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Supplementary Notes

Abstract

This report traces the development of and explains the operation of a Construction Manpower Management System (CMMS) developed for the Virginia Department of Transportation (VDOT). Initial direction for this project was received from the Construction Engineering Manpower Management System Pooled Fund Study and a study performed for VDOT by Price Waterhouse and Roy Jorgensen Associates, Inc. Technical input was received from a project steering committee consisting of VDOT engineers, inspectors, and administrators.

This system has been tailored to the specific needs of VDOT and provides projections of construction inspection staffing needs for both the short-term (the next 18 to 24 months) and the long-term (the next 6 years). The short-term projections are very accurate and appear quite adequate for use as a manpower staffing tool and for VDOT presentations to the General Assembly. As anticipated, the long-term projections, which are based on less certain project schedules in years 4 to 6, are not as accurate as those in the short-term. Thus, little use of long-term estimates are anticipated for planning purposes at this time.

FINAL REPORT

CONSTRUCTION MANPOWER MANAGEMENT SYSTEM

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(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation
and the University of Virginia)

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SUMMARY

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INTRODUCTION

The VDOT recognized a need to develop an effective, systematic, and managerially defensible method to assess and project the needed levels of staff for construction inspection. Accurate estimates of the numbers of inspectors needed are essential to maintaining a high quality construction program for the Commonwealth. The preliminary task in addressing this need was to contract with Price Waterhouse and Roy Jorgensen Associates, Inc. to evaluate the current practices for the management of construction manpower and to outline a design for an effective Construction Manpower Management System (CMMS). This evaluation resulted in a final report dated June 1986 (1). The report concluded that the Department's existing method of determining inspection needs, which is primarily based on construction dollars, is inadequate.

The VDOT administration agreed with the conclusion but believed that an in-house study would be a better way of incorporating the construction management expertise of the Department's engineers. Furthermore, the decision was made that the Research Council should spearhead the effort to develop and implement a CMMS, the urgency of which is dictated by the record-breaking construction seasons now being faced.

PURPOSE AND SCOPE

The purpose of this project was to develop a CMMS using the general design proposed by Price Waterhouse and Roy Jorgensen Associates, Inc. as a guide. The CMMS was tailored to the specific needs of the Department; it contains projections for both long- and short-term manpower needs. The long-term needs are primarily for manpower planning, whereas the short-term projections should be helpful in staffing. Inspection activities include all activities that occupy an inspector's time (with the exception of permits and subdivision work) and thus include all maintenance inspection activities as well as those included in construction project inspection.

The CMMS should provide the administration with a defensible manpower estimate that would be available to support projections made, for example, to the legislature. But primarily, it was designed to be a planning tool for both the Central Office and the districts. Upon implementing the system and comparing the estimated needs with actual needs, the potential exists to use the system as a staffing tool.

The primary requisites for the development of the system were the establishment of an interface with existing automated systems, the maximization of the use of these systems, and the minimization of additional paper work and the requirements for new information.

It was decided early, that the project would address engineering matters, and that policy decisions related to the use of the results were beyond the scope of the project.

APPROACH

Organization

The authors acted as project managers to coordinate the collection of information available in the Central Office and districts. The National Pooled Fund Study "Development of a Construction Engineering Manpower Management System" (CEMM) (2) recommended that the required technical information and guidance be supplied by a steering committee specifically established

- to review and approve the work plan
- to monitor progress
- to provide technical input
- to review system developments
- to coordinate implementation efforts, and
- to act on all matters requiring policy-level decisions.

The committee as appointed in October 1986 consisted of the following persons:

- C. B. Perry II, Northern Virginia District Engineer, Chairman
- J. L. Corley, Bristol District Engineer
- W. R. Davidson, Lynchburg District Engineer
- E. E. Hull, Northern Virginia Assistant District Engineer
- J. C. Cleveland, Suffolk Assistant District Engineer
- C. F. Gee, Central Office, Assistant Construction Engineer, Construction Division
- R. L. Fink, Central Office, Assistant Maintenance Engineer, Maintenance Division
- D. C. Morrison, Richmond District, Chesterfield Resident Engineer
- F. C. Altizer, Jr., Salem District, Salem Resident Engineer
- G. G. Fahnestock, Culpeper District, Project Engineer

- o T. H. Sutherland, Jr., Fredericksburg District, Project Engineer
- o T. A. Chrisman, Staunton District, Project Engineer
- o C. H. Wray, Richmond District, Inspector B
- o J. T. Coe, Bristol District, Inspector B
- o K. W. Wester, Central Office, Assistant Division Administrator, Management Services Division
- o W. B. Ranson, Jr., Central Office, Human Resource Planning Supervisor, Personnel Division
- o H. G. Allen, Central Office, Technical Services Manager, Information Systems
- o W. C. Mitterer, Central Office, Systems Development Manager, Information Systems.

Although not officially members of the committee, three individuals attended several meetings and were instrumental in providing technical information and/or system development. They are

- o R. C. Edwards, Construction Division
- o C. B. Causey, Jr., Information Systems
- o Joe Dubreuil, Information Systems.

Study

The study began by analyzing the Price Waterhouse and Roy Jorgensen Associates, Inc. report and the CEMM. Both reports were very helpful in providing direction for the CMMS.

The project began with the consideration of the following activities, which will be discussed in greater detail in the next section:

1. identification of all activities requiring inspection time
2. description of all inspection activities using the Phase Inspection Guideline as a starting point
3. identification of all project types
4. definition and determination of work units within each project type
5. determination of typical quantities by project type
6. development of staffing guidelines for each inspection activity.

These items form the basis for determining manpower planning for each project.

The system was intended to provide a reasonable degree of accuracy and be based on the best contract information available.

Items Nos. 1 through 4 were determined using the Department's existing practices, such as the Phase Inspection Guidelines or the expertise of the CMMS Steering Committee. However, for item No. 5 it became apparent that there were two different ways of obtaining information. The most accurate was the Construction Division's E03 system, which contains quantitative

estimates of all construction items by project. These are estimated contract bid quantities and are only available for projects that are to be advertised in the next 18 to 24 months. Since the CMMS needs manpower estimates for a period exceeding 24 months, it was decided that for long-term projected quantities, average quantities should be determined by project type based on E03 historical records, which contain final pay quantities and thus are quite accurate. Furthermore, it was decided that the Program/Project Management System (PPMS) would be the device for identifying projects that are in the planning stage, and it would therefore define long-term needs for the next 6 years.

THE CONSTRUCTION MANPOWER MANAGEMENT SYSTEM

Standard Project Types

The CEMM system design manual (2) recommends that the number of contract types used should be the minimum number needed to distinguish contracts according to type of construction and contract characteristics which produce similar staffing requirements. General guidelines for determining the number of contract types needed were also recommended by the CEMM. The contract types chosen should represent approximately 75 percent of the number of contracts and 90 percent of the dollars in the construction program. Other state's construction management programs were reviewed, and the number of project types varied from 5 for West Virginia to 23 for North Dakota (3). The premise used in this study was that the number of project types should be sufficient to describe the types of construction activities being conducted but be as few as possible so as not to complicate the system.

The Construction Division analyzed the types of projects over the last three years and provided the distribution of projects and money shown in Table 1.

Table 1

Distribution of Contract Types

Type	Percent Projects	Percent Money
Construction	46.2	56.0
Bridge - New Construction Bridge - Reconstruction	14.7	22.4
Resurfacing	18.4	8.4
Widening	7.0	5.1
Miscellaneous	6.8	4.2
Safety	6.9	3.9
Total	100.0	100.0

The cumulative distribution indicates that New Construction, Bridge, Resurfacing, and Widening account for more than 90 percent of the money spent, and New Construction, Bridge, and Resurfacing account for more than 75 percent of the projects. Therefore, based on the criteria used in the CEMM system, Miscellaneous and Safety could be deleted as types of projects. However, it was the opinion of the steering committee that the CMMS would be more accurate if Safety were retained as a type of project. With the addition of Safety, over 93 percent of the projects and 96 percent of the contract money is covered. The use of a category called Unique was considered to take care of unusual projects such as a bridge-tunnel, but the committee felt that these projects occur so infrequently that they would be better planned for and staffed separately from the normal system. The final definitions for types of standard projects are as follows:

1. Construction (C). New construction of or additions to divided or undivided highways. Also, the removal and replacement or reconstructing or upgrading of an existing facility. May include short relocations. Includes widening equivalent to one lane width or wider. Includes all major phases of construction--site preparation, earthwork, drainage, and paving. Minor items such as signing, landscaping, and guardrail are included unless they are in separate specialty contracts.

2. Widening and Resurfacing (W & R). Widening and resurfacing of existing highway facilities when the total added width is equivalent to less than one lane width and grades are not changed. Includes minor grading, extending culverts, etc.

3. Safety (S). Placement or replacement of guardrail, signs, lighting, traffic signals, and other safety and traffic control devices when let on a specialty contract basis. Includes intersection improvements and minor construction or reconstruction of streets or highways. Normally includes some item removal, grading, drainage, and paving.

4. Bridge New Construction (B.N.C.). Includes complete structures. (Manpower requirements determined by standards staffing for each bridge occurrence by highway system.)

5. Bridge Reconstruction (B.R.C.). Includes structures when decks are replaced on existing substructures or decks are widened and substructures extended. (Manpower requirements determined by standard staffing for each bridge occurrence by highway system.)

6. Maintenance. Overlaying existing roads with hot mix, surface treatment, slurry seal, or cold mix. Includes bridge repair and painting, guardrail, pavement marking, concrete repair, sidewalk, curb, and gutter construction let as maintenance contracts. Manpower requirements included as a baseline value with estimated annual increases. (Although this is not staffed per project, as mentioned previously, the steering committee felt it needed to be accommodated by the system.)

Inspectable Items

The inspectable items were obtained from the Department's Phase Inspection Guideline list, which was expanded by the steering committee. The expanded list of inspectable items is shown in Table 2.

Table 2

Expanded List of Inspectable Items

1. Mobilization
2. Clearing and grubbing
3. Pipes, culverts, and storm drains
4. Excavation and embankment
5. Undercut excavation
6. Soil stabilization - lime and cement
7. Application of select material subbase course and aggregate base course
8. Cement stabilized aggregate subbase and base course
9. Bituminous surface treatment prime coat and seal coat
10. Slurry seal
11. Bituminous concrete pavement
12. Slip form continuously reinforced portland cement concrete pavement
*13. Placement of jointed, reinforced portland cement concrete pavement
*14. Milling - asphalt
*15. Grinding - PCC
*16. Patching - PCC
*17. Slab stabilization
*18. Adding edge drains
*19. Shoulder repair
*20. Box culverts
21. Incidental concrete items - drop inlets, manholes, junction boxes, intake boxes, spring boxes, paved ditches, sidewalks, steps, median barriers, etc.
22. Incidental construction items
23. Roadside development - topsoil and seeding
24. Bridges and structures and substructures
25. Bridges and structures and superstructures
26. Traffic signs
27. Overhead traffic signs
28. Signalization

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*Items added to the Phase Inspection Guideline list

As the steering committee developed work units and staffing guidelines to use with the inspectable items, it became clear that this list was too detailed to be efficient. Thus the inspectable items were reduced to the 11 shown in Table 3.

