STATISTICAL APPROACH TO ESTABLISHMENT OF MAINTENANCE LEVELS

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•MOST of those in attendance at this Maintenance Management Workshop would agree, we believe, that today there is much more use of scientific methods of management in highway maintenance work than there was two years ago when a conference similar to this one was held in Columbus to exchange ideas about such methods. In the Ohio Department of Highways, since the 1968 Maintenance Workshop, we have completed a brief training program in which our 88 county superintendents and other division maintenance personnel were introduced to the application of management principles to highway maintenance. We have initiated new work-planning procedures at both the county and division level. Improvements have been made in the reporting of maintenance costs to provide a means for better control. A new method of budgeting maintenance funds has been put in use. In addition to these items, we are currently in the process of developing a method by which we expect to measure the quality of our maintenance effort.

This development work began with the collection of data relating to ice and snow removal in the early part of this year and we have just completed the collection of additional data gathered from approximately 3,000 miles of Ohio highways. As a major part of the development and testing still remains to be done, this presentation is limited to a description of the methods being used.

During the past decade in Ohio there has been an increasing use of statistical methods by the highway department. I refer to the use of statistical sampling and multiple linear regression. A maintenance cost study has been in progress in Ohio for a number of years to determine lane-mile costs for adequate maintenance and to determine the major factors contributing to such costs. This study is a federal-aid highway research project undertaken in cooperation with the Department of Transportation, Federal Highway Administration, Bureau of Public Roads. Statistical sampling and multiple linear regression have been used in the study. Over the past two years the division of operations has utilized linear regression models to improve the method of distributing maintenance funds to 12 field divisions. Multiple regression models are being used in the division of planning and programming to project traffic volumes in 14 urban transportation studies.

There are 38,800 lane miles of highway in Ohio's state highway system. With this large mileage and our previous use of statistical methods, it was natural for us to consider statistical sampling as an economical approach to the measurement of the quality of maintenance and level of services to the user. Any other means of doing this would require a relatively large number of people with specialized training. We believe that by using statistical sampling procedures our present staff of field engineers can do the necessary field inspection work.

The problem was discussed with Tallamy, Byrd, Tallamy and MacDonald, consulting engineers, and they suggested that a method could be developed which would require a limited amount of field inspection and still give us the result we were seeking. Subsequently an agreement was entered into with Tallamy, Byrd, Tallamy and MacDonald to: (a) develop measures for the quality of maintenance being achieved on Ohio's highways; (b) develop measures of services provided highway users; and (c) determine the relationship between the quality of maintenance and the level of service to the user. The department's objective is to develop a method that will be used on a continuing basis for the determination of these measures of quality and service. Field engineers of the Ohio Department of Highways have just finished gathering data that will be used by the

consultant in the development of the method. These same engineers will later apply the method developed by the consultant.

THE BASIS FOR THE METHOD

Briefly stated, Tallamy, Byrd, Tallamy and MacDonald proposed that the quality of highway maintenance can be evaluated in terms of its influence on four factors contributing to the level of service on the highway. Such an evaluation requires that the relationship between the four items and a related group of specified variables be known. The four items, or influence areas, to be used in the method for measuring quality of maintenance are:

1. The physical integrity of the elements of the highway;
2. The safety of the facility for the user;
3. The rideability of the pavement; and
4. The aesthetics of the highway.

Quality of highway maintenance is a function of these four influence areas and the maintenance expenditure or investment.

The consultant will establish the relationships between these four influence areas and variables which include both those determined by field inspection and those taken from existing records.

Three conditions were established as a framework for the conduct of the development study:

1. The method should be based on a sample of the highway system in order to minimize inspection time;
2. The measurement should be based on objective criteria which could be obtained by regular maintenance personnel; and
3. The results of the evaluation should be presented in a simple, easily understood format.

The quality of highway maintenance influences both the physical integrity of the highway and the users of the highway; and the influence on the user can be divided into the three areas of safety, rideability, and aesthetics. To be sound, the method used for evaluating highway maintenance should take into account the four areas of influence. Although there are about 50 maintenance activities performed by the maintenance forces, each having varying impact on the four areas of influence, it did not seem practical or necessary to try to evaluate each maintenance activity. In place of a detailed study, the total maintenance effort was divided into eight categories of activity with the intent to establish a method for evaluating the quality of maintenance in each category. After evaluating each category, weighting factors based on broad objectives will be applied to produce a single measure of maintenance quality. The eight categories being used in the study are: (a) ice and snow removal, (b) pavement maintenance, (c) shoulder maintenance, (d) vegetation control, (e) maintenance of structures, (f) roadsides and medians, (g) drainage, and (h) appurtenances.

