by establishing methods of data collection, processing, and reprinting that are understandable.

All of these objectives build on data, procedures, and products already in use at field offices.

Essential System Requirements

System Products

The basic system objectives could be met through the production of three standard reports:

- Personnel Projections Schedule;
- Quarterly Personnel Summary; and
- Daily Personnel Assignments Schedule.

The first two would be specifically planning reports and the last would be an operational report.

Personnel Projections Schedule Figure 4 illustrates the general format of the Personnel Projections Schedule. The scales would be at a low level of detail: time in weeks (or quarter-months) over a 2-year period, personnel in crews and classification levels, and projects at gross level of tasks. The 2-year term has been chosen to represent the biennium unit used for much of the department's planning. The four sections are as follows:

- *Section 1*—the bar chart, which would be the main schedule overview.
- *Section 2*—a summary of the number of crews required for each time period.
- *Section 3*—a table of the classification levels that make up each crew.
- *Section 4*—a projection of the number of personnel needed in each classification level.

Quarterly Personnel Summary The Quarterly Personnel Summary is a summary of the Personnel Projections Schedule specifically for district personnel planning. Figure 5 illustrates the Quarterly Personnel Summary report, which indicates the projected person-months needed in the field office for construction, location, and administration.

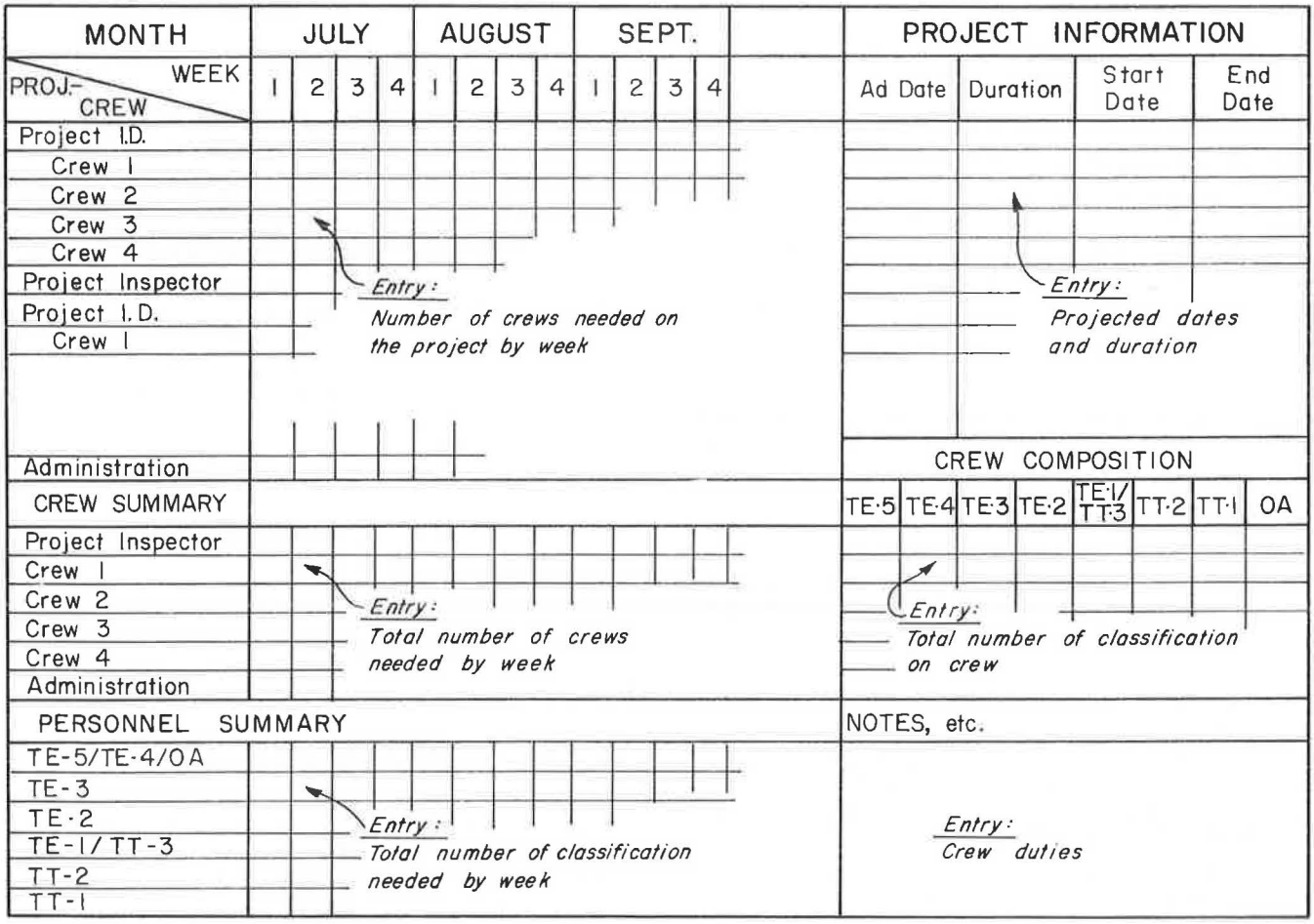

FIGURE 4 Personnel Projections Schedule.

PROJECT ENGINEER

	REPORT PERIOD _____												