Table 3

Finalized List of Inspectable Items

Items	Subtopics
1. Lump Sum Earthwork	
2. Earthwork	Clearing and Grubbing Excavation and Embankment Undercut Excavation
3. Pipes	
4. Select Material, Aggregate, or Cement Stabilized Subbase and Base Course	
5. Surface Courses	
a. Surface Treatment	
b. Portland Cement Concrete Pavement	
c. Bituminous Concrete Pavement	
6. Box Culverts	
7. Drop Inlets	
8. Incidental Construction Items	Includes Topsoil and Seeding, Edgedrains, & Shoulder Repair
9. Bridges and Structures (Substructures and Superstructures)	
10. Environmental	Erosion and Siltation Control
11. Work Zone Safety	Traffic Maintenance, Traffic Control Devices, Worker Safety

Work Units and Staffing Guidelines

A work unit is defined, in this project, as a quantity of work for a given inspectable item that can be inspected in one-half to two days. Work units are in the unit of measure used in contract bid tabulations, e.g., Earthwork is in cubic yards. For many inspectable items, subtopics use varying work units, and these were combined for the system to function properly. For example, Earthwork includes clearing and grubbing (acres), excavation and embankment (cubic yards), and undercut excavation (cubic yards). Therefore, it became important when selecting the staffing guidelines, i.e., the number of man-hours necessary to inspect the work units, to include all the inspection activities covered in the inspectable item.

Teams were selected from the steering committee to develop work units and staffing guidelines for each inspectable item. An example of the assumptions and logic used to develop staffing guidelines is shown for Bridges and Structures in Appendix A. Each team presented its estimate of the staffing guideline to the entire steering committee to obtain comments

before finalizing the values. Table 4 shows the resultant work unit and staffing guidelines for each inspectable item.

Table 4

Inspectable Items, Work Units, and Staffing Guidelines

	Inspectable Item	Work Unit	Staffing Guideline
1.	Lump Sum Earthwork	Per mile of project	120.0 Man-hours
2.	Earthwork	10,000 cu yds	8.0 Man-hours
3.	Pipes	50 ft installed	6.0 Man-hours
4.	Select Material, Aggregate, or Cement Stabilized Subbase and Base Course	600 tons	8.0 Man-hours
5a.	Surface Treatment	170 tons	8.0 Man-hours
b.	Portland Cement Concrete Pavement	1,000 sq yds	5.0 Man-hours
c.	Bituminous Concrete Pavement	500 tons	14.0 Man-hours
6.	Box Culverts	50 cu yds	16.0 Man-hours
7.	Drop Inlets	5 inlets	12.0 Man-hours
8.	Incidental Construction Items	Per mile of project	150.0 Man-hours
9.	Bridges & Structures (Substructures and Superstructures)	5 cu yds	8.0 Man-hours
10.	Environmental	100 lin ft of barriers	24.0 Man-hours
11.	Work Zone Safety	60 group II barricade-days	10.0 Man-hours

Since all inspectable items do not occur on all project types, a distribution of inspectable items by project type was necessary. Again, using the steering committee's expertise, the inspectable items are shown in Table 5 for each project type. Bridge New Construction and Reconstruction use only the inspectable item Bridges and Structures.

It became obvious that the inspectable items, work units, and staffing guidelines listed in Table 4 did not address several inspection functions. Administration functions such as maintaining a project diary, record-keeping for a myriad of programs, training, travel to the residency office, etc. were not included. The committee decided that a conservative estimate of an inspector's time required to accomplish these functions is 15 percent. Therefore, this value was used as an additive factor when establishing manpower values for a project.

Table 5

Inspectable Items/Standard Project Type
(Numbers Refer to Inspectable Items List)

STANDARD PROJECT

Construction		Widening and Resurfacing	Safety
Plant Mix	Surface Treatment		
Earthwork (EW)	(EW)	(EW)	(EW)
Pipes (P)	(P)	(P)	(P)
Select Material (SM)	(SM)	(SM)	(SM)
Surface Treatment (ST)	(ST)	(ST)	(ST)
Bituminous Pavement (BP)	(IC)	(BP)	(BP)
Drop Inlets (DI)	(ENV)	(IC)	(DI)
Incidental Construction (IC)	(WZS)	(ENV)	(IC)
Environmental (ENV)		(WZS)	(ENV)
Work Zone Safety (WZS)			(WZS)

NOTE: Not all inspectable items in Table 4 occur in this table. Those items not included are used in the short-term staffing assessment.

Modifiers

It became clear when establishing staffing guidelines, that typical values for inspectable items were not typical in some locations and under some construction conditions.

One of the ways recommended by the CEMM to address out-of-the-ordinary contract characteristics was to use modifiers to the staffing guidelines, usually to increase the man-hours of inspection required by the unusual characteristics. The steering committee decided that modifiers were the proper way of taking into consideration these anomalous situations. Therefore, the committee developed a list of modifiers that would apply to certain inspectable items under certain construction conditions. This list of modifiers is shown in Table 6.

Table 6

Modifiers

Modifier	Applies To	Factor
Mountains	Lump Sum Earthwork, Earthwork, Pipe, Box Culverts, Drop Inlets, and Environmental	2.0
Wetlands	Lump Sum Earthwork and Earthwork	1.5
Wetlands	Environmental	2.0
Subgrade Stabilization	Lump Sum Earthwork and Earthwork	1.25
Semiurban	All	1.5
Urban	All	2.0

The modifiers are applied in both the short-term and the long-term to a city or county if they have been described as having mountainous terrain, wetlands, soils requiring subgrade stabilization and/or urban conditions. (NOTE: Semiurban and urban designations were determined by population density for a given location.) There are instances where modifiers must be combined, and the decision was made that they should be additive. For example, the staffing guideline for the inspectable item Earthwork in Virginia Beach would be determined as follows:

Characteristic	Modifier Factor
Wetlands	1.50
Subgrade stabilization	1.25
Urban construction	+ 2.00

Total modifier factor for Earthwork at Virginia Beach: 4.75

The full table of modifiers is in Table 5 of Appendix B.

Maintenance

There are many inspection activities included under Maintenance. However, these activities are relatively constant, and thus the estimate of manpower needs for these activities was judged to be best estimated by using a base-line manpower estimate with an annual percentage increase. The activities that require inspection under maintenance contracts are:

- o plant mix resurfacing
- o surface treatment (chip seal) resurfacing
- o slurry seal application

- o cold mix placement
- o pavement marking
- o maintenance restoration
- o bridge repair
- o sidewalk repair
- o curb and gutter repair
- o coal severance resurfacing
- o revenue sharing activities
- o airport, industrial, and recreational access construction.

In order to determine the anticipated needs for these activities, it was deemed reasonable to use recent and anticipated inspection usage. Thus, the districts were asked to provide the number of man-hours used for the above mentioned activities for 1986 and an estimated annual increase in man-hours for the same activities during the next three years. The data are presented in Table 7.

Table 7

Maintenance Manpower Requirements by District

	Present Usage, Man-hr/yr	Anticipated Annual Increases, Man-hr/yr
Bristol	51,754	9,620
Salem	19,050	2,860
Lynchburg	11,416	570
Richmond	28,753	4,830
Suffolk	33,459	1,840
Fredericksburg	20,864	3,340
Culpeper	19,624	0
Staunton	18,827	3,170
Northern Virginia	65,170	1,440
Total	268,917	27,670

The estimated annual increase was calculated to be 10.3 percent of the present usage. Based on the experience of Central Office administrators and the steering committee, this figure was judged to be too high, and an increase of 5 percent annually for each the next three years was decided upon for the CMMS.

Contract Quantities

As stated earlier, in the analysis of short-term manpower needs, contract bid quantities are available on a project basis from estimates available in the Construction Division's E03 system. However, for long-term manpower needs, PPMS, which contains projects in the Department's six-year

plan, has no quantities, only general descriptive data such as type of construction, length, etc. It was decided that for projects in PPMS, each inspectable item would have an assigned typical quantity based on the average quantity obtained from recent pay quantities obtained from the Construction Division. For these quantities to be of use, they had to be determined in relation to the inspectable items/project type (see Table 5). Therefore, for example, the typical (average) quantity of earthwork was determined as follows:

Project Type	Typical Quantity/Mi (Cu Yds)
Construction - Plant Mix	38,312
Construction - Surface Treatment	20,191
Widening and Resurfacing	23,331
Safety	26,392

NOTE: The typical quantities shown above were those originally developed through the E03 system, and, as will be discussed later, they were modified for use in the proposed system.

Manpower Planning Value

The manpower planning values (MPV) for each project are easily determined by (1) dividing each inspectable item quantity by the appropriate work unit and then multiplying by its staffing guideline, (2) summing these values for all applicable inspectable items, and (3) multiplying by the length. An example of this calculation is shown in Table 8.

Table 8

MPV Sample Calculation

Project Type: Construction - Surface Treatment
Length: 0.7 Mi.
Location: James City County
Modifiers: Subgrade stabilization, wetlands, and semiurban

Insp. Item*	Standard Quantity** (per mile)		Work Unit**		Staffing Guideline** (man-hours)		Modifier**		MPV/I.I. (per mi)
EW	4867.35 cu yds	■	1000	x	8.00	x	4.25	=	165.49
PI	945.66 ft installed	■	50	x	6.00	x	1.50	=	170.22
SM	5725.26 tons	■	600	x	8.00	x	1.50	=	114.51
ST	446.94 tons	■	170	x	8.00	x	1.50	=	31.55
IC	1.00 per mile	■	1	x	150.00	x	1.50	=	225.00
EV	8.87 linear ft of barriers	■	100	x	24.00	x	3.50	=	7.45
WZ	1201.99 group II barricade days	■	60	x	10.00	x	1.50	=	300.50
							MPV/mi		1014.72
							Admin.	x	1.15
							MPV/mi		1166.93
							Length	x	0.7
							Total MPV		816.85

*From Table 5
**From Table 4 of Appendix B

Bridges

Establishing MPVs for Bridge New Construction and Reconstruction presented a challenge. As mentioned earlier, the steering committee felt that the inspectable item, structures and substructures, was sufficiently encompassing to be the only one needed to describe the inspection activities for this project type (see Appendix A). Also, because the 6-year plan does not include bridge lengths, a standard quantity had to be developed that was independent of length. On the other hand, the committee felt that bridge work differed sufficiently on the interstate and primary system as compared to the secondary system that the MPVs developed should be different for the secondary system. Therefore, MPVs were determined for Bridge New Construction on the interstate and primary systems to be 2,000 man-hours per bridge and on the secondary system to be 600 man-hours per bridge. The committee further concluded that for Bridge Reconstruction, an MPV was only needed on the primary and interstate system, and this value was calculated to be 625 man-hours. For secondary Bridge Reconstruction, it was concluded that most of this work should be done under the maintenance replacement activity; thus, this would be addressed under the maintenance base-line value.

