U.K. DEVELOPMENTS IN HIGHWAY MAINTENANCE SINCE THE MARSHALL REPORT

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Recommendations in the Marshall Report encouraged research into many areas of highway maintenance and accelerated the progress of several ongoing developments. The research concerning highway maintenance in the United Kingdom is described, and progress is reviewed. Particular areas studied that may have application to U.S. practices are discussed in some detail. These include a methodology for roadworker and field management training; the evaluation and trials of maintenance standards; means of obtaining objective assessments of maintenance needs and priorities, including the use of measuring equipment and structural assessment systems; a computerized approach to the production of estimates and allocation of resources; the identification of organizational principles; comparability of costing and accounting systems; data collection; and work and method study. Other common problems that have only been tentatively explored or have yet to be studied are also discussed. The paper develops an objective, numerate approach to the management and execution of highway maintenance.

•THE Marshall Report (1) has had a great impact on research in highway maintenance. Many post-Marshall research projects have been omitted to enable some understanding of developments applicable to practices in the United States.

So that interest in the Marshall Report could be maintained, a steering committee was set up to consider the recommendations and implementation of the report.

In conjunction with the establishment of the steering committee, research teams to study the organization and the economics of maintenance were organized from personnel of highway authorities from the different regions of the United Kingdom, the U.K. Road Research Laboratory (now the U.K. Transport and Road Research Laboratory), and the U.K. Ministry of Transport (now the U.K. Department of the Environment) to advise on maintenance problems requiring research, to assist in providing data, to consider the results of research, and to assist in providing opportunities for controlled trials of improved methods and techniques of maintenance.

HIGHWAY MAINTENANCE RESEARCH TEAM

The research teams on highway maintenance were set up in September 1970. Initially, four teams were established:

1. A county research team on the organization of maintenance,
2. An urban research team on the organization of maintenance,
3. A county research team on the economics of maintenance, and
4. An urban research team on the economics of maintenance.

The research team was to advise the U.K. Transport and Road Research Laboratory (TRRL) on specific maintenance problems requiring research, to assist in providing

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data for maintenance research studies, to consider TRRL research results on maintenance, and to help provide opportunities for controlled trials of improved methods and techniques of maintenance.

PREVIOUS MAINTENANCE RESEARCH

Most research work done on roads in the United Kingdom before 1970 was from the viewpoint of materials and not of maintenance. A very limited, hurried research program had been carried out for the Marshall committee primarily to identify areas requiring investigation.

Factors considered in previous research have been the source of information and its accessibility, the availability of the resources required, and the urgency or time restraints. Four methods have been used:

1. Research contracts with consultants or local authorities,
2. Local authority researchers acting individually or in groups,
3. Local authority researchers in conjunction with TRRL groups, and
4. TRRL groups.

Typical examples of each method are

1. A cost study by 19 highway authorities under contract to TRRL,
2. A computerized system to produce estimates of resources required and work programs developed by a highway authority under contract to TRRL,
3. A comprehensive manual on surface dressing by a researcher and specialist subgroup,
4. A study of highway authorities' maintenance organization by a local authority researcher and TRRL staff,
5. Development of a maintenance rating system by local authority and TRRL researcher, and
6. Studies of paving operations on a number of major highway contracts by TRRL.

RESTRUCTURING RESEARCH TEAMS

As there was not a great deal of difference between the urban and rural interest, the urban and county research teams were combined on January 1, 1973, and the economics and organization teams were combined to form one team on maintenance in December 1973.

To spread involvement with the subject, a number of task forces headed by a researcher were formed to tackle specific subjects, but the remaining researchers were co-opted from authorities throughout the United Kingdom.