MAN MONTHS REQUIRED	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	
LOCATION													
CONSTRUCTION													
ADMINISTRATION P.E. Assist. Office Engr. Secretary													
OFFICE TOTAL													

EMPLOYEE ROSTER

_____ PERMANENT

_____ ON LOAN TO

_____ BORROWED FROM

_____ IN TRAINING

_____ TEMPORARY

_____ TOTAL

NOTE: REQUIRED PERSONNEL SHOULD INCLUDE 10% TO COVER ANNUAL AND SICK LEAVE

SURVEY & MATERIALS INSPECTION TO BE INCLUDED IN LOCATION OR CONSTRUCTION

FIGURE 5 Quarterly Personnel Summary.

Daily Personnel Assignments Schedule Figure 6 illustrates the general format of the Daily Personnel Assignments Schedule, a bar chart showing how each person is scheduled over 4 weeks. The scales would be at a fine level: time in days covering a 4-week period, personnel by individual names and classification level, and projects broken into tasks at each point where the size or type of crew changes. Below the bar chart would be the project summary, which would list each project's tasks and total the number of personnel assigned daily to each task. Creation of the bar chart would require creation of two side reports, which are then combined into the main schedule.

System Processing Overview

Planning Steps Summary Figure 7 is a flowchart illustrating the process required to achieve both the Personnel Projections Schedule and the Quarterly Personnel Summary. The proposed system is not intended to cover specific individuals or highly detailed project tasks and must allow for two types of flexibility. The first is easily adjustable start and end dates that incorporate new information as it becomes available. The second is flexibility in producing the two reports, of which the second report is dependent on the first. Furthermore, the system must recognize variations in types of data available

