Staffing Analysis for the Maintenance Department of the Kansas Department of Transportation

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This study examined variables that contribute to the workload of a local highway maintenance crew. It was determined which of these work-influencing factors correlate most closely with the work hours available to maintain Kansas highways. A computer program of multiple regression analysis was used to accomplish this task. The multiple regression analysis revealed that work hours show a dependency on the following variables in the indicated percentages: 55 percent on two-lane kilometers, 20 percent on centimeters of precipitation, 4 percent on average annual daily traffic, 1 percent on square meters of buildings, and 20 percent on all other variables combined. The multiple regression analysis program redistributed the available labor among the 114 local subarea shops throughout the state based on the amount of each of the influencing variables present within the boundaries of each subarea.

It is the duty of any organization to optimize the use of available resources. The major resources of the maintenance department of the Kansas Department of Transportation (DOT) are equipment, material, and labor. The cost of each of these has increased greatly in the past few years. Thus, each has become more precious. In almost all highway agencies, maintenance operations account for the largest number of employees and, in many state agencies, represent the largest expenditure of state funds. Since it is such a large operation and totally state financed, the maintenance function makes a prime target for a management study. To ensure that the maintenance function is executed effectively and efficiently, the distribution of labor must be predicted and precisely followed. Management must have intimate knowledge of the cause-and-effect relation of work activities to determine the distribution of labor.

Highway maintenance in Kansas is a highly dispersed operation that covers 16 090 km (10 000 miles). Any such organization that employs a large number of persons must understand and be capable of justifying the distribution of these workers. Management must know what creates or most nearly establishes the work load for the labor on hand to ensure the efficient use of that labor.

Because of the large number of employees involved, the efficient use of each is highly important. Labor accounts for approximately 40 percent of the $50 million budget of the highway maintenance operation in Kansas. It is therefore obvious that management must devise and justify a very precise and explicit staffing plan for the entire 16 090-km network of Interstate, U.S., and Kansas routes throughout the state. The department must know the current distribution of labor as well as future requirements. This distribution must be fully understood and recognized by the funding agency.

Managers manage money, materials, and people. All must be allocated within budgetary limits according to need. Just precisely what creates this need must also be determined by management. The engineer-manager must develop management policies based on sound engineering judgment.

The efficient and effective use of labor, which is the means by which any maintenance is accomplished, is a most challenging task for the engineering manager. Labor must be distributed in the appropriate locations to attain the desired results.

For the purposes of administration, the Kansas DOT has divided the state into six geographical districts. Each district is divided into four to six maintenance areas. Each maintenance area is again divided into two to six maintenance subareas. The subarea is the basic unit of the maintenance management system and is responsible for all routine maintenance within that subarea. Each of these subareas generally covers 160.9 two-lane km (100 two-lane miles) of highway. It has always been a part of the policy-setting responsibility of the headquarters maintenance department to establish a staffing plan for all levels of management to know exactly the number of personnel to be assigned to each office. It is the staffing of each of these 114 subarea shops that is the concern of this study.

When the current system of areas and subareas was designed, it was mandatory that the state maintain its bare-pavement policy for snowstorm coverage. Therefore, this was used as the basis for staffing each subarea shop. Each shop was allotted the number of workers and trucks necessary to combat the average winter storm. This resulted in a statewide average of two workers and one truck for each 40.2 two-lane km (25 two-lane miles) of highway, which allowed each worker a 12-h shift with the truck during a storm. Thus, uninterrupted snow removal on the entire network during a storm was accomplished. Throughout the year, at times when snowstorm coverage was not necessary, management was to use these workers and this equipment to accomplish what work they could on surface repair, bridge repair, traffic services, land management, and capital improvements. Any work beyond the possible accomplishment by maintenance forces would be contracted.

The previous staffing plan was drawn carefully and meticulously by using engineering judgment and management experience. The architects of this plan were those who had extensive field experience and an intuitive feel for field operational requirements and work-crew capabilities. Of course, there have been additional adjustments in the staffing plan for various factors throughout the years. The staffing plan has been reviewed and updated every 5 years. In updating the plan, it was decided to investigate and examine each factor that may contribute to the amount of work within a subarea.

It was the purpose of this study to examine all of the possible variables that contribute to the maintenance work load to determine which specific variables have the most influence on the work accomplished. Once this relation was established, it was used to construct a staffing plan that equitably and logically distributed personnel throughout the state system of maintenance shops.

The factors (independent variables) considered in this study are any geologic, climatic, or physical factor that is common to all subareas and theoretically attributable in some way to the workload of the subarea. To determine these independent variables, complete familiarity with the functional activities of maintenance is required. What is done and how it is done must be thoroughly un-

Table 1. Independent variables and ranges of statewide subarea quantities.