Bridges do occur on project types other than Bridge New Construction and Bridge Reconstruction. Construction projects sometimes include bridges, and Widening and Resurfacing occasionally include bridges. The committee felt that these projects needed the same additional staffing per bridge. So a construction project with a bridge would be staffed according to the Construction MPV plus the appropriate Bridge New Construction MPV. Bridges on other project types would be staffed with the project MPV plus the appropriate Bridge Reconstruction MPV. A complete list of Bridge MPVs are in Table 9.

Table 9

Bridge MPVs

Project Type	MPVs - Man-hours	
	Primary/Interstate	Secondary
Construction - Plant Mix	2000	600
Construction - Surface Treatment	-	600
Widening and Resurfacing	625	-
Safety	625	-
Bridge New Construction	2000	600
Bridge Reconstruction	625	-

MPV Accumulation

Accumulating MPVs for a given time frame was not as simple as first imagined. MPVs cannot simply be added because this does not take into consideration scheduling. The anticipated project start date and duration

must be determined along with MPV to determine how many MPVs are needed in a geographical area for any given month.

The first assumption that had to be made concerned the project starting date. This was estimated to be 10 weeks after the advertisement date. The next information needed was an estimate of project duration based on contract type and highway system. To get this information, the assistant district engineers for construction were polled on their experience as to how long various project types took for completion. This information was presented to the steering committee, which recommended a few changes resulting in the duration estimates in Table 10.

Table 10

Project Duration, Months

	Construction		W&R	B.N.C.	B.R.C.	Safety
	S.T.	P.M.				
Rural	10	18	18	-	-	12
Rural with Bridge	12	21	21	12	12	-
Urban	24	24	21	-	-	15
Urban with Bridge	30	30	24	15	15	-

The starting date and duration are used in combination with the project MPVs to determine the accumulated MPVs necessary by residency as shown in Figure 1. The calculation requires the following steps.

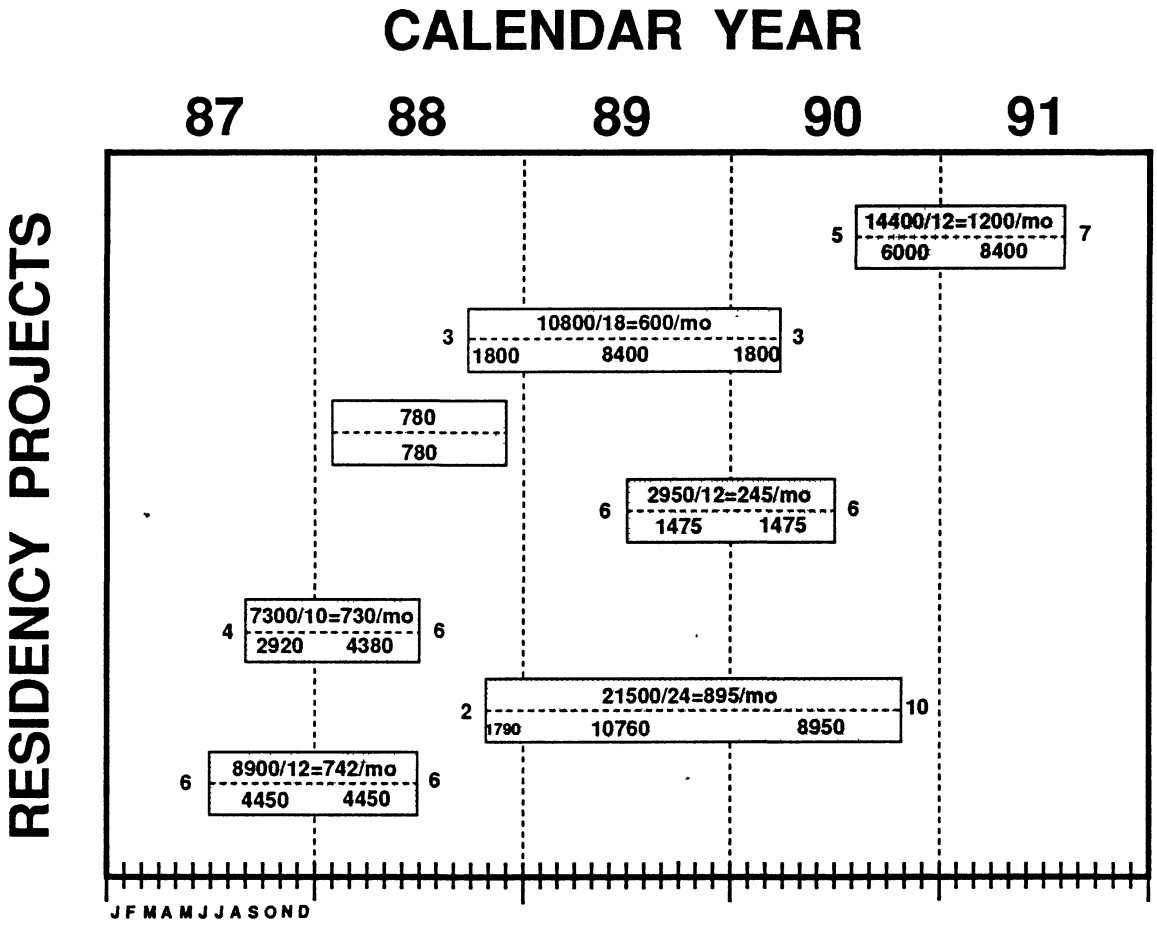
1. Accumulate MPVs (including administration) by project (see Table 8).

2. Apportion MPVs by project by month within a calendar year with the starting date being 10 weeks after the advertisement date and the duration according to Table 10.

3. Accumulate MPV/yr by project including maintenance for each residency and district (Figure 1).

Full Time Equivalent

The committee deliberated a great deal over the proper way to convert from MPVs (man-hours) to full-time equivalents (FTEs). Several figures ranging from 1,832 to 2,288 have been used. The committee concluded that CMMS should use the same conversion as used by Department-wide staff planning to convert man-hours to FTEs, which currently is 1,832. This figure does not include overtime.



MPV/YR (Const.)	13200	19435	18225
MPV/YR (Maint.)	3600	3780	3960
TOTAL MPV	16800	23215	32185

Numbers above time line refer to the MPVs divided by project duration. Numbers below time line refer to the apportioned MPV by calendar year. Numbers at end of time line are prorated months of project duration.

Figure 1. Determination of accumulated man-hours by residency.

SYSTEM OPERATION

Using the components of the conceptual design as discussed in the previous section, the actual conversion of project listings to manpower needs can be explained. Figure 2 shows a very basic flowchart for the system's operation in both the long- and short-term. For a more detailed description of the system operation refer to Appendix B.

Long-Term

For the long-term, projects are taken one-by-one from PPMS and screened. Projects not meeting certain criteria such as valid starting dates or appropriate status classification are omitted and the remaining projects are staffed. An accepted project is classified by type as one of the standard project types. Based on the project type, a standard set of inspectable items and item quantities per mile is assigned. The actual project length contained in PPMS is then used to calculate the total item quantities. The number of work units are then derived from these totals. The location of the project along with the staffing guidelines dictate the set of modifiers used to determine the total MPV for a given project. (Refer to Table 8 for a sample MPV calculation.)

Short-Term

For the short-term, projects are taken one-by-one from PPMS and screened using the same criteria used for the long-term, except the time period is only two years. Since a specific project is staffed based on the occurrences and quantities of inspectable items, project type is of no consequence to MPV calculation for the short-term. E03 quantities are converted to CMMS item quantities and staffed by using the same work units, modifiers, and staffing guidelines that are used for the long-term.

FTE Distribution

Once MPVs have been calculated for all appropriate projects, they are converted to FTEs, sorted by district and residency, and distributed and accumulated according to project duration. Obviously, the short-term numbers should be more accurate since specific projects are staffed by actual item quantity occurrence. Although the occurrence of items may be the same for the long- and short-term, they may not be; even if they are the same, there can still be considerable difference in the quantities of the items. Unfortunately, since there are no specific quantity estimates available for use in the long-term, the only feasible approach to obtain these data was to use standard project types with standard inspection items to determine average item quantities per mile.