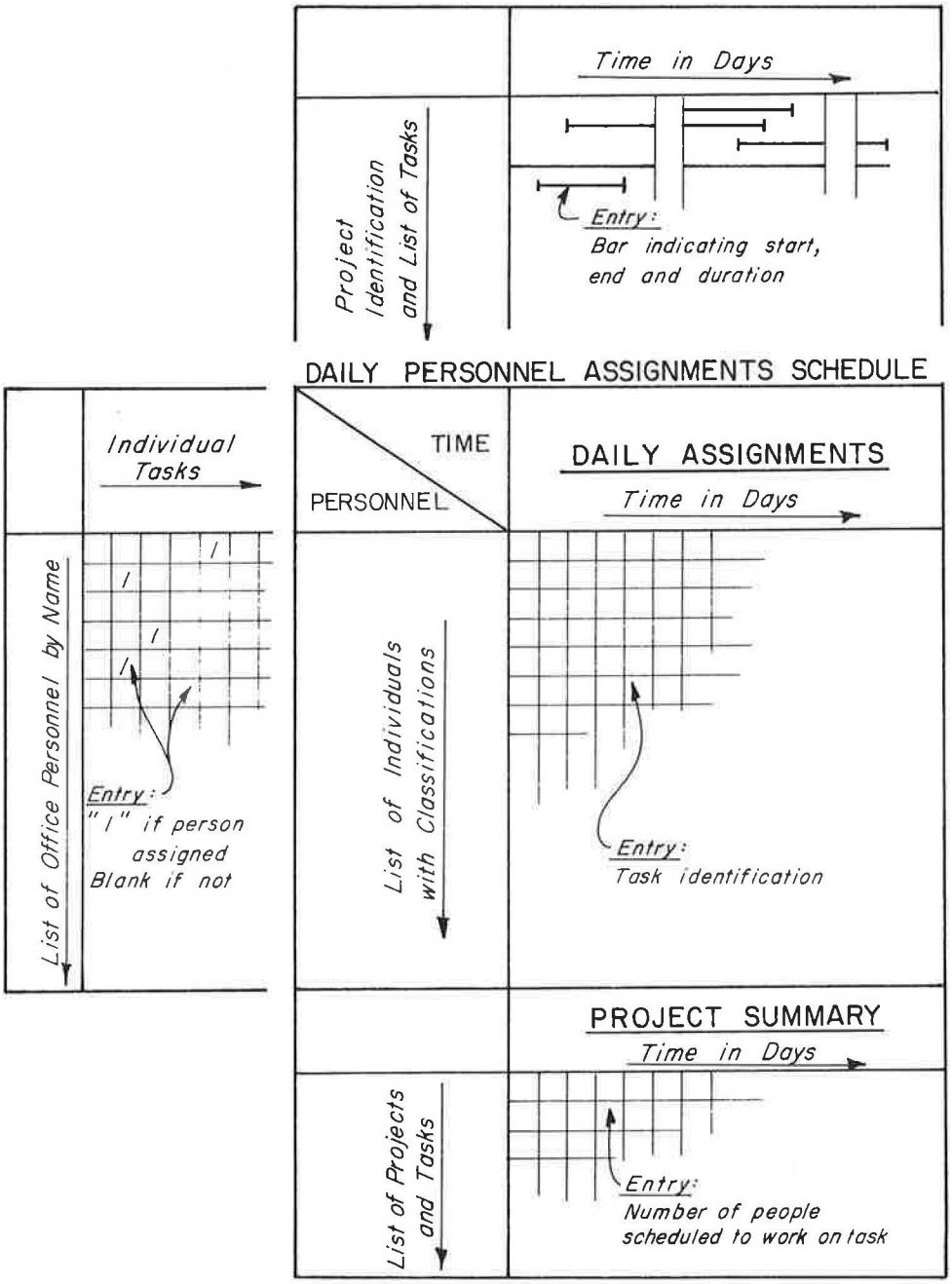

FIGURE 6 Daily Personnel Assignment Schedule.

