ENGINEERING RESOURCE PLANNING AND USE IN THE STATE OF WASHINGTON

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After a management system for maintenance was successfully implemented, Washington State initiated a program to develop a manpower management and information system to assist the work of its engineers and right-of-way personnel. The system is based on the basic functions of planning and scheduling, measuring and comparing, and acting and reacting. The development effort was performed by a team of Washington State Department of Highways personnel with maximum participation by all levels of engineering classifications. The system centers around the development of performance standards and flow-time standards. These are applied to components of a work plan, including schedules, to determine manpower requirements. The system will eventually be automated but has been successfully used manually in its initial phases. The cost of developing the system is expected to be amortized in 2⅓ years, when increased efficiencies will result in lower operating costs.

•THE Washington State Department of Highways has been acutely aware of the need for an effective manpower management program since the mid-1960s. Early in 1967, the department began the development of the maintenance control system. This system was designed to respond to the requirements for better highway maintenance and to consider human and financial resource needs. It was developed in 18 months and implemented by 1969. Some of the benefits of the maintenance control system are

1. Increased productivity that resulted in a direct or indirect savings of approximately $1.7 million per year,
2. A performance budgeting system acceptable to and understood by the legislature and the state budgeting agency,
3. Better scheduling of time and assignments by employees and managers,
4. Continued evaluation of accomplishment as related to budget expenditures of both human and monetary resources.

In 1972, approximately 27 percent or 1,250 of 4,600 highway department employees were working under the maintenance control system requirements. Encouraged by the system's success, the department began considering a similar system of resource management for its engineers and technicians.

As in most states, highway construction in Washington is decreasing and is being influenced by many outside factors. Department managers were faced with the possibility of having excess personnel for preliminary and construction engineering. The effect of this excess could be eased if a system could be developed that anticipated and accounted for most influencing factors in the planning process.

Washington legislators were also interested in the productivity and use of the department's engineering employees. At its last regular session, the legislature required the department of highways to develop and implement nonexpenditure workload performance criteria for approximately 2,000 engineering and right-of-way personnel.

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Fortunately, the manpower utilization program, which the department had decided to develop, could be adapted to fulfill this requirement.

At the beginning of the manpower utilization program, the department had the basic scheduling and data collection systems to develop a comprehensive program. These systems needed to be tied together and expanded or modified to fit the needs. This new program was identified as the manpower management and information system (MMIS). The unit to develop the system was organized, funded, and staffed with six full-time department employees in July 1972. A comprehensive work plan outlined the functional tasks and activities to be undertaken in developing the system. The work plan included the services of an engineering management consultant in an advisory capacity and extensive contributions by many engineering disciplines within the department. The work plan was ambitious in that it affected engineering work activities for preconstruction, construction engineering, and right-of-way. The work plan involved refinements of project scheduling systems, development of labor standards, development of flow-time standards, and design of an automated data processing subsystem to satisfy management information needs. Development of the system was complicated by the fact that the department's organizational structure is decentralized.

The overall project is guided by an advisory board. The board consists of the deputy director, two district engineers, four assistant directors, the state director of personnel, and a union representative. The advisory board reviews policy determinations and makes recommendations to the director of highways regarding policy matters.

MANPOWER MANAGEMENT AND INFORMATION SYSTEM

The system contains elements with which district and headquarters administrators can plan, organize, direct, and control the day-to-day efforts of their staff. It provides major input into an annual performance budget for the highway construction program. It relates elements of construction programs to labor requirements and will ultimately provide the information needed for cost comparison purposes.

Maximizing use of engineering personnel requires realistic planning and scheduling, immediate and continued visibility of actions taken, and response to deviations from the plan or schedule. Simply stated, MMIS is based on planning and scheduling, measuring and comparing, and acting and reacting. The system recognizes the human factors vital to the success of this type of project. The importance of the understanding and cooperation of workers is a basic factor contributing to increased efficiency. A totally mechanical approach to improving work procedures will not guarantee desirable results. Worker cooperation and motivation, even if combined with relatively ineffective work methods, will frequently give better results than impersonal automated control in which the worker has no input. It is only through consideration of the worker as an individual that a work improvement or management program can be effective.