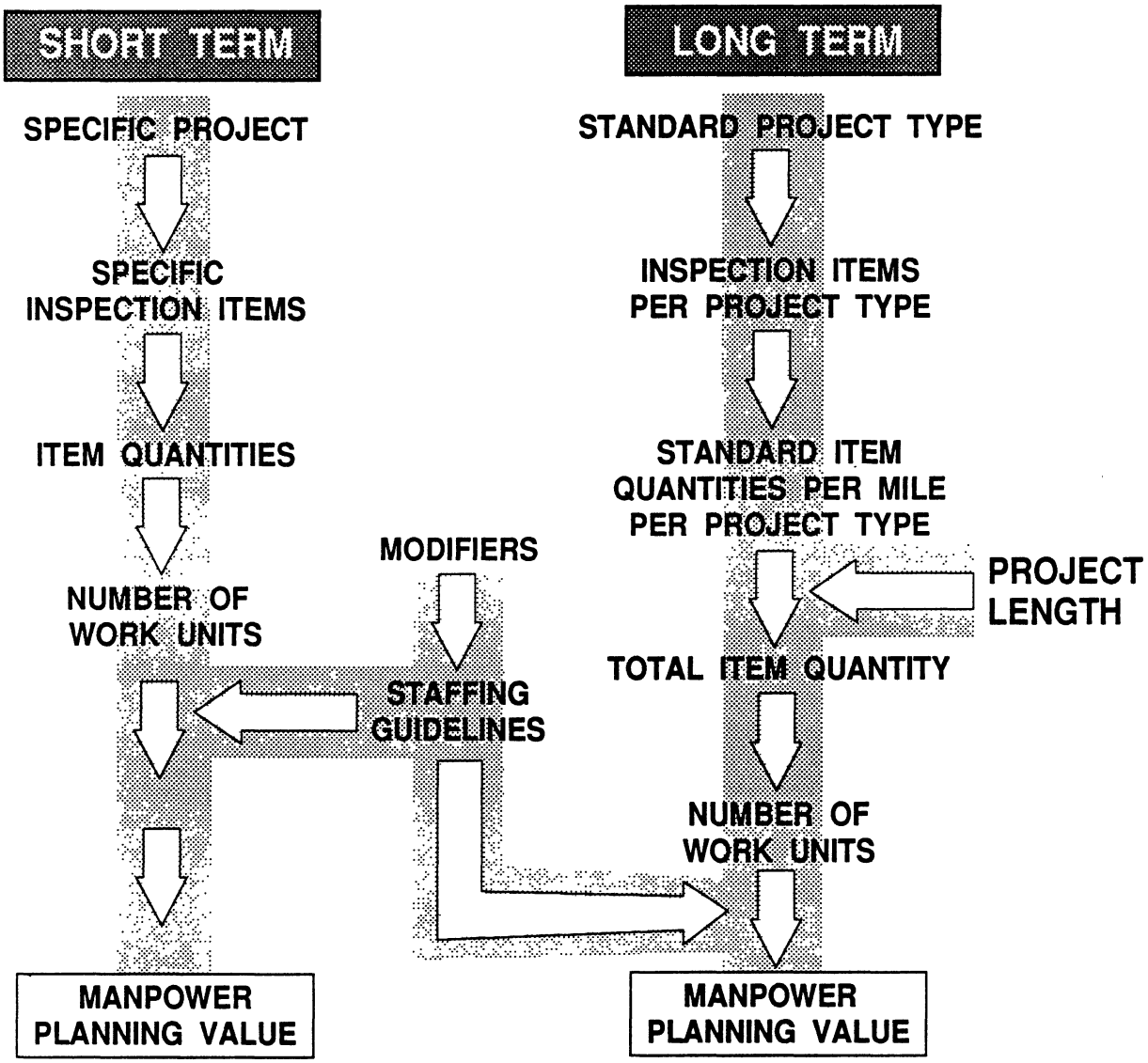


Figure 2. CMMS flowchart.

OUTPUTS

Printouts

Hard copies of both the short-term and long-term estimates are provided by residency and district by year: short-term for the present and the next calendar year, and long-term for the present and the next five calendar years.

Delivery of Printouts

The steering committee decided that the listed printouts should be sent to the following offices.

Commissioner	Statewide and district totals
Chief Engineer	Statewide and district totals
Construction Engineer	Statewide, district, and residency totals
Districts	District and residency within district totals
Residency	Residency totals

Scheduling of Printouts

The Construction Division with input from the assistant district engineers for construction agreed that printouts would be needed three times a year, in April, September, and November. The April printout will allow them to assess their immediate needs as the construction season begins. The September printout will allow them a chance to check the system to see if the estimated FTE needs from the CMMS agree with their estimates and provide time for updates, corrections, etc. before the November printout, which would be used primarily for estimates of required staffing for the next calendar year. This printout would also be the primary one for the Construction Division to use in discussions with the administration.

RESULTS

Long-term

An example of the long-term estimate over the next six years is shown in Table 11. Two results are obvious. First, a comparison between FTEs for long-term (Table 11) and short-term (Table 12) show that the long-term underestimate the short-term by about 35 percent. This is a disturbing result. It is caused by the difference in quantities and the occurrence of inspectable items used in the two parts of the system. For the short-term, actual bid quantities per project are used; whereas, for the long-term a set of average, typically occurring quantities must be used. In a detailed

analysis of the discrepancy in FTEs, it was found that 39 of the 45 residencies had short-term and long-term estimates reasonably close. The primary source of the difference was found in six residencies, all of which administered construction contracts in urban areas. This led to the conclusion that the average quantities used for the long-term were underestimated for urban construction.

Table 11

Commonwealth of Virginia, Department of Transportation
Construction Manpower Management System (Long-Term)
Projected Construction Inspector Manpower Needs (FTE)
By VDOT District and Calendar Year

	Calendar Year					
District	1989	1990	1991	1992	1993	1994
Northern Va.	145.6	173.0	130.4	98.9	137.4	101.1
Bristol	119.0	154.7	149.2	133.7	110.3	115.2
Salem	122.8	140.5	116.3	93.3	90.5	82.9
Lynchburg	60.0	65.3	69.5	70.6	64.8	51.6
Richmond	175.1	160.0	143.7	171.1	154.5	121.5
Suffolk	129.8	182.4	195.2	208.6	172.6	124.7
Fredericksburg	53.6	64.0	51.2	48.7	47.2	42.2
Culpeper	29.9	37.3	45.9	44.5	47.7	38.1
Staunton	77.3	90.5	79.8	85.8	67.0	59.6
State Totals	913.2	1,067.8	981.3	955.2	891.9	737.0

Table 12

Commonwealth of Virginia, Department of Transportation
Construction Manpower Management System (Short-Term)
Projected Construction Inspector Manpower Needs (FTE)
By VDOT District and Calendar Year

Calendar Year 1989

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Northern Va	183.0	196.1	229.4	240.5	237.6	252.1	251.9	254.8	255.0	256.8	257.0	264.6	239.9
Bristol	114.0	121.8	121.7	120.7	128.2	134.4	127.3	127.4	132.3	147.0	150.1	146.6	131.0
Salem	140.9	138.2	146.0	156.4	157.5	157.4	158.0	164.4	169.2	208.4	211.8	202.8	167.6
Lynchburg	47.0	49.4	53.3	50.2	50.6	50.6	55.2	54.0	54.0	71.0	73.9	74.2	57.0
Richmond	285.3	282.4	293.9	284.5	287.9	291.8	294.8	293.3	274.1	303.3	309.7	303.5	292.0
Suffolk	216.2	216.5	214.8	258.8	241.2	239.9	240.2	244.6	239.1	252.5	253.3	266.8	240.3
Fredericksburg	41.5	41.9	41.6	51.1	52.7	54.2	55.4	56.1	56.4	63.5	64.3	63.0	53.5
Culpeper	30.8	30.8	34.3	32.2	37.7	37.8	34.8	32.5	31.5	30.4	31.0	29.8	32.8
Staunton	50.6	52.5	55.7	58.5	70.4	72.2	79.1	78.8	77.7	88.8	91.8	93.0	72.4
State Totals	1,109.3	1,129.6	1,190.7	1,252.9	1,263.9	1,290.5	1,296.8	1,305.8	1,289.3	1,421.6	1,443.0	1,444.4	1,286.5

To determine the effect of urbanization on the typical quantities, two new sets of quantities were generated that separated urban from other projects using the classifications given in the modifier table (Table 5 in Appendix B). Using these estimates of quantities, another computer run was made and these results were compared to the originally determined standard quantity results.

Table 13 shows the weighted percent difference between short-term and long-term manpower estimates for standard quantities for all projects and for quantities separated by urban/nonurban. The percent listed for each district is based on the proportion of the total statewide difference that that district contributes.

Table 13

Contract Quantities based on Standard and Urban/Nonurban, Weighted % Difference

District	Standard	Urban/Nonurban
Bristol	0.5	0.6
Salem	4.1	3.4
Lynchburg	0.3	0.7
Richmond	8.8	6.2
Suffolk	11.2	7.9
Fredericksburg	0.1	0.9
Culpeper	0.1	0.1
Staunton	0.1	0.5
Northern Va.	9.7	5.5
Total	34.7	25.7

The first conclusion from these data is that the separation of quantities based on urban/nonurban classification brings the short-term and long-term estimates closer. The figures in the "total" row indicate that the long-term is lower than the short-term by 34.7 and 25.7 percent for the standard and urban/nonurban quantities, respectively. Thus the separation of quantities based on urban and nonurban location brings the two estimates closer together by 9 percent. Also these data indicate that the three districts of Richmond, Suffolk, and Northern Virginia create most of the difference between the long-term and short-term estimates with both standard and urban/nonurban quantities. In every case, separating the quantities reduced the percentage difference. The urban residencies of Chesterfield, Norfolk, and Fairfax still account for 13.2 percent of the total 25.7 percent difference. However, even with this information, it was felt that no additional adjustments to the urban quantities were justified, i.e., the authors felt that the best estimates of quantities available were being used. The finalized quantities by project type and urban designation are included in Appendix B.

Short-term

An example of the short-term estimates by district is shown in Table 12. This estimate for 1989 indicates a requirement of 1286.5 FTEs. This compares very well with the independently derived manpower needs assessment made by the districts and construction division. When their estimated FTEs of 1017 is increased by 25 percent to cover typical overtime allocations it becomes 1271 FTEs.

SYSTEM IMPLEMENTATION

Verification

Verification efforts incorporated in the development of this system have included comparisons with staffing estimates submitted by field personnel, and as previously discussed, the results indicate close agreement for the short-term estimates and somewhat less agreement for the long-term.

A more objective approach to verification of the short-term figures was also included. CMMS was used to estimate needed staffing levels for 1985 through 1988, and these figures were compared to the actual hours of inspection recorded through the Human Resource Planning System (HRPS) for the same period of time. Table 14 gives these figures. Even though the HRPS numbers include overtime, comparisons can be made on an equivalent basis since HRPS does not inflate the hours to reflect the time-and-a-half pay rate.

Table 14

Comparisons of CMMS Short-Term
Estimates to Actual Hours of Inspection

Year	CMMS FTEs	Actual FTEs	Difference
1985	594	623	-29 (4.7%)
1986	780	669	+111 (16.6%)
1987	935	846	+89 (10.5%)
1988	1,266	977	+289 (29.6%)

With the exception of 1985, the CMMS estimates are higher than HRPS. Further examination of these discrepancies revealed several inherent reporting problems with HRPS that would tend to make the HRPS numbers lower than the actual hours charged. Probably more importantly, the HRPS figures do not include any consultant or contract inspection hours. So, HRPS hours do not reflect the real hours required for adequate inspection, whereas, CMMS hours do. The variability of the differences should be a function of the adequacy of the size of the VDOT inspection work force to handle the construction workload. Certainly, 1988 was the most ambitious construction

year of the four; therefore, one might anticipate the greatest difference there. So, considering the potential differences with the HRPS numbers, the CMMS estimates appear to be right on target.

This analysis further indicates that an acceptable level of accuracy is afforded in the short-term portion of CMMS; however, future efforts should include some additional means of verification such as comparisons to consensus staffing estimates from a panel of experts or some other defensible means.

Accurate Database

As the system goes into operation, added emphasis must be placed on keeping the PPMS database as up-to-date and accurate as possible. Since CMMS derives its project listings for all staffing estimates from PPMS, it is critical that field personnel submit their project information to PPMS in a complete and accurate form. Errors in project information like type, length, location, surface, etc. can have a direct impact on staffing projections.

Finally, CMMS is a system that will need to be monitored and updated from time to time. There should be periodic feedback from the field about the estimates. Although the system has been designed as carefully as possible, there may be some bugs still in it, and this feedback is important to working out these bugs and to monitoring the numbers to assess the possible need for system changes in the system.