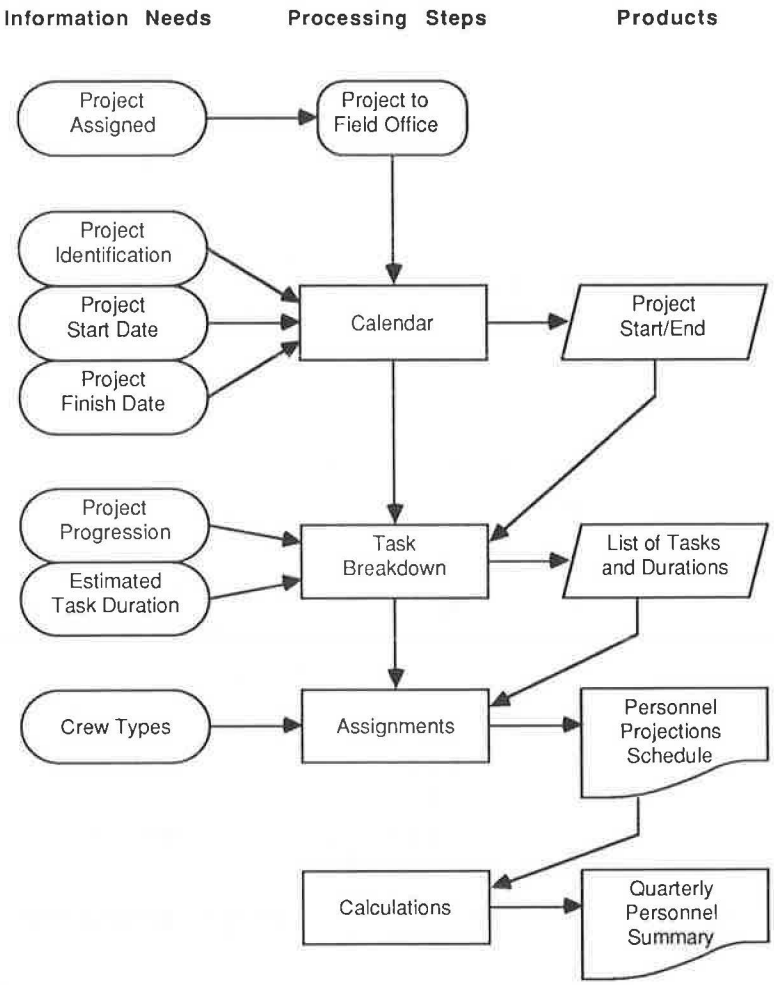

FIGURE 7 Flowchart for Personnel Projections Schedule and Quarterly Personnel Summary.

and permit the project engineers to use their own judgment in assessing future total crew needs for project tasks.

The process to achieve these schedules is initiated by the assignment of the project to the field office. Steps include

1. *Calendar step*. Place the project onto a master calendar, using a project identifier, the first date anyone in the office was expected to begin work on the project, and a date for the project's completion. The information could be calculated from the ad date.
2. *Task breakdown step*. Break the project into tasks that different crews would perform using the probable project progression and the estimated duration of the tasks estimated from the first step.
3. *Assignments step*. Determine crew demand by project using information from the first two steps. Partial weeks are acceptable.
4. *Reports step*. Calculate the remainder of the Personnel Planning Schedule and the Quarterly Personnel Summary. Generation of the demand by time period by crew type, the crew summary of Figure 4, would be done first. Extending the crew type out by the number of persons per crew would lead to person-demand by week, termed the personnel summary. The Quarterly Personnel Summary would be generated from information located on the Personnel Projections Schedule. The personnel summary section would be an estimate of the number of personnel by classification by week (or quarter-month) required in the field office. The monthly average of personnel by classification could be calculated and added together for the office totals required on the Quarterly Personnel Summary.

Operations Steps Summary Figure 8 illustrates the process required to create and maintain the Daily Personnel Assignments Schedule. The proposed system is expected to cover specific individuals in daily detail over short time periods. It must be flexible enough to allow constant adjustment of individual assignments as new information becomes available, while maintaining a slightly longer view on upcoming changes. This schedule is expected to be updated at least weekly, to maintain as high a level of accuracy as possible.

The system's steps are as follows:

1. *Project task schedule step*. Convert the project into crew-related tasks and associate these with a daily calendar that covers a maximum time period of 4 weeks. Task duration