Independent Variable	Subarea Quantity Minimum	Subarea Quantity Maximum	Statewide Subarea Average
Roadside facilities (rest areas and picnic areas)	0	14.0	3.3
Hours on work program (work backlog)	16 000	162 000	51 670
Two-lane kilometers	96.5	288.0	164.1
Centimeters of precipitation	40.6	106.7	69.6
Centimeters of snowfall	25.4	88.9	54.1
Average annual daily traffic	454	35 226	2 707
Kilometers of city connecting links	1.1	98.5	17.2
Square meters of bridge deck	1 808	254 278	23 832
Square meters of buildings	332	1 590	594
Percentage of truck traffic	6	28	16
Kilometers of concrete pavement	0	136.3	4.1
Kilometers of asphalt pavement	6.1	288	140.5
Sufficiency rating	39	89	67.1

Note: 1 km = 0.62 mile; 1 cm = 0.39 in; and 1 m^2 = 10.76 ft.

derstood. Any variable that is a "what" or may create a "what" as well as any variable that may require a different or varying degree of "how" in each subarea was considered for inclusion. Input from field forces was an invaluable aid in compiling the list of independent variables.

The independent variables, i.e., those that may affect the number of work hours allotted to a subarea, and a list of maximum, average, and minimum subarea values are given in Table 1. This table gives an indication of the wide range of variable values that exist across the state. The list of variables shows that a multitude of data were needed. Almost all data were stored in the data bank maintained by the planning department of the state DOT. By describing the physical limits of each subarea to the computer, the desired information was retrievable by individual subarea values. Values for variables such as sufficiency rating and average annual daily traffic (AADT) were weighted subarea averages for the highways within the subarea.

The dependent variable for this study was available work hours—the number of person-hours of work available in each subarea. An average of 2000 h/position was used.

To accomplish the task of personnel distribution based on the relation of work-influencing factors, a statistical computer program that automates the routine tasks of data processing was used. The program package enables the user to perform many different types of data analysis in a fairly simple manner. The procedure used in this study is multiple regression analysis. Multiple regression is a general statistical technique by which one can analyze the relation between a dependent variable and a set of independent variables. Computational techniques of this program permit the handling of a large number of independent variables in a fast and accurate manner. The basic goal of multiple regression is to produce a linear combination of those independent variables that will correlate as highly as possible with the dependent variable. This linear combination is then used to predict values of the dependent variable and the importance of each of the independent variables. The main focus of analysis by means of this method is the evaluation and measurement of the overall dependence of a set of variables on another variable.

The purpose of the project was to determine which are the most influential independent variables and to predict the number of work hours (of personnel) to be assigned to each subarea shop based on the amount of each influencing variable present in a subarea. The multiple regression technique provided a mathematical equation that indicates how values of independent variables are weighted and summed to obtain the best possible prediction of work hours to be assigned to each subarea shop. To develop this prediction equation and determine the relation of the independent variables to work hours, the multiple regression analysis program builds a multiple axis coordinate system. The dependent variable, work hours, is the vertical ordinate, and there is a horizontal axis for each independent variable. A graph of work hours versus all independent variables is plotted on this multidimensional axis. A best fit line that passes through all planes of the multidimensional axis is determined; this is the prediction or distribution line. An indicator of the goodness of fit of the prediction line with the plotted values of each independent variable is calculated. This goodness of fit is a measure of the strength of the dependence of work hours on each independent variable. This strength relation could also be described as the proportion of variance in work hours that is "explained" by each independent variable.

The multiple regression analysis program revealed no surprise in that 55 percent of the variation in work hours from subarea to subarea is explained by the independent variable of two-lane kilometers. This was hoped for because it is the present basis for staffing.

The next most influential independent variable was somewhat of a surprise. The analysis showed that 20 percent of the variation in work hours is explained by centimeters of precipitation. It is recognized that the amount of moisture establishes a need for maintenance. Evidently the degree of influence of this relation had not been fully realized before; it had been anticipated that hours on work program, sufficiency rating, or AADT would be the second most influential variable.

Third in priority is the AADT variable, which accounts for 4 percent of the variation in work hours. Square meters of buildings ranked fourth, accounting for 1 percent of the variation in work hours. The balance of the variance was attributed to all other variables combined, none of which individually contributes a significant influence. The presence of several variables of minor influence substantiates for the researcher the fact that all practical variables were considered in the study.