COLLECTION OF DATA

Data are required for two purposes. The immediate need is for data to use in developing the method. After the method is established, data will be collected once during each year in each field division to evaluate the quality of maintenance in that division.

For activities other than ice and snow control the consultant asked that data be collected by field inspection in three divisions of the state. These divisions differed primarily in climate and terrain with some differences in the type of highway construction and type of labor available for maintenance work. For development work, approximately two-thirds of the highway mileage was used as a sample in each of the three divisions. It was decided to utilize department personnel as much as possible in the collection of data, using data forms designed by the consultant. For this field inspection two engineers were used in each division and the regular roughometer crew took roughometer readings in all three divisions.

Data for ice and snow removal were gathered statewide from 10 locations in each of the 88 Ohio counties. For gathering the ice and snow removal data 6 engineers, 88 county superintendents, and a large number of truck drivers were used.

ACTIVITY CATEGORIES

Ice and Snow Removal

Ice and snow removal provides a service to the user. The elimination of the influence of ice and snow on the roads increases both the safety and the rideability of the road. The sooner the road conditions are brought back to normal the more effective the maintenance operation is considered to be. Therefore, the approach taken to evaluate the quality of ice and snow removal was to measure the length of time that a road was not in a normal condition. This was called the storm impact period and defined as the interval from the start of the storm to the time when the pavement becomes completely clear. The storm impact period is believed to be a function of the following variables: storm duration, snowfall, traffic, temperature, daylight, route priority, wind, and roadway condition.

To evaluate effectively the quality of the ice and snow removal effort in terms of the impact period, a relationship between impact period and the variables listed above was needed. To establish this relationship, storm data were required. Procedures and forms were developed to obtain such data and during February and March of this year our truck operators, county superintendents, and field engineers provided us with such data. Ten locations were selected in each of the 88 Ohio counties and these locations were identified as to section, priority, and average daily traffic volume.

Truck operators were requested to fill out data cards for each location for each storm. These preprinted cards provided the following data:

1. The time when pavement surface maintenance operations were begun to eliminate any adverse influence of a storm;
2. The time when maintenance operations, related to clearing the pavement surface, were terminated; and
3. The time when snow or ice was cleared from the pavement surface. The term "clear" was defined to include wet pavement where snow and ice were limited to the outer pavement edges.

A second data form was distributed to 88 county superintendents with a request to record information on storm duration, temperatures, snowfall, and wind velocity for each storm (Fig. 1).

The six field engineers on the Bureau of Maintenance staff were asked to observe the sample locations at random times during a storm for the purpose of evaluating the condition of the pavement, shoulders, bridges, and drains. Figure 2 shows the form used by the field engineers for this evaluation.

Between February 7 and March 29, 24 days of storm activity were reported. The reported snowfall varied from a trace to six inches. The number of observations reported by truck drivers at the sampling locations exceeded 4,500. The data thus obtained by our own personnel have been screened, coded, and placed in a data processing tape file by the consultant. In addition, U. S. Weather Bureau data were obtained by the consultant for the same storm days and correlated with the data reported by department personnel. The consultant has developed a computer program to generate the following variables from all available information for each of the storm observations: storm impact period, storm duration, snowfall in inches, traffic volume during impact period, high temperature, low temperature, average temperature and direction of change, percent of daylight, wind velocity, and time interval between start of storm and initiation of maintenance operation on the road.

All of the variables thus obtained will be analyzed by the consultant using multiple regression analysis with the intent of identifying significant variables which can be incorporated into a model to predict storm impact period. When by the use of the model the impact period can be predicted for given storm conditions we will be able to evaluate the quality of our ice and snow removal effort in terms of the predicted impact period.

Division ____________________ Date ____________

County ____________________

1. STORM PERIOD

	a.m.	p.m.	Date
Beginning of precipitation:			
End of precipitation:			

2. TEMPERATURE

Beginning of precipitation: ____________ °F

End of precipitation: ____________ °F

All pavement completely-cleared: ____________ °F

3. ESTIMATED SNOWFALL

During storm period: ____________ INCHES

4. ESTIMATED WIND VELOCITY

Beginning of storm period: ____________ mph.

All pavement completely-cleared: ____________ mph.