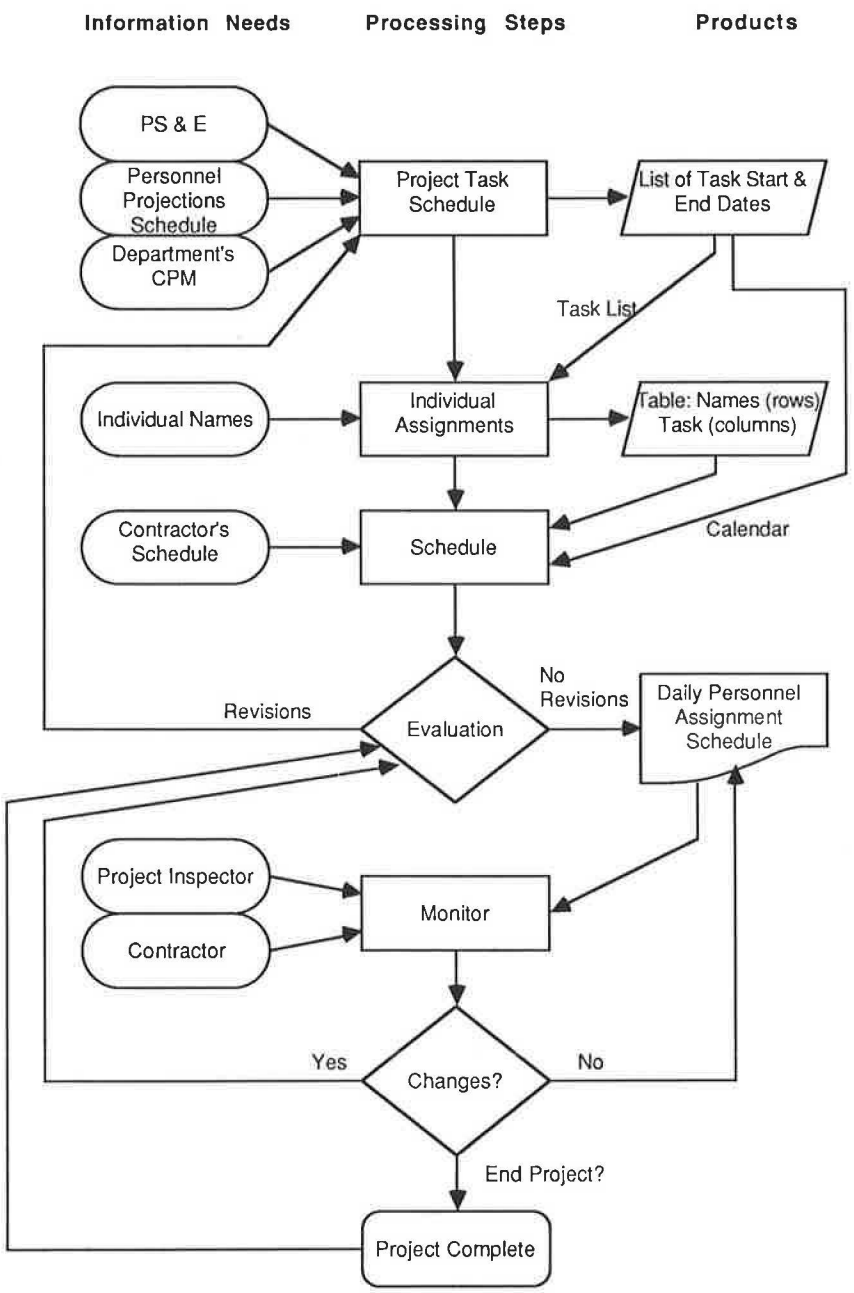

FIGURE 8 Flowchart for Daily Personnel Assignments Schedule.

would depend on a crew size or type change. Information required to do the task breakdown would include the project identification, the project plans, the ad or construction start date (or both), and total project duration.

2. *Individual assignments step*. Assign individuals by name to each defined project task. The information required for this matching would be a list of all members of the office staff and their classification levels and the list of tasks and durations developed above. Determine at this time whether overtime or per diem would be required. The result would be a table with columns listing project tasks and rows listing individuals; entries at the junction of the columns and rows would indicate when the individual was assigned to a task.

3. *Schedule step*. Combine the information from the first two steps and create the proposed operations schedule with the daily task assignments for each person over the next 4 weeks, as well as the project summary, which outlines tasks and summarizes crew totals by task.

4. *Evaluation step*. Evaluate the schedule for whether all project tasks were adequately staffed and whether all personnel were committed at, or close to, 100 percent time throughout the period. If adjustments were not necessary, a usable schedule would exist; if adjustments were required, revisions would be made.

5. *Monitoring step*. Continue to collect the best information available on task start and end changes and personnel adjustments, ideally updating the schedule weekly. Two basic sources, the project inspector and the contractor, would be available for this information. Continue to evaluate the schedule for reasonable staffing levels and resource use.

Component Interaction

The planning and operations components of the system are expected to interact in two ways. First, the planning schedule could be used as the initial project task schedule for operations, refined as necessary to meet the detail requirements of operations. Second, current operations information on projects in progress would be periodically incorporated into the Personnel Projections Schedule. This process would be done at least quarterly and would result in easier scheduling methods and better foresight into potential scheduling problems.