CMMS Monitor

There needs to be a person, probably in the Construction Division, who will serve as this CMMS monitor. This person will keep up with the feedback from the field and troubleshoot the problems that arise. An important tool the monitor will have at his/her disposal for assistance with discrepancies between the CMMS estimates and field estimates will be detailed proof sheets of just how CMMS arrived at each estimate for each project. (A sample proof sheet can be found in Appendix B - Figure 2.) Using these proof sheets, the monitor will be able to determine the cause of the discrepancy. The monitor will then decide whether the problem is with the system, the project data, or the field estimate and proceed accordingly to remedy the problem.

In addition to handling differences in estimates, the monitor must thoroughly understand the details of the system so that he/she can determine whether and when basic changes may be needed. For example, if the Department's policy changes on the level of staffing desired on construction projects, staffing guidelines will need to reflect this. If maintenance inspection needs change or locations become classified as semiurban or urban, the baseline maintenance level will need to be changed, or the modifier table will need updating. Also, the applicability of project types and inspectable items will require periodic review. The monitoring and updating portion of

the implementation of the system will be very important with respect to the acceptance and usefulness of the systems.

CONCLUSIONS

1. With guidance from the CEMM Nationally Pooled Fund Study and the Price Waterhouse and Roy Jorgensen Associates, Inc. study, a CMMS has been devised for VDOT.

2. The CMMS appears to provide accurate construction staffing levels for short-term estimates, i.e., the next 18 to 24 months.

3. The CMMS appears to provide less accurate construction staffing levels for the long-term estimates, i.e., the next 6 years.

4. The difference between short-term and long-term estimates (the latter is approximately 25 percent lower than the former) appears to stem from the use of standard quantities and is most apparent in residencies in which urban construction conditions are found.

5. Short-term construction estimates appear sufficiently accurate for VDOT to use them as a district planning tool and as a means of presenting statewide needs to the General Assembly.

RECOMMENDATIONS

1. Additional verification is needed to provide additional credibility to the system. A panel of experts should be convened to provide independent estimates of typical project staffing, which can then be compared to the CMMS estimates. Also, further efforts should be undertaken to analyze the differences between the long-term and short-term staffing projections.

2. It is important that residency personnel who are responsible for PPMS inputs be instructed as to the importance of the accuracy of this data because it can have significant impact on the residencies staffing estimates for the future.

3. A CMMS monitor position should be established in the Construction Division to serve as liaison between the Construction Division and the field. This person would be very knowledgeable in the way the system operates and will help update the system as needed. It is anticipated this effort will require about .75 FTE.

REFERENCES

1. Price Waterhouse and Roy Jorgensen Associates, Inc. 1986. A report on construction manpower management. (manuscript)

2. Newman, R. B. and F. D. Hejl. 1978. Development of a construction engineering manpower management system. Publication No. DOT-FH-11-9122. Washington, D. C.

3. Newman, R. B. 1989. Staffing considerations in construction engineering management. NCHRP Synthesis 145. Washington, D.C.: Transportation Research Board.

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APPENDIX A

Sample Staffing Guideline Estimation

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CONSTRUCTION MANPOWER MANAGEMENT SYSTEM

Inspectable Items
Bridge Structures and Substructures
Bridge, Structures and Superstructures

BRIDGE MODEL

Three-Span Bridge
Span Layout: 1-42'0", 1-76'0", and 1-42'0"
Steel Rolled Beams
Width: 42'6" Face to Face of Curbs
Length: 162'3-5/8"
S.Y. of Deck Surface: 766.42 s.y.
Cost: $423,731.60

Mobilization	$ 36,000.00
Surveying	9,000.00
A3-Conc.: 274.2 c.y. @ $187.50	51,412.00
Reinf. Steel: 30,000 lbs. @ $.39	11,700.00
Struct. Excav.: 275 c.y. @ $18.00	4,950.00
10" Steel Piles: 2609 l.f. @ $16.50	43,048.50
Pile Points: 64 @ $40.65	2,601.00
Driving Test: 164 l.f. @ $24.00	3,936.00
Slope Protection: 654 s.y. @ $26.00	17,004.00
SUB TOTAL	$179,652.60
Rolled Beams: L.S.	168,000.00
Epoxy Resteel: 33,170 lbs. @ $.52	17,248.40
A4 Conc.: 200.3 c.y. @ $222.00	44,466.60
Conc. Parapet: 342 l.f. @ $42.00	14,364.00
SUB TOTAL	$244,079.00

Inspection of Bridge Substructure Footings

For new construction will consist of checking out the bridge stake out #1. Checking elevations for excavating of footings #2. Checking the pile locations and actual checking the driving of these piles #3. Checking footing forms and placement of reinforcement in same #4. Testing concrete and inspecting the placement of this concrete #5. Inspection of how concrete is cured #6.

Substructure (Neat Work)

Inspection of line, grade, forms, and reinforcing steel placement #1. (#2 is same as #5 & 6 of footings)

Work units needed to inspect substructure per cu. yd. of conc. is (formula) cu. yds. conc. A.3 on plans x 4.0 man hrs. per cu. yd. by 8 hrs. per day is = to work unit days.

B601 A.3 conc. 594 x 4.00 = $\frac{2366 \text{ hrs.}}{8 \text{ hrs./day}}$ = 296 man days

Staffing Guideline = 2 cu. yd. of conc. per man day

Bridge Superstructure

Inspection of beam placement (#1) (#2) will be same as #4, #5 and #6 of substructure. Inspection of parapet walls (#3) will be performed in the order as #4, 5 and 6 of substructure. Inspecting the placement of linseed oil on decks (#4).

Work units needed to inspect superstructure per cu. yd. of conc. is (use same formula as substructure)

525 cu. yds. A.4 x 1.0 man hrs. = $\frac{525 \text{ hrs.}}{8 \text{ hrs/day}}$ = 66 man days

Staffing Guideline = 8 cu. yd. of conc. per man day

Administration

(Checking) EEO, WBE, DBE, Construction Health and Safety Standards, P. R., recordkekeping and all bookkeeping needed to be performed on superstructure and superstructure on entire bridge.

Work units need to perform these duties per cu. yd. of conc. total of sub and superstructure is (formula) cu. yds. of A.3 + cu. yd. of A.4 x 1 man hr. or

1119 x 1 = $\frac{1119 \text{ hrs.}}{8 \text{ hrs/day}}$ = 140 man days

Staffing Guideline = 8 cu. yd. of conc. per man day

STAFFING GUIDELINES

Using sq. yds. of Deck Surface

$\frac{766.42 \text{ s.y. of Deck Surface}}{502 \text{ man days}}$ = 1.5 s.y. of Deck Surface per man day

APPENDIX B

System Operation Detail

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The long-term portion of the Construction Manpower Management System (CMMS) obtains all the project information used for project staffing from the Department's Program/Project Management System (PPMS). The projects contained in PPMS are screened in order to establish a list of projects to be staffed by CMMS.

First, projects that are to be built with state forces are eliminated since no inspection time is allocated to such projects. Next PPMS projects with scope-of-work classifications that are not included in CMMS are eliminated. Tables 1 and 2* show that projects with PPMS scope-of-work codes 06, 07, 11, 13, or 14 are dropped. Table 3 shows status codes that are assigned to each PPMS project. Obviously, staffing assessments for projects that have no dates set, have been deferred or put in storage, or have been completed would be of little use; therefore, projects with status codes 10, 30, 35, 55, 60, 65, 70, 75, and 80 are further eliminated from consideration by CMMS. Finally, only those projects that will be actively under construction during the 6-calendar-year period which constitutes the staffing window for the long-term portion of CMMS will be staffed. For purposes of CMMS, if a project's start date (advertisement date plus 10 weeks) falls within the 6-year period, it is considered active. All inactive projects are dropped.

Table 1

Project Type Codes (CMMS TYPE)

Project Type	CMMS #	PPMS-Scope-of Work Code
New Construction Plant Mix	1	01, 02, 03
Widening and Resurfacing	2	04, 05
Safety	3	12
New Construction - Surface Treatment	4	15, 16
Bridge New Construction	5	8, 9
Bridge Reconstruction	6	10

*All tables in Appendix B with parentheses refer to Information Systems table names.

Table 2

PPMS Scope of Work Codes

Code	Title
01	New Construction
02	Relocation
03	Reconstruction
04	Major Widening
05	Minor Widening
06	Restoration and Rehabilitation
07	Resurfacing
08	New Bridge
09	Bridge Replacement
10	Major Bridge Rehabilitation
11	Minor Bridge Rehabilitation
12	Safety/Traffic Opers/TSM
13	Environmental Related
14	Preliminary Studies Only
15	New Construction-Surface Treatment
16	Reconstruction-Surface Treatment

Table 3

PPMS Project Status Codes

Code	Title
10	Unschedule Construction
13	No Dates Set Yet
14	Under Review by PPMS
15	Activity Dates Set
16	Need D.L.E. Action
17	Need M.S.H. Action
18	Need G.E.F. Action
19	Need J.G.R. Action
20	Temporarily Deferred (For Decision)
25	Indefinitely Deferred (For Decision)
30	Storage (Inactive)
40	Advertised
45	Awarded
50	Construction Started
55	Construction Completed
60	Final (Estimate Paid)
65	Closed (All Claims Paid)
70	Zeroed
75	Misc Funds/Monitoring Only
80	Budget Item Only

Staffing requirements referred to as manpower planning values (MPV) are calculated in man-hours for all projects remaining after the screening process. Projects classified as types 1 through 4 are given total man-hours per mile staffing requirements from Table 4. A project is considered urban if it has an urban highway system code or if it is in an urban location. Location is taken from the city, town, or county code in the project number. All cities and counties with population densities greater than 200 people per square mile and all incorporated towns with total populations greater than 10,000 and densities greater than 200 per square mile are classified as urban.

Project location is also used to assign a set of modifiers to each project to increase the inspection time required for various inspectable items according to project type. These modifiers are determined from Table 5. Once the modifiers have been applied, each project may have an adjusted staffing requirement per mile. The adjusted staffing value is then increased by 15 percent for administrative overhead. Individual project MPVs are determined by multiplying project length by the final staffing value. Table 6 shows a sample MPV calculation.

Before a project's MPV is finalized, a check is made to see if the project includes any bridges. If there are any bridges, an additional MPV is added for each bridge (see Table 7). For project types 5 and 6, total project MPVs are determined from Table 7 only.

In order to apportion staffing needs over the six-year planning period, projects must have a duration. Durations are assigned according to Table 8 by project type. Using project start dates and project durations, CMMS apportions individual project staffing requirements equally by month over the life of each project. Once all projects' staffing requirements have been apportioned, MPVs are accumulated by calendar year, district and residency. Residency annual MPV totals then have needed maintenance MPVs added to them. The first year's maintenance needs are shown in Table 9. An estimated annual increase of 5 percent is added for the next 3 years with the needs remaining constant for the last 2 years of the 6-year period. MPVs are divided by 1832 for conversion to FTEs. An example of MPV accumulation is shown in Figure 1. Finally, summary printouts are produced by district and residency for all of the long-term results.