In addition to benefits to management, benefits should also accrue to employees under the system. The system will provide a way by which projects can be rescheduled to use the department's staff effectively. Personnel will then be ensured of a continuous work program and employment. The system also has features that can motivate the employee to establish goals to guide his career development and everyday activities.

In development of the system, an engineering management consultant was used in an advisory capacity and engineering employees contributed extensive input. Employee expertise was focused through three active working committees plus ancillary teams. One committee was an 18-man team of district and headquarters personnel who coordinated the efforts of the MMIS project. Another 12-man team of engineers and technicians developed task definitions in the area of preconstruction engineering. An eight-man team was used in a similar capacity in the area of construction engineering. Other teams of engineers and technicians in districts and headquarters were trained to conduct the long cycle time and work sampling studies. In addition, the MMIS project staff carried out personal interviews with 75 percent of the department's project engineers and support group managers.

The system can best be symbolized as a pipeline with a funnel at the beginning. The

Figure 1. Highway project planning process.

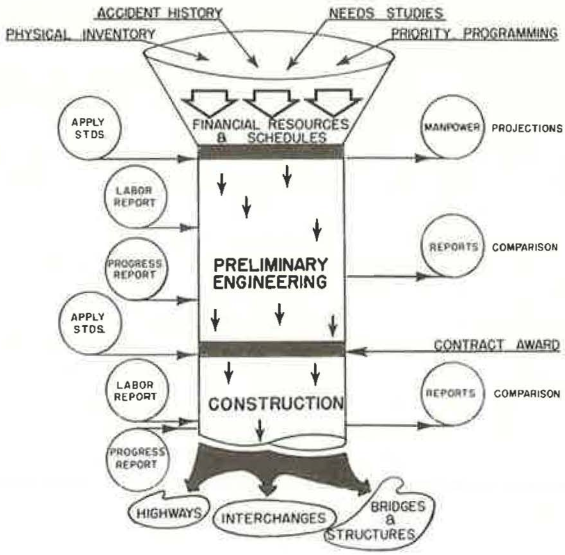

Figure 2. Project input information for design.

Project Number: 11123B-201

Sign Route: 002 MP 147.96 to MP 148.44

Project Title: SUNSET INTERCHANGE

Project Type (Select One): Length of Project:

[X] Major Construction Rural 0.48

[ ] Major Construction Urban

Project Features:	Unit of Measure	Quantity
[X] Action Plan Group 1	/////	/////
[ ] Heavy Vegetation	/////	/////
[ ] Mountainous Terrain	/////	/////
[ ] ◊ Interchange	Each	
[X] Major Interchange	Each	1
[X] Intersection	Each	3
[X] Frontage Road	Mile	2.0
[ ] Rest Area	Each	
[ ] Weigh Station	Each	
[ ] Railroad	/////	/////
[X] Access Points	Each	1
[X] Photogrammetry Products	Sq. Mile	3
[X] Special Studies	Each	2
[X] Landscaping	Acre	10
[X] Noise Study	Mile	0.48
[X] Air Study	Each	1
[X] Biological Study	Each	1

funnel represents the planning process through which a project is conceived (Figure 1). A wide range of information is combined to form the basis of a single project as it passes through the pipeline. The system considers the results of continuing needs studies, public input, traffic data analysis, and legislative direction. When a project prospectus is determined, it enters the pipeline and is processed through the scheduling system. Manpower projections are made for each activity by applying the standard data included in the work criteria for these activities. As each milestone is reached, the project can be reevaluated and new personnel requirements can be projected.

As the project becomes refined, the work criteria become more finite, and more accurate manpower projections can be made. After the project arrives at the advertising stage, construction labor standards are reapplied to the components of the project and construction engineering requirements are projected. Thus, engineering costs can be identified more accurately. The present method of estimating engineering cost in Washington is to assign a percentage of the estimated construction costs. The system will provide planning for multiple projects and control of individual projects.