SYSTEM DESIGN APPROACHES

Manual System Approach

The manual implementation of these procedures would closely resemble the lists, tables, and charts used in the conceptual system. Each of the reports, the Personnel Projections Schedule, the Quarterly Personnel Summary, and the Daily Personnel Assignments Schedule, would become a form to fill in. Tables and charts, used to create the final reports, would also be fill-in forms. The steps would be done manually to process the information into the reports.

The only advantage to this approach would be that a standardized procedure for scheduling would be available. For field offices lacking formal scheduling capabilities, these procedures would result in documented personnel schedules. The major disadvantage of the approach is that it is time-consuming to use, causing three system objectives to be compromised. Constant recalculation and redrawing would not encourage ease of use; the monitoring aspect, which would allow the system to minimize reactive management, would require swift responses; and when creating a schedule becomes so time-consuming, the effective use of personnel fails. Consequently, this system is not recommended for implementation except in limited circumstances.

Spreadsheet System Approach

Implementing the outlined system on a spreadsheet program is a reasonable alternative. All field offices currently have access to at least one spreadsheet program, Lotus 1-2-3, which would allow the direct implementation of the proposed reports and procedures. The degree to which the overall system was automated could vary, depending on the extent to which the designer wished to use various program capabilities. Planning and operations schedules would be completed separately in a spreadsheet system. Implementation of the schedules would closely parallel the procedures outlined earlier and would produce the final form of the reports as described.

Advantages are as follows:

- Many of the manual calculations would be removed from report production, offering flexibility.
- Sections pertinent to each final report could be printed directly from the spreadsheet, with forms similar to the products described earlier.
- The graphics extension capability would be used to visualize resource distribution.

The disadvantage would be the time required to set up this system. Each report section would need to allow for the addition and deletion of projects, project tasks, and personnel and for the recalculation of the summaries. Familiarity with spreadsheet programs and the macro programming language would be necessary for the designer to accomplish the task.

Network System Approach

The third approach, also a reasonable one, would incorporate the use of network-based project management software. Programs such as Microsoft Project, which is supported by WSDOT, are thought to fit naturally into the context of any type of project management environment. Although they use a different method of input and report production, these programs still encompass scheduling and use of resources in a process much the same as the steps presented earlier in the description of the required system procedures.

Advantages to using a network program are as follows:

- All calculations that are necessary to scheduling are already built in and no system development is required.
- Updating is easy for both task start and end dates and classification/crew and individual resource files.
- Master files with static information can be created.
- Planned schedules can be compared with actual schedules.

Disadvantages are as follows:

- Some time is required to understand completely the advantageous use of the program.
- The reports are not in the same format as the conceptual system has envisioned.
- The systems are based on traditional resource leveling methodology, which is not applicable to the construction field offices.
- Data for the Quarterly Personnel Summary are not able to be extracted automatically, at least from Microsoft Project.
- Operations schedules may be better used as interactive screens rather than being constantly reprinted.

Approach Assessments

Three approaches to implementing the personnel scheduling management system have been suggested. Although the manual system is not recommended for use in the construction field offices, it still might be useful. At least partial implementation of the manual form, perhaps simplified or in conjunction with some already in use, would help field offices that do not have any documented system. Adding features from the proposed manual system to existing manual systems also would make true schedules out of levels of scheduling that are missing certain essential elements.

The two computer-based systems each have different focuses and strengths that could be advantageous to a field office, depending on the focus of the personnel scheduling system manager. It is also possible that a combination of the two computer-based systems would work best for an office. The spreadsheet system is focused on the end products, the reports.

The process is defined in terms of what the output should be like, and the system would be established to furnish the products. System design would be more difficult to do initially, but the end product would offer more flexibility, especially because the information could be presented in the proposed conceptual forms.

The network approach is focused on the process involved, the dynamics of the system. The system is already defined, and the user would employ the system to access the outputs that met the personnel scheduling needs. There would be less work in programming, but more in establishing the best way to access the system for the information required.