CURRENT RESEARCH PROGRAM

The current research program includes

1. Program for resource allocation and production of estimates;
2. Plant maintenance and costing systems;
3. Surface dressing manual;
4. Review of standards, engineering, and economic levels;
5. Comparison of contract and direct labor operations;
6. Maintenance rating system;
7. Analysis of cost study data;
8. Organization of highway departments;
9. Techniques, organization, and costs of overlaying, reconstruction, and resurfacing;

10. Techniques, organization, and costs of patching and trench reinstatement;
11. Survey of street lighting systems;
12. Assessment of risk of not doing maintenance; and
13. Management information systems for formulating and estimating costs of overall systems.

ROADWORKER TRAINING

The Marshall Report stated that gains in efficiency from greater attention to training may well be as great as or greater than can be obtained in any other way, and the committee made a number of recommendations (1).

Pre-Marshall Training

Some highway authorities started training programs, the most notable being a regional scheme covering southwest England. A nationally recognized craft qualification for roadmen (2). National conditions of service for roadmen were related to rates of pay, skills and a basis of payment were related to job descriptions, and a defined range of skills was established to enable highway authorities to develop a multiskilled labor force (3). A Local Government Training Board (LGTB) was also established.

Throughout the United Kingdom, there were some 45,000 roadworkers and supervisors, but training only applied to some 700 students involved in the national craft training program, and under 1,000 person weeks/annum were devoted to other systematic training off the job.

Post-Marshall Training

The steering committee and the LGTB were responsible for implementation of the recommendations on training.

Programs

First priority was given to training centers. Research was carried out to establish the criteria for the centers. The stages of implementation were identified, such as the compilation of data on age and grading profiles, labor turnover, and forecasts of future demand for labor so that the volume of training required could be calculated. Training audits were recommended to establish the additional amount of training necessary to update, develop, and extend the skills of the existing labor force.

Methods

A three-phase program was produced:

1. New entrants were taught basic roadman skills,
2. Progressive training was administered up to and including skilled roadman, and
3. Additional skills or preparation was made available for promotion to supervisory or technician grades.

Alternative methods were devised for the second and third phases respectively by using the national qualification method and the modular courses at training centers. The training program is shown in Figure 1, and the modular courses are given in Table 1.

The national conditions of service for roadmen were amended to relate pay grades to training and to make managers responsible for assessing training. Personnel fore-

Figure 1. Training program.

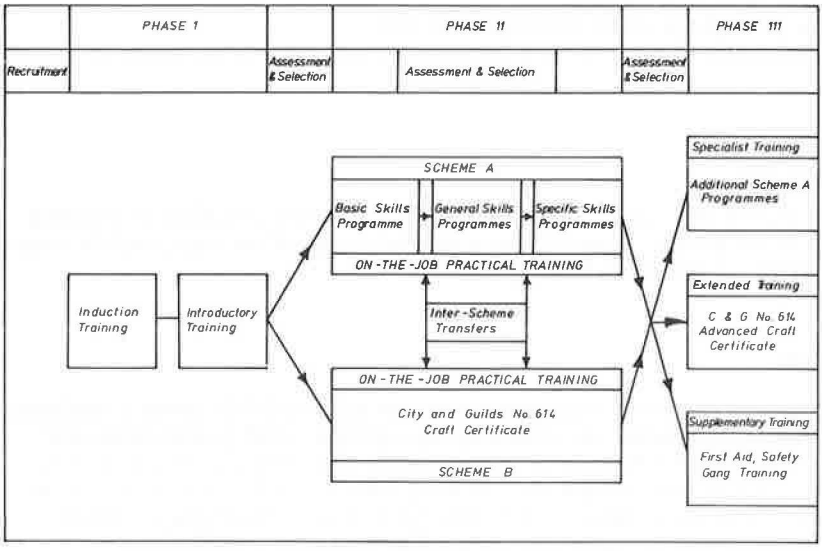


Table 1. Modular courses.