Input to the system must begin at the lowest level of management and must be summarized for all levels. Because of the detail involved in multiproject scheduling, the system should be automated so that the effect of changes resulting from high-level decisions or unavoidable delays due to outside factors can be rapidly identified.

In the system, control input comes from the field or operating forces through the payroll reporting subsystem. One copy of these data is used for payroll purposes and another for management purposes.

Monthly reports will provide each project manager a status report for each project under his control. These reports will compare his crew's work output of the past month to the work planned for that month. Thereby crew performance can be measured and corrective action can be taken if the scheduled performance is compromised. Factors that delay the construction program can be identified and equated to time and money. This output will help top management make decisions that will minimize the effect of delays. The ultimate result of the successful implementation of the MMIS will be that engineers and project managers will become actors who anticipate and prevent problems rather than merely reactors to situations as they occur.

WORK STANDARDS

The backbone of the MMIS is the person-hour work or performance standards and flow-time or long-range planning standards. These standards were specifically developed for work performed during preconstruction, right-of-way, and construction activities. A person-hour work or performance standard is the criterion on which actual performance is evaluated for quality, quantity, and productivity. A flow-time or long-range planning standard prescribes the number of days allowed to complete an activity, milestone, or project.

Each preconstruction engineering activity was defined early in the project development. There are 140 work activities identified as preconstruction engineering and 60 as construction engineering. Each activity is described in a specific work control statement. The work control statement gives the scope of the work involved, the purpose, significant decisions needed, and the necessary staffing by number and skill level. Work performance standards and flow-time standards were developed for each activity. These standards are stored in the computer and are the basis for resource calculations when the construction program is developed.

Examples of typical planning inputs to the automated system shown in Figures 2 and 3 demonstrate the use of work performance and flow-time schedules and the development of manpower forecasts. These figures show the design and construction phases of a project. Similar input is required for other preconstruction phases. Descriptions of the project type and project features key the computer to calculate an estimate of planned person-hours. The input to the computer also keys a calculation to produce a scheduling network. This becomes the basis to calculate and spread the person-months required to complete the phase. Planning reports similar to those shown in Figures 4,

Figure 3. Project input information for construction.

Project Number: 11123B-501

Sign Route: 002 MP 147.96 to MP 148.44 Working Days: 240

Project Title: SUNSET INTERCHANGE

	Project Type	Unit of Measure	Quantity
☐	Reconditioning	Rdwy Mile	____
☒	Major Construction	Rdwy Mile	2.35
☐	Structures	MSF Deck	____
☐	Safety (General)	-----	////////
☐	Safety (Special)	-----	////////
☐	Stockpiling	M Ton	____
☐	Bridge Painting (Misc.)	$ Contract	____

	Project Features	Unit of Measure	Quantity
☐	(M) Urban	Rdwy Mile	____
☒	(M) Earthwork (Embankment)	MCY	100
☒	(M) Structures (Bridge)	MSF Deck	10.5
☒	(M) Retaining Walls	CLF	5
☒	(M) Existing Alignment under Traffic	///////	////////
☐	(M) No Surfacing & Paving	Rdwy Mile	____
☐	(R) Pit	Rdwy Mile	____
☐	(R) Multilane and/or Urban	Rdwy Mile	____
☐	(R) Shoulder Rebuilding	Rdwy Mile	____
☐	(R) Automatic Grade Control	Rdwy Mile	____

	General Features	Unit of Measure	Quantity
☒	Lane Markers, etc.	Rdwy Mile	2.35
☒	Channelization, etc.	Rdwy Mile	2.35
☒	Guard Rail	MLF	0.45
☐	Impact Attenuators	Install.	____
☒	Drainage (30" & Under)	Install.	10
☒	Drainage (Over 30")	Install.	1
☒	Illumination	System	5
☒	Sign Structures	Each	3
☒	Sign Illumination	Each	3
☒	Erosion Control	Acre	40
☐	Aggregate Production	M Ton	____
☒	Federal Aid	///////	////////

Figure 4. Project engineer manpower plan.