OHIO DEPARTMENT OF HIGHWAYS

____
NAME

Figure 1. Snowstorm condition survey by county superintendent.

In practice, by observation, impact periods will be measured during the winter for a number of sample locations in each of the divisions in the state. Variables will be obtained for each observed storm and location. Using the model, a predicted impact period will be generated for each location and storm. The ratio of the observed impact period to the predicted impact period will then be calculated and the average ratio for all observations in a given division will represent a measure of the quality of the removal effort in that division relative to other divisions.

Recordable Condition Survey

The next consideration after evaluating ice and snow removal was the quality of maintenance as it relates to the protection of the physical integrity of the highway. Historically, a series of subjective evaluations has been used to rate the condition of a multitude of physical elements of the highway. The list of elements requiring inspection usually becomes quite long with each element being rated as good, fair, or poor or using a scale of numbers covering the same subjective range. If enough time and resources are available, this approach can be used as a basis for evaluating maintenance quality. However, this approach did not meet the requirement of objectivity set forth for the Ohio study.

The reasons for performing maintenance on the physical elements of the highway were reexamined. It was decided that the ultimate objective is to keep the facility in a safe and usable condition. If maintenance reduces user hazards and ensures the proper functioning of the highway, maintenance can be considered adequate. Hazardous conditions and impaired functional characteristics of the highway can be objectively identified.

Time ____________________ Location ________________

Date ____________________ Priority ________________

County ________________

PAVEMENT CONDITION

Circle the appropriate condition for the highway segment following the code for pavement condition.

Cover	Pavement	Surface
0 1 2 3 4 5 6	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4

Circle the appropriate condition for each of the following items.

Shoulder

Clear	Plowed	Covered

Guardrail

Clear	Partially covered	Covered

Bridge (Relative to the pavement)

Better	Same	Worse

Drain

Open	Partially open	Closed

Cover:

0 Clear ... no snow or ice
1 One edge ... cover up to 12 inches wide
2 Both edges ... cover up to 12 inches wide
3 Edges and center ... cover up to 12 inches on edges and up to 24 inches along pavement centerline
4 All wheel paths clear ... 1 to 3 feet width
5 One-half of wheel paths clear ... 1 to 3 feet width
6 Covered ... entire pavement covered from edge to edge

Pavement:

0 Dry
1 Wet
2 Trace snow ... very little snow and not melting to give wet pavement
3 Glazed ... very thin ice glaze due to wet pavement freezing
4 Loose snow ... some accumulation of snow, generally cold dry and not packing under traffic
5 Packing snow .. generally wet enough to pack under traffic
6 Snow-ice .. packed hard snow
7 Ice ... wet heavily packed snow, more ice than snow at least on the surface
8 Wet slush ... traffic or chemicals making slush from any accumulation of snow or ice
9 Meally slush ... very cold, but chemicals keeping snow from packing -- usually fair traction, appearance is dirty brown

Surface:

0 Normal ... dry or wet without snow or ice
1 Slippery ... wet ice or ice snow surface or any combination resulting in very slippery pavement
2 Smooth ... packed ice and snow which is smooth to ride on and where there is fair traction
3 Rough ... bumpy, rutted ice or snow covered road
4 Brittle ... very cold packed snow or ice where traction is relatively good

Figure 2. Snow condition survey by field engineer.

Therefore, it becomes possible to determine if a particular element of the highway has been adequately maintained. This ability to establish objectively if maintenance is adequate provides a basis for developing various measures of the quality of maintenance being achieved on Ohio highways.

The characteristics of the basic elements of the highway system affecting user safety or proper functioning of the system were next set forth. An inadequate condition was defined as a "Recordable Condition." A code was assigned the "Recordable Conditions" and the definitions used to identify the conditions, as follows:

1. Pavement	a. Obstruction
2. Shoulder	b. Deterioration
3. Structure	c. Drop Off
4. Guardrail	d. Slipperiness
5. Drainage	e. Corrosion
6. Traffic Control	f. Functional Failure
7. Vegetation	g. Erosion
8. Roadway	

Each recordable condition is identified by one number and one letter in combination, i.e., a hole in the pavement surface will be 1b. All structures are included in the annual bridge inspection program and are not a part of this adequacy measuring system. Definitions of recordable conditions follow.