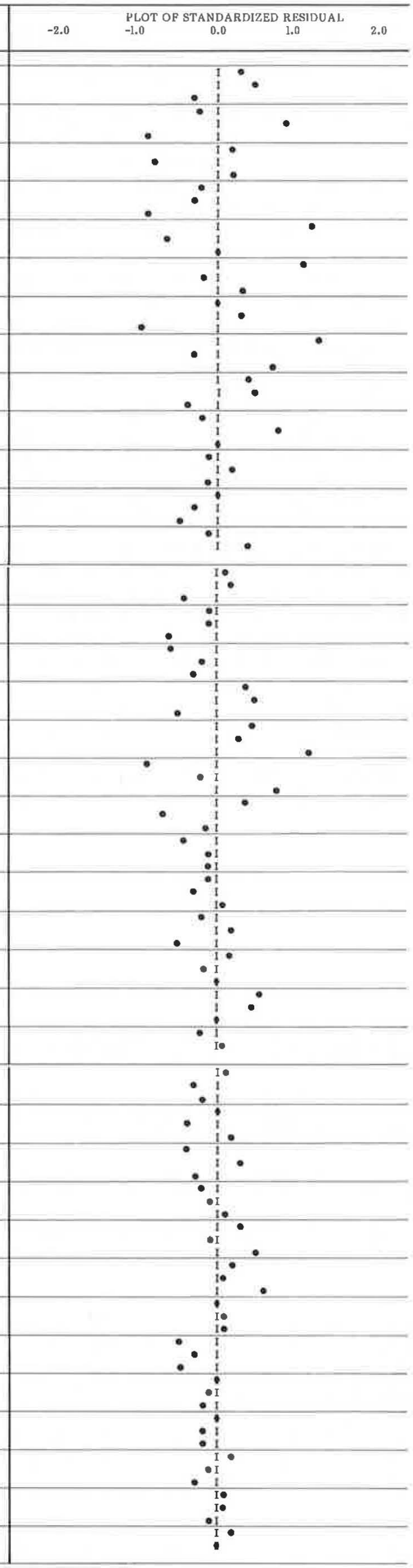
Once the degree of dependency on the independent variables has been established, the program uses these dependencies to predict the necessary number of work hours for each subarea based on the quantities of each of the influencing independent variables present in that particular subarea. The prediction line is of the basic familiar form $y = mx + b$. The equation for the prediction line was given as follows: Allotted work hours = constant + (B_1 × number of two-lane kilometers) + (B_2 × number of centimeters of precipitation) + (B_3 × AADT) + ...

This program provides the constant and each B value. It then makes this calculation for each of the 114 subareas. The result is a printout that shows the number of work hours to be allotted to each subarea annually. This printout is reproduced in Figure 1. It shows the subarea number, observed (current number of) work hours, predicted (allotted) work hours to be assigned to that subarea, and a plot of the standardized residuals. This plot gives a visual indication of the degree of adjustment of work hours that is needed to conform to the new plan.

This program is a double-barreled management tool. It establishes the number of personnel to be allotted to each subarea, and it yields the justifying data to support the prediction, that is, the percentage of dependency on each of the independent variables. Thus, the manage-

Figure 1. Printout of regression prediction.

SUB-AREA	OBSERVED WORKHOURS	PREDICTED WORKHOURS
111	34000	31862
112	34000	30577
113	22000	23763
114	22000	23362
121	38000	32039
122	24000	30304
123	22000	20651
124	26000	31161
131	28000	26954
132	24000	25257
133	22000	23973
141	30000	36270
142	34000	26171
143	24000	28838
144	24000	24252
151	32000	24645
152	26000	27565
153	24000	21815
154	28000	28161
155	24000	22301
161	18000	24770
162	34000	24854
163	28000	29728
164	28000	23586
211	28000	24974
212	30000	26491
213	38000	40579
214	32000	33539
221	28000	22893
222	24000	24196
223	22000	22357
224	24000	22531
231	24000	24916
232	20000	20148
233	28000	29846
234	30000	33598
241	22000	22395
242	42000	39263
243	26000	25106
244	34000	32939
311	20000	23006
312	20000	20537
313	28000	28503
314	18000	22192
321	16000	20169
322	16000	17331
323	16000	17851
324	28000	25331
325	26000	22581
331	14000	17187
332	34000	30440
333	28000	25873
334	34000	26093
335	20000	26304
341	20000	21691
342	30000	24402
343	24000	21483
344	20000	24662
411	34000	34344
412	28000	30903
413	28000	28825
421	22000	22443
422	28000	28385
423	34000	35898
424	20000	19333
431	30000	31467
432	30000	28411
433	30000	33444
441	34000	32716
442	32000	33501
443	28000	28196
451	32000	27997
452	34000	30656
453	38000	37691
511	22000	23570
512	16000	15514
513	16000	15509
514	20000	21776
515	16000	17041
516	14000	13905
521	26000	28464
522	28000	26662
523	18000	20689
531	32000	30238
532	24000	25906
533	26000	27465
541	28000	28348
542	22000	21075
543	22000	20283
544	22000	22766
551	28000	24272
552	32000	30551
553	40000	38990
561	34000	29653
562	34000	33702
611	14000	13312
612	14000	13024
613	16000	19201
614	14000	15809
615	16000	19211
621	20000	20044
622	18000	18757
623	16000	17123
624	16000	16156
631	20000	21139
632	16000	17424
633	20000	18974
634	16000	16407
635	18000	19744
641	20000	19866
642	16000	15560
643	16000	16622
644	16000	14940
645	20000	19794