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PROJECT NUMBER	PROJECT ******DESCRIPTION******	F.Y.	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTAL
			* * * * * * * * * * PLANNED MAN MONTHS * * * * * * * * * * * * * *												
11012H-401	FREEDOM TO WATT ROAD	76	F	F	2.0	4.0	5.0	5.0	6.0	3.0					25.0
	SR 195 MP 003.09 - 005.94	77													
	GR, DR, STR, PAV	78													
11012H-501	FREEDOM TO WATT ROAD	76									3.0	3.0	4.0	6.0	16.0
	SR 195 MP 003.09-005.94	77	6.0	6.0	6.0	6.0	6.0	3.0	2.0	2.0	3.0	3.0	4.0	6.0	53.0
	GR, DR, STR, PAV	78	3.0	2.0											
[illegible]H-501	SNAKE RIVER TO DUSTY	76	15.0	15.0	15.0	15.0	8.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	144.0
	SR 127 MP 079.26-085.77	77	15.0	15.0	15.0	15.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible], DR, PAV, SIGN, ILL	78	6.0	4.0											
11123B-501	SUNSET [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
	SR 002 MP 147.96 - [illegible]	[illegible]												7.0	7.0
	GR, DR, PAV, RAMPS, SIGN, ILL, G.R.	78	12.0	15.0	15.0	15.0	15.0	12.0	10.0	10.0	12.0	15.0	15.0	15.0	161.0
ORG. 442501 J. JONES	* * * * *	76	17.0	18.0	20.0	23.0	23.0	21.0	20.0	22.0	27.0	29.0	28.0	30.0	278.0
	* TOTAL *	77	29.0	26.0	26.0	26.0	21.0	16.0	13.0	16.0	21.0	21.0	22.0	28.0	265.0
	* * * * *	78	21.0	21.0	15.0	15.0	15.0	12.0	10.0	10.0	12.0	15.0	15.0	15.0	176.0

5, and 6 are generated.

The input information on the construction phase includes the project type and features. These data key the computer to calculate the planned person-hours for the construction phase of each project. A calendar predicting manpower needs is stored in the computer and is used to allocate the manpower over contract flow time. Another innovation of the system is the use of predetermined flow-time percentages of the total project for each functional activity.

The control aspects resulting from the use of these standards provide the individual manager the opportunity to measure and compare his schedule accomplishments and person-hour expenditures with the original plan. An example of this tool is shown by the project status and expenditure report (Figure 7). The information displayed in the report identifies potential future impacts and isolates specific problem areas.

WORK PLANNING AND SCHEDULING

The system of planning for work uses a critical path scheduling network for all projects and work activities involved in preconstruction engineering. Unfortunately, all projects cannot be planned the same way because of differences in project characteristics. Therefore, each project is planned independently by considering the factors that make each project unique. The final estimate for engineering resources will depend on the project location, environment, sociopolitical influences, and many other considerations.

Development of MMIS was based on the premise that there may be five stages or phases involved in planning, designing, and constructing a highway project. These phases are shown in Figure 8.

Using a critical path scheduling network to develop engineering manpower requirements has been contested by many in the highway field. The primary argument is that, because preconstruction engineering work is so strongly influenced by public reaction, environmental impacts, and dynamic changes in general, it is difficult to determine a final design and schedule; therefore, it is impractical to develop a manpower management system. We take exception to that argument. Changing conditions in planning for construction projects actually justify the development of a manpower management program becuase it becomes more essential to maintain control and direct the efforts being expended.

Six steps describe the operation of MMIS: evaluation of alternatives, balancing district resources, statewide planning and coordination, budget approval, development of operational plan, and direction and control of project.

Evaluation of Alternatives

The policies and goals established by the legislature, highway commission, the director, and other top department officials establish the scope of the highway construction program. Initial decisions on program development are controlled by ongoing needs studies, priority programming, accident histories, physical inventories, and so on.

District Resource Balancing

Headquarters is responsible for estimating future revenue and for preliminary allocations of money to each district. The districts generate a preliminary work plan for a specified period of time by selecting and identifying projects from a 6-year program. After all data related to this program are input to the computer, the resources necessary to accomplish the program are determined. If the results of these calculations are different from the known condition, the program is reiterated until available resources and plans are balanced.