Skill Level	Course Group	Course Number	Course Title
Basic	B	1	Basic roadworking operations
General	D	1	Roadmaking-flexible construction
	D	2	Roadmaking-rigid construction
	D	3	Paints, plastics, powered hand tools
	D	4	Highway fittings and furniture
	D	5	Highway horticulture
	D	6	Light plant operation, part 1
	D	7	Light plant operation, part 2
Specified	F	1	Basic setting out
	F	2	Manholes, catch pits, gullies
	F	3	Curb laying
	F	4	Pipe laying and jointing
	F	5	Fence erection
	F	6	Walling (e.g., drystone)
	F	7	Trench timbering
	F	8	Shuttering
	F	9	Steel fixing
	F	10	Reinforced concreting
	F	11	Scaffolding
Specialist	G	1	Specialist setting out

casting, selection, and recruitment policies and the planning, control, and recording of individual training programs are also required. There is provision for appeal by employees who feel unreasonably denied opportunities for training (4).

Materials

The steering committee established a panel to recommend preferred methods of construction and maintenance and, jointly with LGTB, to produce instructor manuals.

Other Post-Marshall Developments

Developments in national qualifications have enabled an integrated system for progression from skilled roadman to highway superintendent.

EVALUATION AND DEVELOPMENT OF MAINTENANCE STANDARDS

The Marshall committee recommended a set of initial standards for all the functions of highway maintenance and recommended that economic studies should be set in hand for the development of objective standards (1).

The steering committee recommended the adoption of the initial standards, subject to minor modifications, to assess the condition of roads and the adequacy of maintenance but recognized that achieving all the standards might be a long-term project in light of the availability of funds and pressure on national and local budgets. Because of the short time for research, the Marshall standards are largely subjective, and research is required to evaluate the initial standards and to develop more objective standards.

Cost of Adopting Marshall Standards

A cost study was carried out by 19 highway authorities under contract to TRRL since the standards could not be developed without first determining the effect of the initial standards.

The objectives of the study were

1. To estimate costs of raising all roads in a designated area to Marshall standards over a 5-year period,
2. To estimate the annual costs of maintaining the same roads above the Marshall standards thereafter, and
3. To estimate costs for the same roads on the basis of current local maintenance standards.

Three pilot studies were initially undertaken to establish appropriate organization methods and procedures and to identify difficulties. A total of 3,330 miles (5360 km) of roads of all categories were inspected and assessed.

The data obtained were used to estimate the cost of implementing the Marshall standards throughout the United Kingdom.

Engineering Levels of Highway Maintenance Standards

The objective of this study is to assess the Marshall standards for bituminous highways by comparing the maintenance needs, as specified by the standards, with the assessment of a panel of experienced engineers and with the needs indicated by transient deflection measured with a deflectograph or Benkelman beam. A number of highway

authorities under contract to TRRL are providing a range of urban and rural sites for assessment, including construction details and traffic volume. Where construction details are not fully known, cores will be drilled or trial holes dug. Panel members will be unaware of the apparent treatment needs indicated by the Marshall standards from field inspections or the deflectograph measurements, but their opinions will be recorded in a standard manner.

This is a short-term evaluation that is programmed to be completed within a year. A study is also to be carried out of the economic levels of highway maintenance standards, and both studies will be associated with work on estimating the risk attached to deferring maintenance.

USE OF MEASURING EQUIPMENT

The Marshall committee recommended that all highway authorities should make full use of new apparatus becoming available for measuring a road's condition (1): a sideway-force coefficient routine investigation machine (SCRIM) and the Lacroix deflectograph.

Sideway-Force Coefficient Routine Investigation Machine

SCRIM is a machine developed by TRRL for routine monitoring of skidding resistance of roads. The machine is basically a truck-mounted water tank with a test wheel mounted between the front and rear wheels to measure skid resistance in the nearside wheel track and to provide a continuous measurement of skidding resistance on a printout. Items such as changes in surface material and road classification numbers can be recorded. SCRIM can test at speeds ranging from 9 to 62 mph (15 to 100 km/h). The machine has been widely used and is available for purchase and hire by highway authorities in the United Kingdom.