Both computer-based systems would require some manual operations. The spreadsheet would require at least manual entry and updating of start and end dates and resource assignments, as well as initial spreadsheet set-up information, which would be office-specific. Depending on the amount of automation through macros and cell formulas, more manual operations might be required. The network system would require that at least start dates and durations, task breakdowns, and resources be manually entered. Once the network was operating, updating would be performed manually. The Quarterly Personnel Summary would also have to be extracted manually from data provided by the program or sent to the spreadsheet for automatic calculations.

CONCLUSIONS

Given the findings that have been summarized, the following conclusions are drawn:

- The constraints that are operating will continue to restrict any personnel scheduling management system in the construction field offices.
- The system proposed here in conceptual form is expected, when implemented, to improve personnel scheduling management and decisions by standardizing and, in some cases, automating procedures, thus alleviating some of the stresses associated with reactive management.
- The three approaches fulfill the system objectives to varying degrees. The manual system can be implemented without requiring additional expertise but, because of time constraints, is severely limited in its ability to be easy to use, minimize reactive management, and effectively use personnel. The spreadsheet system minimizes the manual calculations required in scheduling and has less time constraints, but it requires a greater set-up time and more expertise for the designer. The network system requires little physical system development and offers the easiest updating methods, but the programs can be time-consuming in learning applications especially because the reports from this system are conceptually different than the proposed approach.

RECOMMENDATIONS

At the conclusion of the study, recommendations were formulated for implementation that could help the construction field offices better manage their personnel scheduling. These recommendations are divided into those that can be implemented by the construction field office directly and those that are dependent on outside actions for implementation.

Inside the construction field office, it is recommended that

- One or more construction field offices design and implement one or more of the proposed systems;
- Implementation of the proposed systems be done in coordination with the technical support personnel available at WSDOT, with both construction field office and technical staff involved rather than only one or the other;
- After the various system approaches have been designed and tested, they be installed in any interested field office; and
- Construction field office personnel experienced in the use of any of the systems help work out formal training sessions to teach both the system concepts and practical experience in system implementation and use.

Outside the construction field office, it is recommended that

- A study be done to establish whether exclusive assignment of a micro to the project engineers for use in scheduling would be the best way to encourage implementation of a scheduling system;
- Steps be taken to alleviate the problem related to construction personnel input into design, which input is not now available in a timely manner; such steps could include, but not be limited to inviting
  - — construction inspectors with some experience to design team meetings when project scope or design is being discussed;
  - — input from the tentatively assigned construction field office when alternatives have been chosen for constructability of the designs; and
  - — construction field office input into special designs for constructability and understandability of the plans.
- Training in critical path method scheduling be more widely available to the entire field office system;
- Encouragement and support by headquarters and district management be given to the project engineers in enforcing the Standard Specifications and Special Provisions where contractors' progress schedules are concerned (*4*,*5*);
- Contractors' progress schedules and updates be required to be more uniform as well as more readily available to the construction field office; and
- Project costs be related more directly to personnel schedules through a revised method of estimating project costs.

ACKNOWLEDGMENTS

This research was done for the Washington State Transportation Commission, Department of Transportation, in cooperation with the U.S. Department of Transportation, FHWA. Their sponsorship is gratefully acknowledged.

REFERENCES

1. Managers Set Strategic Objectives. *Interchange*. Washington State Department of Transportation, Bellevue, Sept. 1987.
2. H. Kerzner. *Project Management: A Systems Approach to Plan-*

ning, Scheduling and Controlling, 2nd ed. Van Nostrand Reinhold, New York, 1984.
3. R. G. Shawcroft and C. E. Barb. *Critical Path Method Scheduling: Basic*. Washington State Department of Transportation, Seattle, Wash., 1986.
4. *1988 Standard Specifications for Road, Bridge, and Municipal Construction*. American Public Works Association, Washington State Chapter; Washington State Department of Transportation, Olympia.
5. *Construction Manual 1984*. Washington State Department of Transportation, Olympia, 1984 with revisions through June 1987.

Publication of this paper sponsored by Committee on Manpower Management and Productivity.