Each project is considered as a MMIS work package that is subdivided into phases

Figure 5. Project schedule and manpower plan.

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PROJECT # 41001A-201
GEORGE CR. VIC. TO MARTHA LAKE
SR 090 MP 100.56 - 106.87

ACT #	ACTIVITY TITLE	FLOAT DAYS	EARLY START	LATE COMPLETE	WORK DAYS	SUPPORT ORG.	***MAN-HOURS*** HDQTR SUPPT	DIST. SUPPT	PROJ ENG	**** MAN-HOURS BY SKILL LEVEL *** ENGR AD	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1
201	SCHEDULE & BUDGET DESIGN	0	02/13/76	03/18/76	25	442001		24	24	24	0	0	0	0	0
203	TRAFFIC DESIGN DATA	1	03/19/76	05/12/76	39	442001		8	34	8	10	16	0	0	0
						333321	168								
204	BASE MAPS & PHOTO	0	03/19/76	05/12/76	40				262	0	22	84	52	52	52
230	FHWA APPROVAL	0	11/18/76	12/02/76	15	322232	16		0	0	0	0	0	0	0
						322250	32								
			* DIRECT TOTAL *				225	190	750	157	120	255	75	68	75
			* INDIRECT *				25	20	156						
			* TOTAL *				250	210	906						

Figure 6. Three-year district planning schedule.

PROJECT NUMBER	PROJECT *****DESCRIPTION*****	ASSIGNED PROJ ENG	FTBP (MO)	FISCAL YEAR	****** PLANNED MAN-MONTHS ****** JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTAL
41001A-502	JEFFERSON COUNTY LINE TO FORKS SR 006 MP 184.62 - 191.07 C, G, GR, DR, S, PAV CONTRACT $'S = 706,000 (FA)	444301		76	24.0	20.0	20.0	3.0	3.0								60
41001A-503	BOGACHIEL RIVER BRIDGE & APPR. SR 00. MP 185.58 185.64 GR, S, PAV, STR CONTRACT $'S = 760,000	------	10	76 77	F 6.0	F 6.0	F 3.0	F 3.0	F 3.0	3.0	3.0	5.0	10.0	12.0	7.0	7.0	47 21
	* * * WORK PACKAGE # 41001A TOTAL *		**	76 77	24 6	20 6	10 3	3 3	3 3	3	3	5	10	12	7	7	107 * 21 *
42023B	JCT. SR 5 TO JCT. SR 8 SR 101 MP 367.26 - 381.70	442502		76	7.0	7.0	8.0	6.0	2.0								30

Figure 7. Project status and expenditure report.

ORG. 444304 T. JOBEY

PROJECT # 43001B-501
SR 395 TO HILLYARD JCT.

WORK ORDER # 0L5823

ACT #	ACTIVITY TITLE	SUPPORT ORG	***START DATES*** PLANNED	ACTUAL	*COMPLETE DATES** PLANNED	ACTUAL	PLAND WORK DAYS	********* MAN-HOURS ********* CUR MO	TO DATE	TOTAL	BALANCE
415	CONTRACT PLAN DRAFTING		4/15/76	4/15/76	12/17/76		120		136	136	
422	FIELD ESTIMATES & COMPILED PSE		10/12/76	11/11/76	4/15/77		120		40	35	5
424	DISTRICT OFFICE - PS&E	442202	5/1/77	6/1/77	6/15/77	7/15/77	30		56	60	4
428	HEADQUARTERS - PS&E AND PIH	322222	8/1/77	8/15/77	9/1/77	9/5/77	20	8	49	60	11
		322232							8	8	
		325530						10	10	10	
433	PROJECT ADVERTISEMENT	327720	9/5/77	9/12/77	9/20/77		10	7	7	24	17
	***** TOTAL PROJECT # 43001B-501 ****		4/15/76	4/15/76	9/20/77		360	25	306	333	27

Figure 8. Highway project stages.