The staffing requirements for the short-term portion of CMMS are determined very much the same way the long-term needs are determined. The main differences are that the short-term staffing window is 2 calendar years, and instead of using standard quantities for each inspectable item, estimated contract quantities for each individual project are used.

The PPMS project listing is still screened to determine which projects will be staffed, and the screening process is the same for the short-term except that only projects with start dates that fall within the 2-year staffing window are included. The projects that remain after screening are staffed according to the inspection time required for specific occurrences and quantities of inspectable items as contained in the Construction Division's E03 system. PPMS projects are matched to corresponding projects

TABLE 4
STAFFING GUIDELINES (ITEMSTAF)

CONSTRUCTION
(PLANT MIX)

(NONURBAN TYPE)

INSPECTABLE ITEM	WORK UNIT	STAFFING GUIDELINE (man-hours)	QUANTITY (per/mi)	STAFFING (per/mi)
Earthwork	10000 cu. yds.	8.0	56251.76	45
Pipe	50 ft. installed	6.0	1439.80	173
Select materials, etc.	600 tons	8.0	7113.62	95
Surface treatment	170 tons	8.0	277.64	13
Bituminous pavement	500 tons	14.0	3260.61	91
Drop inlets	5 inlets	12.0	4.64	11
Incidental construction	1 per mile	150.0	1	150
Enviromental	100 linear ft. of barriers	24.0	7.84	2
Work zone safety	60 group II barricade-days	10.0	1961.99	327
			TOTAL MAN-HRS/MI =	907

(URBAN TYPE)

INSPECTABLE ITEM	WORK UNIT	STAFFING GUIDELINE (man-hours)	QUANTITY (per/mi)	STAFFING (per/mi)
Earthwork	10000 cu. yds.	8.0	161695.7	129
Pipe	50 ft. installed	6.0	5213.50	626
Select materials, etc.	600 tons	8.0	11404.12	152
Surface treatment	170 tons	8.0	145.96	7
Bituminous pavement	500 tons	14.0	11736.02	329
Drop inlets	5 inlets	12.0	34.72	83
Incidental construction	1 per mile	150.0	1	150
Enviromental	100 linear ft. of barriers	24.0	4084.47	980
Work zone safety	60 group II barricade-days	10.0	7144.85	1191
			TOTAL MAN-HRS/MI =	3647

TABLE 4
(cont.)

WIDENING AND RESURFACING

(NONURBAN TYPE)

INSPECTABLE ITEM	WORK UNIT	STAFFING GUIDELINE (man-hours)	QUANTITY (per/mi)	STAFFING (per/mi)
Earthwork	10000 cu. yds.	8.0	94715.61	76
Pipe	50 ft. installed	6.0	4312.46	517
Select materials, etc.	600 tons	8.0	13086.51	174
Surface treatment	170 tons	8.0	247.48	12
Bituminous pavement	500 tons	14.0	11696.13	327
Drop inlets	5 inlets	12.0	0	0
Incidental construction	1 per mile	150.0	1	150
Enviromental	100 linear ft. of barriers	24.0	8.59	2
Work zone safety	60 group II barricade-days	10.0	3100.94	517
			TOTAL MAN-HRS/MI =	1776

(URBAN TYPE)

INSPECTABLE ITEM	WORK UNIT	STAFFING GUIDELINE (man-hours)	QUANTITY (per/mi)	STAFFING (per/mi)
Earthwork	10000 cu. yds.	8.0	75589.79	60
Pipe	50 ft. installed	6.0	5327.06	639
Select materials, etc.	600 tons	8.0	10253.07	137
Surface treatment	170 tons	8.0	57.38	3
Bituminous pavement	500 tons	14.0	16047.92	449
Drop inlets	5 inlets	12.0	0	0
Incidental construction	1 per mile	150.0	1	150
Enviromental	100 linear ft. of barriers	24.0	3531.02	847
Work zone safety	60 group II barricade-days	10.0	13987.62	2331
			TOTAL MAN-HRS/MI =	4617

TABLE 4
(cont.)

SAFETY

(NONURBAN TYPE)

INSPECTABLE ITEM	WORK UNIT	STAFFING GUIDELINE (man-hours)	QUANTITY (per/mi)	STAFFING (per/mi)
Earthwork	10000 cu. yds.	8.0	2937.07	2
Pipe	50 ft. installed	6.0	99.95	12
Select materials, etc.	600 tons	8.0	431.03	6
Surface treatment	170 tons	8.0	5.57	0
Bituminous pavement	500 tons	14.0	667.24	19
Drop inlets	5 inlets	12.0	6.67	16
Incidental construction	1 per mile	150.0	1	150
Enviromental	100 linear ft. of barriers	24.0	16.93	4
Work zone safety	60 group II barricade-days	10.0	619.08	103
			TOTAL MAN-HRS/MI =	312

(URBAN TYPE)

INSPECTABLE ITEM	WORK UNIT	STAFFING GUIDELINE (man-hours)	QUANTITY (per/mi)	STAFFING (per/mi)
Earthwork	10000 cu. yds.	8.0	3558.51	3
Pipe	50 ft. installed	6.0	207.58	25
Select materials, etc.	600 tons	8.0	865.27	12
Surface treatment	170 tons	8.0	8.92	0
Bituminous pavement	500 tons	14.0	1210.98	34
Drop inlets	5 inlets	12.0	2.25	5
Incidental construction	1 per mile	150.0	1	150
Enviromental	100 linear ft. of barriers	24.0	264.41	63
Work zone safety	60 group II barricade-days	10.0	2419.01	403
			TOTAL MAN-HRS/MI =	696

TABLE 4
(cont.)

CONSTRUCTION
(SURFACE TREATMENT)

(NONURBAN TYPE)

INSPECTABLE ITEM	WORK UNIT	STAFFING GUIDELINE (man-hours)	QUANTITY (per/mi)	STAFFING (per/mi)
Earthwork	10000 cu. yds.	8.0	4867.35	4
Pipe	50 ft. installed	6.0	945.66	113
Select materials, etc.	600 tons	8.0	5725.26	76
Surface treatment	170 tons	8.0	446.94	21
Bituminous pavement	500 tons	14.0	0	0
Drop inlets	5 inlets	12.0	0	0
Incidental construction	1 per mile	150.0	1	150
Enviromental	100 linear ft. of barriers	24.0	8.87	2
Work zone safety	60 group II barricade-days	10.0	1201.99	200
			TOTAL MAN-HRS/MI =	567

(URBAN TYPE)

INSPECTABLE ITEM	WORK UNIT	STAFFING GUIDELINE (man-hours)	QUANTITY (per/mi)	STAFFING (per/mi)
Earthwork	10000 cu. yds.	8.0	21261.22	17
Pipe	50 ft. installed	6.0	666.53	80
Select materials, etc.	600 tons	8.0	1877.55	25
Surface treatment	170 tons	8.0	160	8
Bituminous pavement	500 tons	14.0	0	0
Drop inlets	5 inlets	12.0	0	0
Incidental construction	1 per mile	150.0	1	150
Enviromental	100 linear ft. of barriers	24.0	2685.71	645
Work zone safety	60 group II barricade-days	10.0	10306.12	1718
			TOTAL MAN-HRS/MI =	2642

TABLE 5
CMMS MODIFIERS (LOCMULT)

DISTRICT CODE	DISTRICT	COUNTY/ CITY	CO./CITY CODE	SUBGRADE STABILIZATION	MOUNTAINS	WET-LANDS	URBAN	SEMIURBAN	LS	EW	PI	SM	ST	PC	BP	BC	DI	IC	EV	WZ
1	BRISTOL	BLAND	10		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	BUCHANAN	13		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	DICKENSON	25		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	GRAYSON	38		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	LEE	52		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	RUSSELL	83		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	SCOTT	84		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	SMYTH	86		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	TAZEWELL	92		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	WASHINGTON	95		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	WISE	97		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	WYTHE	98		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
1	BRISTOL	BRISTOL	102				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
1	BRISTOL	NORTON	146				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2	SALEM	BEDFORD	09	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	SALEM	BOTETOURT	11		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
2	SALEM	CARROLL	17		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
2	SALEM	CRAIG	22		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
2	SALEM	FLOYD	31		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
2	SALEM	FRANKLIN	33		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
2	SALEM	GILES	35		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
2	SALEM	HENRY	44		X			X	3.5	3.5	3.5	1.5	1.5	1.5	1.5	3.5	3.5	1.5	3.5	1.5
2	SALEM	MONTGOMERY	60		X			X	3.5	3.5	3.5	1.5	1.5	1.5	1.5	3.5	3.5	1.5	3.5	1.5
2	SALEM	PATRICK	70		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
2	SALEM	PULASKI	77		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
2	SALEM	ROANOKE	80		X		X		4.0	4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0	2.0	4.0	2.0
2	SALEM	BEDFORD	141				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2	SALEM	BLACKSBURG	150				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2	SALEM	CHRISTIANSBURG	154				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2	SALEM	GALAX	113				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2	SALEM	MARTINSVILLE	120				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2	SALEM	RADFORD	126				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2	SALEM	ROANOKE	128				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2	SALEM	SALEM	129				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
3	LYNCHBURG	AMHERST	05						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3	LYNCHBURG	APPOMATTOX	06	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3	LYNCHBURG	BUCKINGHAM	14	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

TABLE 5
(cont.)

DISTRICT CODE	DISTRICT	COUNTY/ CITY	CO./CITY CODE	SUBGRADE STABILIZATION	MOUNTAINS	WET-LANDS	URBAN	SEMIURBAN	LS	EW	PI	SM	ST	PC	BP	BC	DI	IC	EV	WZ
3	LYNCHBURG	CAMPBELL	15	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3	LYNCHBURG	CHARLOTTE	19	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3	LYNCHBURG	CUMBERLAND	24	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3	LYNCHBURG	HALIFAX	41	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3	LYNCHBURG	NELSON	62		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
3	LYNCHBURG	PITTSYLVANIA	71	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3	LYNCHBURG	PRINCE EDWARD	73	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3	LYNCHBURG	DANVILLE	108				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
3	LYNCHBURG	LYNCHBURG	118				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
3	LYNCHBURG	SOUTH BOSTON	130				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
4	RICHMOND	AMELIA	04						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	RICHMOND	BRUNSWICK	12						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	RICHMOND	CHARLES CITY	18			X			1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
4	RICHMOND	CHESTERFIELD	20	X		X	X		4.75	4.75	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	2.0
4	RICHMOND	DINWIDDIE	26						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	RICHMOND	GOOCHLAND	37						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	RICHMOND	HANOVER	42						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	RICHMOND	HENRICO	43	X			X		3.25	3.25	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
4	RICHMOND	LUNENBURG	55						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	RICHMOND	MECKLENBURG	58						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	RICHMOND	NEW KENT	63			X			1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
4	RICHMOND	NOTTOWAY	67						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	RICHMOND	POWHATAN	72						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	RICHMOND	PRINCE GEORGE	74	X		X			2.75	2.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
4	RICHMOND	COLONIAL HEIGHTS	106				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
4	RICHMOND	HOPEWELL	116				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
4	RICHMOND	PETERSBURG	123				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
4	RICHMOND	RICHMOND	127				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
5	SUFFOLK	ACCOMACK	01	X		X			2.75	2.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
5	SUFFOLK	CHESAPEAKE	131	X		X	X		4.75	4.75	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	2.0
5	SUFFOLK	GREENSVILLE	40	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5	SUFFOLK	HAMPTON	114				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
5	SUFFOLK	ISLE OF WIGHT	46	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5	SUFFOLK	JAMES CITY	47	X		X		X	4.25	4.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	3.5	1.5
5	SUFFOLK	NEWPORT NEWS	121	X		X	X		4.75	4.75	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	2.0
5	SUFFOLK	NORFOLK	122	X		X	X		4.75	4.75	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	2.0
5	SUFFOLK	NORTHAMPTON	65	X		X			2.75	2.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0

TABLE 5
(cont.)