The information obtained with SCRIM can be used to identify roads requiring antiskid treatment, to supplement other data in studies of accident sites, and as part of the data for a complete condition survey. A SCRIM machine has been used by the Greater London Council to monitor the entire metropolitan road network and to intensively study the skid resistance at traffic-light-controlled intersections and at other known accident spots so that a relationship between skid resistance and accident levels at standardized road locations can be established.

Deflectograph

The deflectograph, a mechanical equivalent of the Benkelman beam, was originally developed, tested, and proved by the French Road Research Laboratory. TRRL has modified the machine to suit stiffer British pavements, and it is now generally available to highway authorities.

The machine measures the transient deflection every 11.5 ft (3.5 m) in both wheel tracks, and a typical day's operation can process about 4 miles (6 km) of highway. The survey can be backed up by a highway coring team to ensure accurate information about the existing road structure.

A printer is used with the machine and produces a graphical trace of the samplings. From this original information, a graphical block diagram processing technique is used to facilitate engineer interpretation of various roadway characteristics (Figure 2).

New Works

Criteria have been developed for assessing new works during construction by assessment at subbase, base, and surfacing levels with any consistent deviations investigated

Figure 2. Operations in analysis of deflectograph survey.

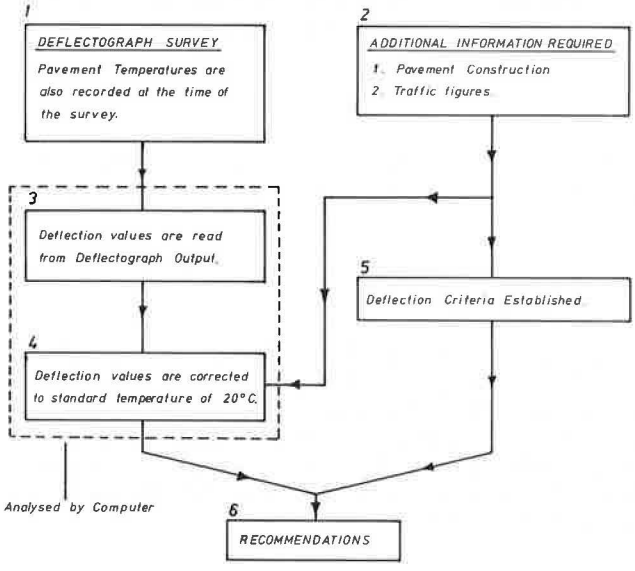


Figure 3. Inspection sheet for maintenance rating system.

HIGHWAYS DEPARTMENT | ROAD REPORT | DATE | C

chainage		paths		kerbs		chbrs		details			deterioration					weighing					totals		division no		road no	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	surveyed by		road class	
from	to	left	right	left	right	left	right	width	marking	drainage	surface	whole surface	n.s. track and edges	surface level	skid resistance	patching	road type	building density	surface retirement	general rating	special factors	columns 13 to 22	chainage	P.R.no - S.R.no	assisted by		road type	
																								year		road length	
																								this sheet chainage	from		to
																								25 ch	26 remarks	sheet no	27

28 chainage		29 length km	30 width m	31 area sq.m	32 S.R.no	33 P.R.no	34 full P.R. code	35 P.R.no	36 suggested action	37 rate per m run	38 price rating	39 year rating

at the relevant construction stage. This technique monitors compliance with specification and adequacy of design method and may well lead to the specification of performance criteria from road pavements at the commissioning stage.

Surfacing Policies

From deflectograph assessments, the relative strengthening properties of different designs and thicknesses of bituminous materials can be assessed, and an optimum economic surfacing policy evolved.

Highway Damage

It is frequently claimed that road openings such as by public utilities have caused damage to the highway. Diversion routes, abnormal loads, and changes in traffic patterns due to traffic management programs have also been held responsible for damage caused by maintenance engineers. Previously such damage could only be assessed by visual inspection and engineering judgment. A survey before and after deflectograph measurement can quantify the damage so that the engineer can cost remedial works to be apportioned to the cause of damage.