Obstruction—Hazardous obstruction on the pavement or shoulder surface which projects more than two inches or growth which creates a hazardous obstruction to the visibility of the user. One unit of obstruction is a single item or a group of items which creates an obstruction at a spot location. Two objects lying together on the pavement in one lane represent one unit whereas two objects in each of the two lanes represent two units of obstruction.

Deterioration—Any structural deterioration which requires repair and which exceeds 6 in. in diameter and 2 in. in depth or exposes reinforcing steel. One unit includes up to 2 sq yd of the condition in a single location. Hazardous obstruction created by the pavement such as blow-ups and warped concrete.

Drop Off—Hazardous drop off between shoulder and pavement edge which exceeds 2 in. One unit of the condition will be 250 ft in length (approximately one-twentieth of a mile) or less.

Slipperiness—Spot reduction in skid resistance caused by the presence of materials on the pavement surface, i.e., loose gravel, cinders, oil, bleeding, or standing water. One unit will be 1 sq yd or greater not to exceed 100 lineal ft of pavement.

Corrosion—Failure of the protective coating on a structure or appurtenance which results in flaking, extensive pitting, or a reduction in steel cross section area. One unit includes up to 1 sq yd of affected area in one spot location.

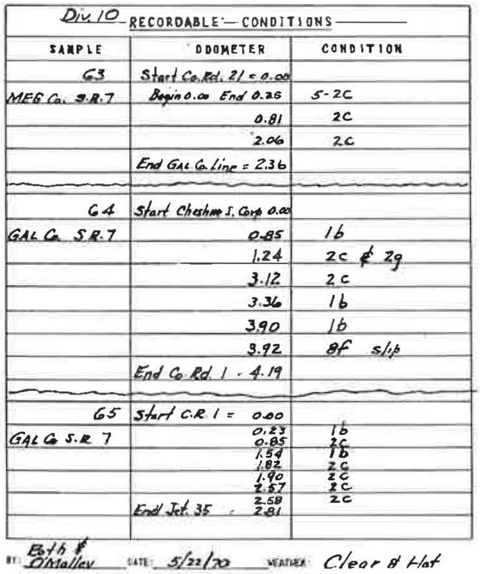
Functional Failure—Failure (50 percent or greater) of the original drainage section caused by obstruction from erosion, slides, etc., deterioration or damage to any traffic control device, guardrail, structure or other highway element which prevents it from functioning. Drainage—each 100 lineal ft of drainage ditch is one unit. Guardrail—each 100 lineal ft of guardrail is one unit. Pavement Marking—each 528 (one-tenth of a mile) lineal ft is one unit.

Erosion—Erosion which has encroached into pavement, shoulder, personal property, or the foundation of any structure more than 2 in. will be considered one unit of recordable condition.

This list, with photographs to supplement the definitions, was used as an inspection manual by our field engineers. The "Recordable Condition" concept has been field tested and evaluated in 3 of the 12 divisions in the Ohio Department of Highways. The maintenance field engineer and traffic field engineer assigned to the selected divisions comprised a two-man team and each team evaluated about 1,000 miles of roads in their assigned division. Figure 3 shows a sample of the form used by these teams.

In addition to using and evaluating the "Recordable Condition" manual, the field study identified the frequency with which each "Recordable Condition" occurred. This fre-

quency will be used by the consultant to establish appropriate sample sizes in the procedure to be used in the future for generating measures of maintenance quality.



Div. 10 RECORDABLE — CONDITIONS

SAMPLE	ODOMETER	CONDITION
63	Start Co. Rd. 21 = 0.00	
MEG Co. S.R. 7	Begin 0.00 End 0.26	5-2C
	0.81	2C
	2.06	2C
	End GAL Co. Line = 2.36	
64	Start Cheshire S. Corp 0.00	
GAL Co. S.R. 7	0.85	1b
	1.24	2c & 2g
	3.12	2c
	3.36	1b
	3.90	1b
	3.92	8f slip
	End Co. Rd. 1 - 4.19	
65	Start C.R. 1 = 0.00	
GAL Co. S.R. 7	0.23	1b
	0.85	2c
	1.54	1b
	1.82	2c
	1.90	2c
	2.57	2c
	2.58	2c
	End Jct. 35 - 2.81	

BY: Beth & O'Malley DATE: 5/22/70 WEATHER: Clear & Hot

Figure 3. Recordable conditions.