DISTRICT CODE	DISTRICT	COUNTY/ CITY	CO./CITY CODE	SUBGRADE STABILIZATION	MOUNTAINS	WET-LANDS	URBAN	SEMIURBAN	LS	EW	PI	SM	ST	PC	BP	BC	DI	IC	EV	WZ
5	SUFFOLK	PORTSMOUTH	124	X		X	X		4.75	4.75	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	2.0
5	SUFFOLK	SOUTHAMPTON	87	X		X			2.75	2.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
5	SUFFOLK	NANESMOND	61	X		X			2.75	2.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
5	SUFFOLK	SUFFOLK	133	X		X		X	4.25	4.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	3.5	1.5
5	SUFFOLK	SURRY	90	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5	SUFFOLK	SUSSEX	91	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5	SUFFOLK	VIRGINIA BEACH	134	X		X	X		4.75	4.75	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	2.0
5	SUFFOLK	YORK	99	X		X	X		4.75	4.75	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	2.0
5	SUFFOLK	EMPORIA	109				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
5	SUFFOLK	FRANKLIN	145				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
5	SUFFOLK	POQUOSON	147				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
5	SUFFOLK	WILLIAMSBURG	137				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
6	FREDERICKSBURG	CAROLINE	16	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6	FREDERICKSBURG	ESSEX	28	X		X			2.75	2.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
6	FREDERICKSBURG	GLOUCESTER	36	X		X		X	4.25	4.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	3.5	1.5
6	FREDERICKSBURG	KING AND QUEEN	49	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6	FREDERICKSBURG	KING GEORGE	48	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6	FREDERICKSBURG	KING WILLIAM	50	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6	FREDERICKSBURG	LANCASTER	51	X		X			2.75	2.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
6	FREDERICKSBURG	MATHEWS	57	X		X			2.75	2.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
6	FREDERICKSBURG	MIDDLESEX	59	X		X			2.75	2.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
6	FREDERICKSBURG	NORTHUMBERLAND	66	X		X			2.75	2.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
6	FREDERICKSBURG	RICHMOND	79	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6	FREDERICKSBURG	SPOTSYLVANIA	88	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6	FREDERICKSBURG	STAFFORD	89	X				X	2.75	2.75	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
6	FREDERICKSBURG	WESTMORELAND	96	X					1.25	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6	FREDERICKSBURG	FREDERICKSBURG	111				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
7	CULPEPER	ALBEMARLE	02						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
7	CULPEPER	CULPEPER	23						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
7	CULPEPER	FAUQUIER	30						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
7	CULPEPER	FLUVANNA	32						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
7	CULPEPER	GREENE	39		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
7	CULPEPER	LOUISA	54						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
7	CULPEPER	MADISON	56						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
7	CULPEPER	ORANGE	68						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
7	CULPEPER	RAPPAHANNOCK	78						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
7	CULPEPER	CHARLOTTESVILLE	104				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

TABLE 5
(cont.)

DISTRICT CODE	DISTRICT	COUNTY/ CITY	CO./CITY CODE	SUBGRADE STABILIZATION	MOUNTAINS	WET-LANDS	URBAN	SEMIURBAN	LS	EW	PI	SM	ST	PC	BP	BC	DI	IC	EV	WZ
8	STAUNTON	ALLEGHANY	03		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
8	STAUNTON	AUGUSTA	07		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
8	STAUNTON	BATH	08		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
8	STAUNTON	CLARKE	21		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
8	STAUNTON	FREDERICK	34						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
8	STAUNTON	HIGHLAND	45		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
8	STAUNTON	PAGE	69		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
8	STAUNTON	ROCKBRIDGE	81		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
8	STAUNTON	ROCKINGHAM	82		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
8	STAUNTON	SHENANDOAH	85		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
8	STAUNTON	WARREN	93		X				2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0
8	STAUNTON	BUENA VISTA	103				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
8	STAUNTON	CLIFTON FORGE	105				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
8	STAUNTON	COVINGTON	107				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
8	STAUNTON	FRONT ROYAL	112				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
8	STAUNTON	LEXINGTON	117				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
8	STAUNTON	HARRISONBURG	115				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
8	STAUNTON	STAUNTON	132				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
8	STAUNTON	WAYNESBORO	136				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
8	STAUNTON	WINCHESTER	138	X			X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	NO. VA.	ALEXANDRIA	100	X			X		3.25	3.25	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	NO. VA.	ARLINGTON	00				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	NO. VA.	FAIRFAX	29	X			X	X	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	NO. VA.	LOUDON	53	X			X	X	2.75	2.75	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
9	NO. VA.	PRINCE WILLIAM	76	X			X		3.25	3.25	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	NO. VA.	FAIRFAX	151				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	NO. VA.	FALLS CHURCH	110				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	NO. VA.	HERNDON	235				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	NO. VA.	LEESBURG	253	X			X		3.25	3.25	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	NO. VA.	MANASSAS	155				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	NO. VA.	MANASSAS PARK	152				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	NO. VA.	VIENNA	153				X		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Table 6

MPV Sample Calculation

Project Type: Construction - Surface Treatment
Length: 0.7 Mi.
Location: James City County
Modifiers: Subgrade stabilization, wetlands, and semiurban

Insp. Item	Standard Quantity* (per mile)		Work Unit*		Staffing Guideline* (man-hours)		Modifier**		MPV/I.I. (per mi)
Earthwork	4867.35 cu yds	■	1000	x	8.00	x	4.25	=	165.49
Pipe	945.66 ft installed	■	50	x	6.00	x	1.50	=	170.22
Select Material	5725.26 tons	■	600	x	8.00	x	1.50	=	114.51
Surface Treatment	446.94 tons	■	170	x	8.00	x	1.50	=	31.55
Incidental Constr	1.00 per mile	■	1	x	150.00	x	1.50	=	225.00
Environmental	8.87 linear ft of barriers	■	100	x	24.00	x	3.50	=	7.45
Work Zone Safety	1201.99 group II barricade days	■	60	x	10.00	x	1.50	=	300.50
							MPV/mi		1014.72
							Admin.	x	1.15
							MPV/mi		1166.93
							Length	x	0.7
							Total MPV		816.85

*From Table 4
**From Table 5

Table 7

Bridge MPVs (CMMS BRDG)

Project Type	MPVs - Man hours	
	Primary/Interstate	Secondary
Construction - Plant Mix	2000	600
Construction - Surface Treatment	-	600
Widening and Resurfacing	625	-
Safety	625	-
Bridge New Construction	2000	600
Bridge Reconstruction	625	-

Table 8

Project Duration, Months (CMMS DUR)

	Construction		W&R	Safety	B.N.C.	B.R.C.
	S.T.	P.M.				
Rural	10	18	18	12	-	-
Rural with Bridge	12	21	21	-	12	12
Urban	24	24	21	15	-	-
Urban with Bridge	30	30	24	-	15	15

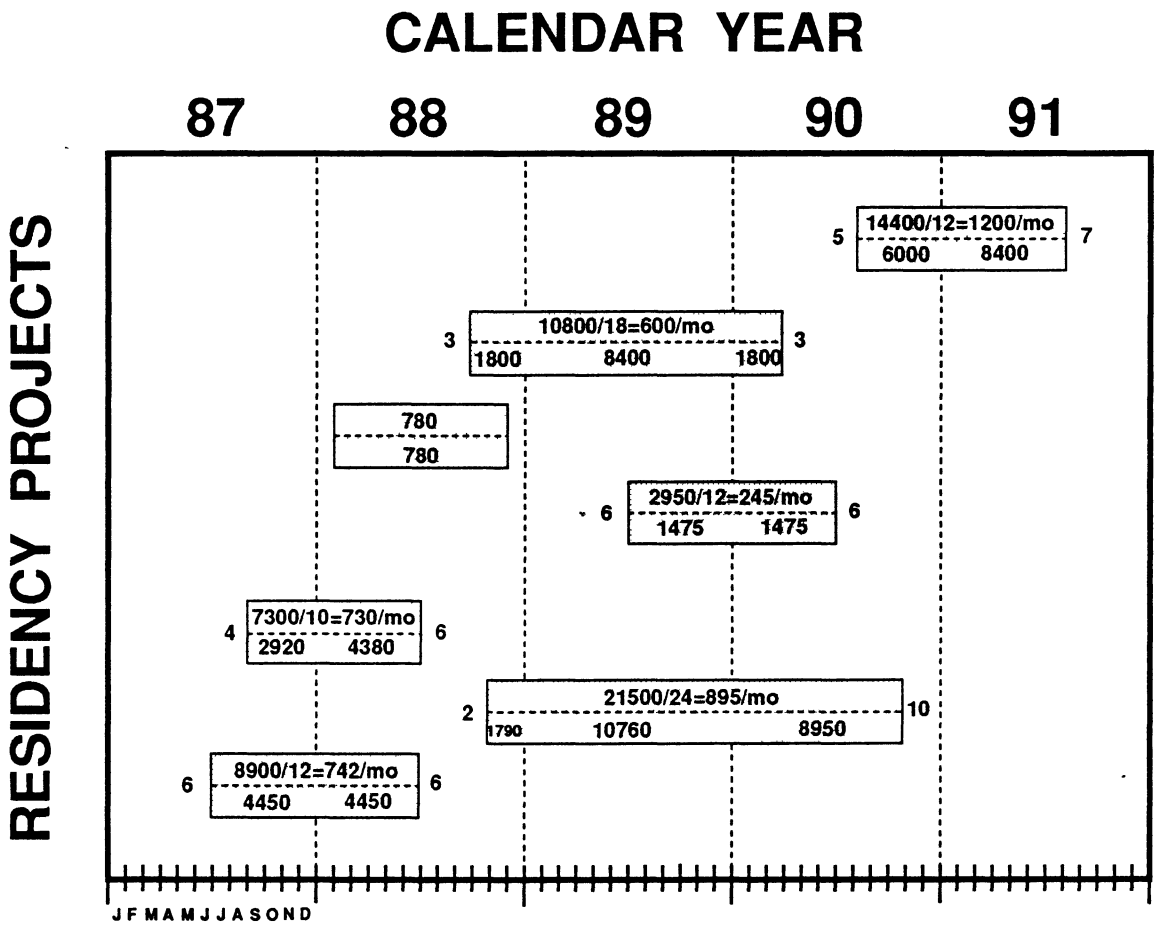
Table 9

Maintenance Manpower Requirements by Residency (CMMS MANT)

District	Residency		Present Usage, Man hr/yr
Bristol	01		15755
	03		03206
	04		15755
	06		03114
	08		03023
	58		03756
		Total	44609
Salem	09		03080
	11		03739
	12		03625
	13		01846
	14		04122
	16		02638
		Total	19050
Lynchburg	17		02537
	18		02537
	19		02114
	20		02114
	22		02114
		Total	11416
Richmond	23		04321
	24		03744
	25		03456
	26		09749
	27		03099
	28		04384
		Total	28753
Suffolk	31		03664
	32		03664
	33		03664
	34		11203
	35		07600
	36		03664
		Total	33459

Table 9 (cont.)