STRUCTURAL ASSESSMENT SYSTEMS

The Marshall committee recommended that authorities should use a maintenance rating system as the basis of regular documented inspection of all their roads (1). A maintenance rating system (1) was produced based on visual assessment; points were given to various defects, which were subsequently weighted, and then each assessed aspect was judged critical or satisfactory. The system's defect is that results are primarily based on an inspector's subjective visual assessment. A typical inspection sheet for maintenance rating is shown in Figure 3.

Requirements of Structural Assessment System

A system was needed that minimized subjective judgment and optimized an objective, numerate, quantitative approach.

MARCH System

The MARCH system is a coarse-data system in which the data are collated by totals of defects, e.g., length, areas, and numbers within a given length of road, so that the locations of individual defective lengths, areas, or units making up the totals are not known. Data are collected in a form from which the computer input can be directly punched. The output includes priority lists of maintenance lengths and treatments required based on the worst defect present and lists of maintenance lengths with full assessment and inventory data. The system also includes a rough costing option with an editing facility to produce finer costs. An inspection sheet is shown in Figure 4, and the system outline in Figure 5.

CHART System

The CHART system is a fine-data system in which the defects data are located by distance along a road from the start of each section, and this enables precise analysis. An inspection sheet is shown in Figure 6.

Figure 4. MARCH inspection sheet.

City Engineer's Group
Highway Maintenance System

Field Assessment - Flexible

Road _____

from _____ to _____

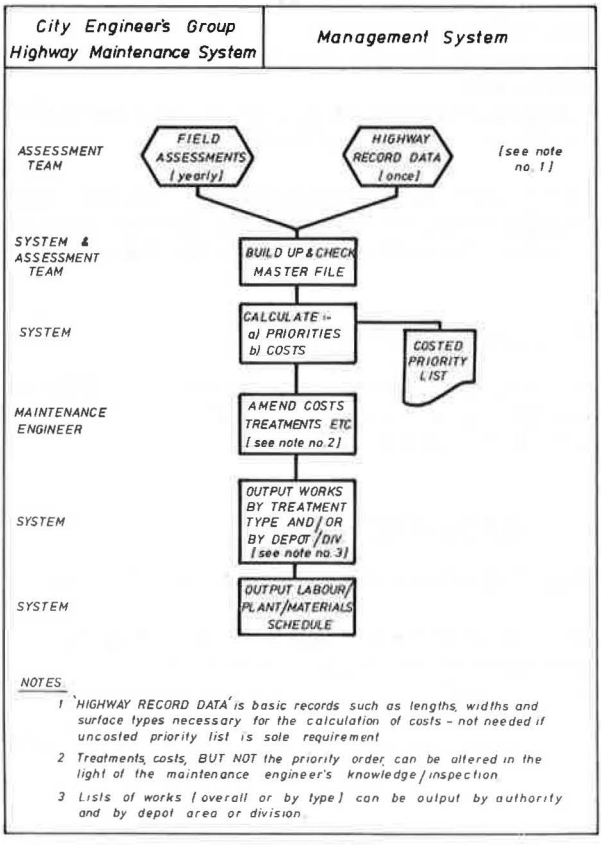
MAINTENANCE LENGTH REFERENCE
[D - depot area no. C - road class R - road no. M - section no.]

D	C	R	M
4			

Field Notes	Item	Item Description	Assessment
	1	Deterioration of whole surface	▽
	2	" " wheel tracks	▽
	3	" " edges	▽
	4	Wheel track rutting	▽
	5	Need for patching	▽
	6	Camber	▽
	7	Surface irregularity	▽
	8	Skidding resistance	▽
	9	Drainage	▽
	10	Left kerb condition	▽
	11	Left kerb face [mm]	▽
	12	Left verge	▽
	13	Left footway	▽
	14	Right kerb condition	▽
	15	Right kerb face [mm]	▽
	16	Right verge	▽
	17	Right footway	▽
	18	Existing unsatisfactory patching	▽
	19	Month of assessment	▽
	20	Year of assessment	▽
	21	Total of all assessment values	▽

Assessor _____ Date _____

Figure 5. MARCH system outline.