ment task of establishing staffing levels and justifying these levels is accomplished through the use of this type of analysis.

It was one of the ideals of the study to verify the efficient and economic use of labor and to determine changes that may be needed to ensure that each local unit of the maintenance operation is supplied with an equitable number of work hours according to individual subarea needs. It was not the purpose of this study to attempt to justify a need for additional personnel. Actually, this study does not even indicate a need for additional personnel; it only predicts an ideal distribution of existing personnel. The sole purpose is to document what criteria (variables) are to be used in determining staff distribution and to conduct an investigation to ensure that existing personnel are located where they should be so as to provide an efficient and economical operation that renders necessary services to the motorist.

Lower levels of management are entitled to a logical explanation for the size of their crew. They also deserve to know what actually affects the work and how much it is affected. This automatically provides them with priorities for scheduling, planning, and accomplishment of work. If they know what creates the work as well as what resources are available to get the job done, they are more respected as managers. Knowledge of the variables that have the most influence on the work load of a subarea will enable local managers to understand better why they have been supplied the staff they have according to the amount of each influencing variable within the subarea. This, of course, will enable them to become more effective and efficient managers.

As a result of this study, there is now an exact inventory of conditions, as they pertain to these variables, in each subarea. The maintenance department now possesses a computerized process for distributing personnel for existing, proposed, or revised subarea boundaries or conditions. Whenever subarea boundaries change, or if additional subareas are created, the new parameters may be described to the data bank and a new set of values for all variables of each subarea can be obtained. These revised variable values may then be used in the regression analysis program and a new staffing plan developed.

This plan has generally gained acceptance among district personnel. Some have conducted studies on their own that relate work hours to be accomplished each year to those available in each subarea. These types of investigations have further substantiated the findings of the regression analysis method. At the time of this study, the new plan had not been in effect in Kansas long enough to allow many of the position transfers to be accomplished. Since changes in position locations are accomplished as vacancies occur, the implementation of this plan is incremental, but as time goes on and some of these changes are made, the effectiveness may be measured in terms of improved work accomplishment. The number of work hours required to perform a specified unit of work should be comparable among the subareas. At that point, the task of management to attain optimal staffing and quality of work, with focus on economic considerations, will have been realized.

This study has provided management with a knowledge of the cause-and-effect relation between the variables and the amount of the total resource of labor to be assigned to each subarea. The responsibility of management for establishing staffing levels and justifying these levels has been completed.

Publication of this paper sponsored by Committee on Maintenance and Operations Systems.

Abridgment

Cultural Practices for the Establishment of Grasses From Seed for Roadside Erosion Control

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Oklahoma has over 19 350 km (12 000 miles) of federal and state highways and more than 300 000 hm^2 (750 000 acres) of roadsides to maintain. These roadside areas are subject to erosion during and after the initial construction period. In construction, it is a common practice to remove the native vegetation along with the soil that has formed from the parent material in order to stockpile the topsoil for replacement after this phase is completed.

The topsoil is not in the best condition to support good vegetative growth (1, 2). It has been handled at least two times, which results in a disintegration of much of the macrostructure of the soil and exposure of much smaller particles that will erode as soon as the soil is replaced.

Bermuda grass [Cynodon dactylon (L.) Pers.] is commonly used for roadside erosion control. Because of the risk of winterkill during the year of seeding, vegetative parts (sprigs or sod) are commonly planted. The cost of establishing Bermuda grass from sprigs on 1.6 km (1 mile) of Interstate highway [approximately 16 hm^2 (40 acres)] can exceed $50 000.

To reduce maintenance activities to a minimum on highway rights-of-way and maximize the effectiveness of those practices, research was initiated to determine the best cultural methods and species to use in roadside