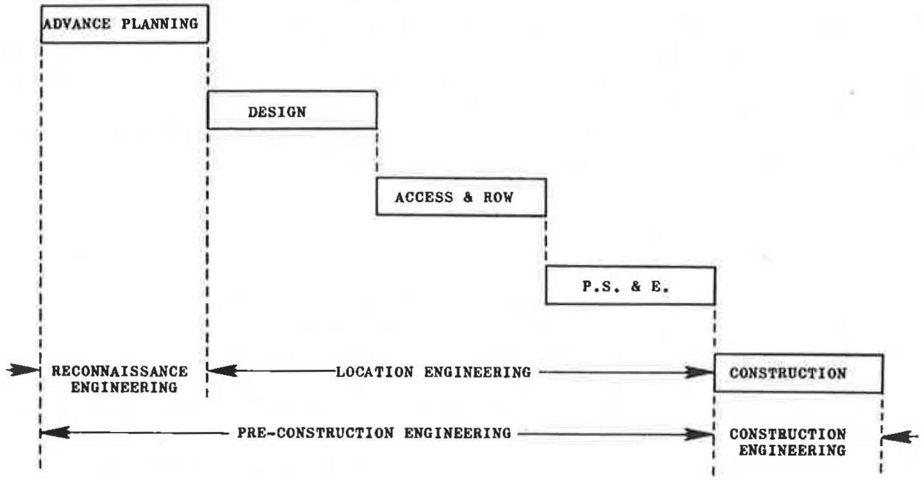
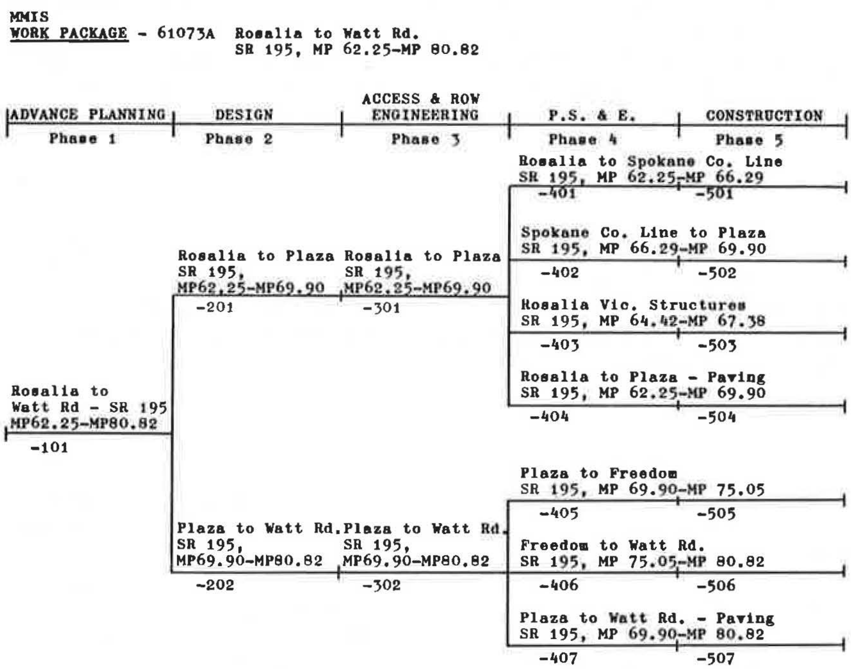


Figure 9. Highway project fragmentation.



and into its most probable project fragmentations. A typical fragmentation of a work package is shown in Figure 9.

These preliminary planning data are input to the system so that work package planning schedules may be developed. Manpower standards and flow-time standards are stored in the computer as base data. These data are used to calculate preliminary schedules and manpower requirements for individual projects at the district level. The output data are reviewed by top-level district management to ensure that financial and manpower resources are balanced. This review allows the district work plan to be formulated with as many reiterations as necessary. A typical planning report resulting from this procedure is the 3-year district planning schedule shown in Figure 6. This and other reports are distributed only to the district engineer and his planning staff. The purpose of these reports is to review schedule feasibility and to show project start and completion dates. They are also used for balancing manpower resources and as an aid in assigning projects to respective project engineers. They are updated and produced once a year and are the basis for the yearly operational plan.