NOTES

1 'HIGHWAY RECORD DATA' is basic records such as lengths, widths and surface types necessary for the calculation of costs - not needed if uncosted priority list is sole requirement

2 Treatments, costs, BUT NOT the priority order, can be altered in the light of the maintenance engineer's knowledge/inspection

3 Lists of works [overall or by type] can be output by authority and by depot area or division

The output includes a map of all roads inspected, showing the location of defects and features along the road; histograms of the combined ratings for all defects present; critical subsections, i.e., 330-ft (100-m) lengths; and individual defect and treatment length lists in order of priority of need for treatment.

Application of Systems

The MARCH coarse-data system may be more suited to urban areas where treatment lengths, i.e., city streets, are comparatively short and where the precise location of defects is less critical than an assessment of overall condition. The CHART system, however, seems more appropriate to rural areas where treatment lengths are longer but are only part of the total length of a road.

PROGRAM FOR RESOURCE ALLOCATION AND PRODUCTION OF ESTIMATES

The Marshall committee recommended that highway authorities should introduce management control systems to provide full information for the planning of future demand on labor, plant, and material resources (1).

Pre-Marshall System Development

A system that was partly manual and partly computer based was developed by the Lindsey (now Lincolnshire) County Council. It used a standard computerized system for bills of quantities production together with

1. A detailed comprehensive list of items of work [library of standard operations (LOSO)] normally encountered in highway works arranged under heads compatible with standard practice;
2. Normal methods for study and work measurement techniques applied to each LOSO operation; and
3. Unit rates synthesized from work-study data subdivided into labor, materials, plant, and total costs for each LOSO item.

This system was used for producing and pricing bills of quantities for estimation and resource requirements, but considerable difficulty was experienced in manually updating wage rates, material prices, and plant rates.

Post-Marshall System Development

The obvious development required was to transfer this sytem to a computer and to eliminate the manual operations. Therefore, a TRRL contract was entered into with the Lindsey County Council.

Comparison With Traditional Methods

The traditional bill of quantities approach to estimation uses

1. Labor and materials constants and multipliers,
2. Published prices of measured work, and
3. Historical costs.

This approach is not effective for job control. More reliable cost data, the use of

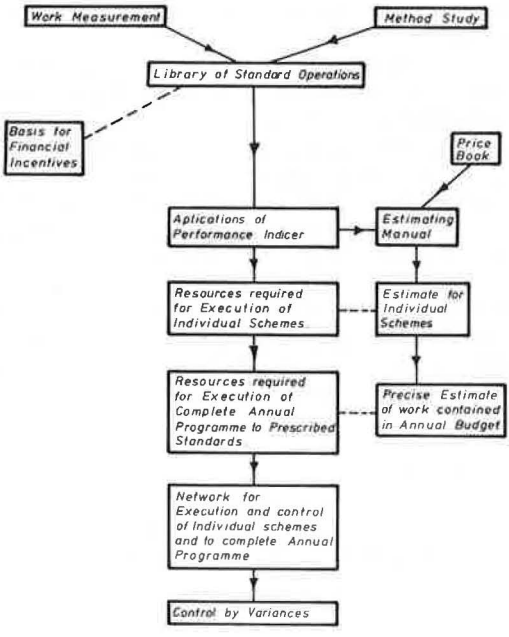
Figure 6. CHART inspection sheet.

Section identifier	Node to Node		Sheet number

Name of road ..... from ..... to .....

		0	50	00	50	00	50	00
LEFT								
Features								
Ditch distance								
FOOTWAY	Levels							
	Type							
	Width							
	Detn.							
VERGE	Type							
	Width							
	Detn.							
KERB	Type							
	Detn.							
	Upstand							
CARRIAGEWAY	Width							
	W/Course							
	Features							
	Edge L							
	Wt rut L							
	Wt crk L							
	WC							
	Major							
	WT crk R							
	WT rut R							
	Edge R							
	Exg. patch							
	WC minor							
	Refl. Crk							
KERB	Type							
	Detn.							
	Upstand							
VERGE	Type							
	Width							
	Detn.							
FOOTWAY	Levels							
	Type							
	Width							
	Detn.							
Ditch distance								
Features								
RIGHT		0	50	00	50	00	50	00

Figure 7. Program for resource allocation and production of estimates.