District	Residency		Present Usage, Man hr/yr
Fredericksburg	37		03655
	39		02383
	40		08092
	41		06734
		Total	20864
Culpeper	42		02998
	43		06814
	45		04361
	46		05451
		Total	19624
Staunton	50		04463
	53		05138
	54		02989
	55		03839
	56		02398
		Total	18827
Northern Virginia	47		49245
	48		12000
	49		03925
		Total	65170



MPV/YR (Const.)	13200	19435	18225
MPV/YR (Maint.)	3600	3780	3960
TOTAL MPV	16800	23215	32185

Numbers above time line refer to the MPVs divided by project duration.
Numbers below time line refer to the apportioned MPV by calendar year.
Numbers at end of time line are prorated months of project duration.

Figure 1. Determination of accumulated man-hours by residency.

contained in E03 to obtain item quantities. E03 items are converted to CMMS inspectable items according to Table 10. The staffing is then determined using the staffing guidelines given in Table 11. Next, a value of 150.0 man-hours per mile of project length is added to the project MPV. Modifiers are applied, and overhead is added just as it is in the long-term. MPV apportionment and accumulation are also done like the long-term, except that staffing needs are accumulated by month instead of just by year.

Table 10

E03 Item Code Conversions (ITEM CONV)

E03 Item Code	CMMS Inspectable Item
00125, 00126	Lump sum earthwork
00120, 00127 - 00300	Earthwork
00580 - 06001	Pipes
10013 - 10021, 10080 - 10231	Select materials, etc.
10468 - 10481	Surface treatment
10771 - 10982, 11011 - 11014	PCC pavement
10321 - 10323, 10510 - 10552, 10580	Bituminous pavement
00520 - 00522	Box culverts
06745 - 09003	Drop inlets
27505, 27506	Environmental
24278	Work zone safety
60403 - 60420, 68030, 68040, 65010 - 65093, 69030 - 69040, 68602, 68620, 68005 - 68010	Bridges and structures (substructures and superstructures)

Table 11 (ITEM STAF)

Inspectable Items, Work Units, and Staffing Guidelines

	Inspectable Item	Work Unit	Staffing Guideline
1.	Lump Sum Earthwork	Per mile of project	120.0 Man-hours
2.	Earthwork	10,000 cu yds	8.0 Man-hours
3.	Pipes	50 ft installed	6.0 Man-hours
4.	Select Material, Aggregate, or Cement Stabilized Subbase and Base Course	600 tons	8.0 Man-hours
5.	Surface Courses		
	a. Surface Treatment	170 tons	8.0 Man-hours
	b. Portland Cement Concrete Pavement	1,000 sq yds	5.0 Man-hours
	c. Bituminous Concrete Pave	500 tons	14.0 Man-hours
6.	Box Culverts	50 cu yds	16.0 Man-hours
7.	Drop Inlets	5 inlets	12.0 Man-hours
8.	Incidental Construction Items	Per mile of project	150.0 Man-hours
9.	Bridges & Structures (Substructures and Superstructures)	5 cu yds	8.0 Man-hours
10.	Environmental	100 lin ft of barriers	24.0 Man-hours
11.	Work Zone Safety	60 group II barricade-days	10.0 Man-hours

The long-term and short-term portions of CMMS have been presented separately simply because each portion derives staffing needs differently; however, both are still part of the same system. Both outputs are produced together, and in some cases, the two portions actually share staffing assessments. In order to prevent some projects' staffing needs from being omitted because of glitches in the data, a default system has been built into the system. If a PPMS project is screened for the short-term and accepted but for some reason an E03 matching project cannot be found, the long-term staffing value is substituted for the short-term. Conversely, if a long-term project cannot be staffed, typically because it has a length of 0.0, the short-term value is substituted.

The long-term and the short-term each staff years Nos. 1 and 2. Only the long-term staffs years Nos. 3 through 6. It was suggested that only one set of staffing values be produced for the first 2 years; however, because of the short-term's greater accuracy and the need for consistency in the long-term 6-year projections, separate staffings are produced for years Nos. 1 and 2.

When a default value is needed for the long-term in years Nos. 3 through 6 (or any other time when there is no short-term value available), a default value of 2 FTEs (3664 man-hours) is used. Before this default value is used, a check is made to see if there are any bridges in the project. If there are any bridges in the project, then it is staffed according to the number of bridges. Certainly, staffing projects with default values is not desirable, but it is much better to account for those projects in some way rather than simply to omit them.

Field personnel may have concerns about their projected staffing needs in CMMS. In order to help locate where discrepancies between field assessments and CMMS assessments might be, a detailed, project-level proof sheet can be generated by CMMS. Proof sheets show total staffing and apportionment by project for both the long-term and the short-term. These sheets should enable field personnel to spot problems like the use of default values, omission of projects, and erroneous project data.

Figure 2 is a sample proof sheet. The first column is the district-residency code followed by the county, state project number, and PPMS number. The next two columns are the PPMS scope of work and CMMS project type as defined in Tables 1 and 2. Start date is projected from the advertisement date. Length is total project length in miles and number of bridges is count. Highway system is coded as follows:

I	--	Interstate System
PA	--	Primary Arterial Network
PR	--	Regular Primary System
RU	--	Urban System
S	--	Secondary System

All modifiers that apply to a given project are marked with an "X."

SG	--	Subgrade Stabilization
M	--	Mountains
W	--	Wetlands
U	--	Urban
SU	--	Semiurban

The next column is the long-term MPV with the corresponding short-term MPV right beneath. For the first project, the long-term MPV is 600.0 and the short-term is 2410.64. Each of these numbers is followed by the corresponding FTEs in the next column. The remaining columns all pertain to the apportionment of the MPVs/FTEs over the life of the project. The same format is used in these columns as the other staffing columns--the first numbers in the column are long-term and the next ones are short-term. Start and end months are in reference to month 1 of calendar year 1. In the case of the sample proof month 1 is January 1989. The column headed by year refers to the years during the staffing window which each project will span. All projected staffing may not be shown in the remaining columns if the project extends beyond the staffing window (6 years for long-term and 2 years for short-term). Based on the start and end months, the MPVs are divided among the appropriate calendar years in the next to the last column with the FTE equivalents being given by year in the last column.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF TRANSPORTATION
CONSTRUCTION MANPOWER MANAGEMENT SYSTEM
DETAIL PROJECT PROOF SHEET

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DIST RES	CO	STATE PROJ NUMBER	PPMS NUMBER	SCOPE WORK	CMMS TYPE	START DATE	LNGTH	NO. BRG	HWY SYS	MODIFIERS SG M S U SU	CONTRACT LT & ST MPV/FTES		STRT MO	END MO	YR	YEARLY MPV/FTES LT & ST YEARLY	
428	42	0611042249	00001667	09	5	19900201	0.4	01	S		600.00	0.3	14	25	2	550.00	0.3
															3	50.00	0.0
											2,410.64	1.3	14	24	2	2,209.90	1.2
428	42	0615042241	00001627	16	4	19900601	0.8	00	S		520.72	0.2	18	27	2	364.70	0.1
															3	156.30	0.0
											1,509.41	0.8	18	24	2	1,056.30	0.5
428	42	0617042P65	00008705	03	1	19930901	3.4	00	S		3,546.37	1.9	57	72	5	788.00	0.4
															6	2,364.00	1.2
428	42	0627042167	00001497	03	1	19910801	1.1	00	S		1,147.36	0.6	32	49	3	318.50	0.1
															4	764.40	0.4
															5	63.70	0.0
428	42	0627042254	00001654	05	2	19910201	1.8	00	S		3,674.25	2.0	26	43	3	2,245.10	1.2
															4	1,428.70	0.7
428	42	0640042262	00001522	03	1	19910501	0.6	00	S		625.83	0.3	29	46	3	278.40	0.1
															4	348.00	0.1
428	42	0643042253	00001662	12	3	19890901	0.2	00	S		71.76	0.0	09	20	1	24.00	0.0
															2	48.00	0.0
											1,017.95	0.5	09	20	1	339.20	0.1
															2	678.40	0.3
428	42	0657042261	00001651	09	5	19930901	0.2	01	S		600.00	0.3	57	68	5	200.00	0.1
															6	400.00	0.2
428	42	0658042P44	00001620	16	4	19901001	1.8	00	S		1,171.62	0.6	22	31	2	351.60	0.1
															3	820.40	0.4
											2,071.46	1.1	22	24	2	621.30	0.3
428	42	0667042255	00001653	09	5	19921001	0.8	01	S		600.00	0.3	46	57	4	150.00	0.0
															5	450.00	0.2
428	42	0675042P42	00001622	03	1	19890901	0.7	00	S		730.14	0.3	09	26	1	162.40	0.0
															2	487.20	0.2
															3	81.20	0.0
											739.11	0.4	09	24	1	164.40	0.0
															2	493.20	0.2
428	42	0676042235	00001594	09	5	19880401	0.3	01	S		600.00	0.3	01	03	1	150.00	0.0
											759.32	0.4	01	03	1	189.90	0.1
428	42	0683042P43	00001586	05	2	19911201	1.3	00	S		2,653.63	1.4	36	53	3	147.40	0.0
															4	1,768.80	0.9
															5	737.00	0.4

Figure 2. Sample proof sheet.