Statewide Planning and Coordination

The district preliminary work plans are transmitted directly to headquarters for processing, review, and subsequent approval. When the preliminary work plans are received, the data are consolidated and formatted in accord with existing policies and procedures. The projects included are input to the computer. Schedules and manpower output reports are reviewed by the organizational units affected. Each unit makes adjustments to ensure that the best balance of human resources is attained on a statewide basis. This is accomplished by personal and telephone contacts between units.

The statewide planning and coordination may require several iterations. After a balanced program has been achieved within each district and supported by the affected headquarters units, the recommended plan is presented to the approving authorities. A typical balanced planning report resulting from this procedure is shown in Figure 4.

This and other reports are distributed to the appropriate organization in the districts and headquarters. The district reports are forwarded to the district engineer and his planning staff, project engineers, and support group managers. The headquarters reports are forwarded to the appropriate support group managers and assistant directors.

Budget Approval

When headquarters has received all recommended program plans, the pertinent information is extracted and summarized in a prescribed format for review and approval. Upon approval by appropriate authorities, headquarters allocates the financial and human resources to the various districts and headquarters support groups. These allocations are related to the approved program.

Operational Plan Development

After the program is approved, district and headquarters units are furnished an operational plan from the MMIS control group. Computer printouts of the plan provide project schedules and manpower requirements that are within the scope of the approved program. The operational plans come in two formats: the project schedule and manpower plan (Figure 5) and the support group activity schedule and manpower plan.

The project schedule and manpower plan is the project engineer's yearly operational plan. The project engineer uses this report in conjunction with the project engineer manpower plan (Figure 4) to schedule day-to-day operations and coordinate support work performed by other organizational units. The operational plans are updated and furnished once a year or on a demand basis if projects have been rescheduled.

Before work can be performed in the operational plan, the district staff must ensure that funds are available for work in progress. If new projects are planned, a new fund and work order authorization request must be prepared.

Project Direction and Control

When work is performed by highway employees on projects appearing in the operational plan, their labor time charges are reported through the regular accounting labor reporting system. These charges are coded to report the actual type of work accomplished by each individual. The project engineer or support group manager is responsible for the reporting of key activity completions. The scheduling and planning efforts expended in the operational plan development process result in a series of management reports. Management at all levels have the opportunity to monitor, compare, and evaluate the progress and performance of planned accomplishments and expenditures. A typical report that provides management with progress and performance is the project status and expenditure report (Figure 7). This and other monthly reports are distributed to management levels within districts and headquarters that have a need for them.

SUMMARY

The Washington State MMIS development is nearly a reality. Development of labor standards has been instrumental in helping the district and headquarters management to better predict engineering manpower requirements for the 1975-77 period. The labor standards were initially applied manually for fiscal year 1975 so that standards could be tested prior to the 1975-77 period. Revamping the scheduling system has introduced a new dimension into the area of project planning by isolating the work into specific phases of preconstruction and construction engineering.

The work remaining on the project involves testing labor standards, completing the data processing system design, programming, and testing. The total system is planned to be operational soon.

This project has attempted to consider every facet of preconstruction and construction engineering activities. These range from establishing standards for survey crew sizes to involving interdisciplinary teams associated with the action plan. Although reluctance on the part of employees to accept the system was anticipated, it never materialized. This can be attributed to the deep involvement of many department employees who directly contributed to the development of the system. The commitment of top management to support development costs on this project was based on the premise that the benefits would far outweigh the development costs. Management is still holding to this premise.

Should other transportation agencies consider the development of a similar system, information on the Washington experience is available. For those who are interested in costs, the MMIS 3-year development and implementation will cost $700,000 when fully implemented. The total cost will be distributed as follows:

Item	Percent
In-house labor	53
Data processing design, programming, and testing	35
Consultant	7
Miscellaneous	5

As was demonstrated by the development of the Washington maintenance control system, the total development costs are expected to be recovered rapidly and should be related directly to increased productivity. Our goal is to realize a cumulative 5 percent improvement in productivity and employee use for at least 5 years. We expect to break even in 2⅓ years.

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