Logic Diagram

work-study data, and preferably activity-based bills of quantities based on direct labor work are needed to provide a method for accurate estimation and the effective control of work and costs.

The computerized system produces activity or nonactivity, priced or unpriced, bills of quantity for direct labor or contract schemes. Resource requirements and materials schedules for direct labor work and drawn networks for activity-based programs can be linked to computerized costing systems and PERT analysis systems.

System Advantages

Advantages of the management control system include

1. Estimation of resources free from subjective judgment and past history,
2. Resource requirements fully documented and available for use by any engineer,
3. Unbiased unit rates providing facility for checking validity of rates in contract tender documents, and
4. Itemized traditional bills of quantities and activity-based bills of quantities produced in direct relationship to an associated network.

Scope of System

The system can be extended to cover all construction and maintenance work and thus encompass all the operations of a direct labor organization. The logic for the development of the complete system is shown in Figure 7.

HIGHWAY AUTHORITIES MAINTENANCE ORGANIZATION

The Marshall committee recommended that all highway authorities should reconsider their maintenance organization in an attempt to provide more effective and efficient use of resources (1). Therefore, after the Marshall report, a research team was set up to identify the functions common to all the maintenance organizations and to define the principles of organization by which these functions could be performed most efficiently. This is a long-term study, but the advent of local government reorganization necessitated an urgent study.

The team's report (5) describes the desirable principle that emerged from surveys of 19 highway maintenance organizations. An attempt was made to relate the functions of a maintenance organization to the scope of the overall workload of a highway department in relation to the effective employment of resources. Based on the principle of corporate management, there are proposals on organizational structure that incorporate determination of staffing by job evaluation and objective assessment of workload. It is suggested that, for maximum efficiency, a structure should have short, direct lines of communication and use modern methods of information transmission; control is emphasized.

The structure suggested in the report is related primarily to circumstances envisaged in the new, nonmetropolitan U.K. counties, but there may be underlying principles of effective maintenance management that have a wide application; this may be revealed by the results of the long-term study.

SURFACE DRESSING MANUAL

The Marshall Report defined the objective and provided a standard of critical highway deterioration justifying treatment by surface dressing (1).

The Need for a Manual

Although the technique of surface dressing is well advanced in the United Kingdom and considerable research has been carried out, the end result is not always satisfactory because the wealth of knowledge available has never been combined into a single guide to the subject. Therefore, a subgroup was set up to produce a surface dressing manual.

Scope and Content of Surface Dressing Manual

The manual attempts to provide a readable, comprehensive description of surface dressing and contains the following:

1. A complete list of publications about the various aspects of surface dressing, and
2. A section on planning, including site inspection, selection of materials, selection and running of the plant, preparation of the surface, delivery, storage, and testing of materials; a section on treatment, including traffic control, sweeping before dressing, protection of ironwork, application, sampling of materials, rolling, sweeping after dressing, replacement of road markings, warning signs, recording work, work study, and bonus incentive; and a section on post treatment, including immediate post treatment, interim post treatment, and historical records.

RECOMMENDATIONS ADOPTED

A number of recommendations in the Marshall Report are well on the way to full implementation:

1. Adoption by highway authorities of common accounting heads for maintenance activities,
2. Production of standard specifications for contract maintenance and the supply of materials,
3. Universal adoption by highway authorities of work-study-based incentive programs,
4. Bulk purchasing systems for materials,
5. Rationalization of highway responsibilities in the reform of local government, and
6. Minimization of the effect of heavy axle loads on structurally weak minor roads by prescribing truck routes.

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