Pavement Maintenance

Pavement maintenance is one of the most important categories of maintenance activity for two reasons. First, approximately 20 percent of the total maintenance funds are invested in this category and, second, the pavement has the greatest impact on the highway user. Pavement maintenance affects all of the influence areas; namely, physical integrity, safety, rideability, and aesthetics. In the development of a measure for pavement maintenance, each influence area was considered separately. First, the physical integrity of the pavement is unacceptable if the pavement has severe deterioration, evidenced by extensive potholes and pavement disintegration. "Recordable Conditions" as they apply to the pavement were defined to reflect severe pavement deterioration. If, in surveying the pavement, such "Recordable Conditions" are noted, then pavement maintenance has not been adequate because the physical integrity of the pavement has not been retained. This admittedly does not quantify the quality of maintenance, but it does permit a yes or no answer to be given to the question "Is pavement maintenance adequate"? When this concept is first considered the following questions may come to the maintenance engineer's mind. "What about extensive cracking, open joints, depressions, rutting, faulting, extensive spalling, pumping, etc.? Aren't these all evidence of lack of maintenance?" To be sure, they are, but evidence of the need for maintenance is not necessarily evidence that the physical integrity of the pavement has been impaired. It must be understood that identifiable maintenance needs are not synonymous with inadequate maintenance. As defined in this study, maintenance is adequate until the impairment to the physical integrity of an element creates a hazard to the user or until a functional failure of some element of the highway occurs.

Once the physical integrity of the pavement has been ensured, i.e., adequately maintained, then the quality of the maintenance performed on the pavement can be evaluated. The approach in this instance was to assume that the quality is the result of a combination of maintenance investment, rideability, safety, and aesthetics.

Of course, the quality level achieved for each of these is partially dependent on broad environmental and physical factors such as weather, traffic, construction, and age. Therefore, a portion of our method study is concerned with evaluating the impact of these factors. The following variables are being identified for each highway section of different surface age on the 3,000-mile sample being used for method development: surface roughness (roughometer), surface type, traffic volume, pavement width, base type (where identifiable), route type classification, weather factors, and annual pavement maintenance expenditures.

Tallamy, Byrd, Tallamy and MacDonald will use appropriate correlation techniques to determine the levels of safety, rideability, and aesthetics that can be associated with the above variables. After such relationships are established as a reference base, sections will be sampled throughout the entire state and evaluated in terms of the base value. Our present thinking is that the information collected on sample sections will be confined to a "Recordable Condition" survey, a pavement roughness survey using the department's BPR roughometer, and a photographic survey. Such surveys are expected to identify the conditions on the highway which affect user safety, in addition to establishing the adequacy of maintenance. The roughometer will provide a measure of the

rideability. A method for evaluating the impact of highway aesthetics on the user has not been established, but the idea of comparing pictures of a sample section with standard pictures is being considered.

Shoulder Maintenance

Shoulder maintenance affects the influence areas of physical integrity, safety, and aesthetics. The physical integrity of the shoulder is acceptable if it has no severe deterioration as evidenced by disintegration or loss of material. Once the physical integrity of the shoulder has been assured, then the quality of the maintenance performed on the shoulder can be evaluated. It will be a function of investment, safety, and aesthetics. Environmental and physical factors, such as weather, traffic, and construction will also be involved. Appropriate correlation of various factors will then permit the quality of shoulder maintenance to be evaluated from identified "Recordable Conditions," investment, and appearance.

Vegetation Control

Vegetation control affects the influence area of aesthetics. Maintenance is adequate if it conforms to existing state directives. This again will be established in the "Recordable Condition" survey. The quality of vegetation control will be a function of investment, weather, and appearance.

Maintenance of Structures

In the early part of 1968 the Ohio General Assembly passed a law requiring regular and systematic inspection of bridges on or over public highways and streets. The law provided for the preparation of a bridge inspection manual to establish standards and procedures for inspectors charged with the responsibility of bridge inspection. The form used for such bridge inspection is included here (Fig. 4) and is entitled, "Bridge Inspection Report." The manual and form for bridge inspection result in rating each bridge as (a) satisfactory, (b) in need of housekeeping maintenance, (c) in need of minor repair, or (d) in need of major repair. It is planned to evaluate the quality of maintenance on structures using the bridge inspection reports which are made once a year for each structure. The exact method has not yet been established but, because such information is already available and is stored in computer files, statistical methods will be applied using these data.

Other Activity Categories

In addition to the five activity categories discussed above there are three others that are considered to be of lesser importance. These are roadsides and medians, drainage, and appurtenances. The "Recordable Condition" survey identifies inadequate maintenance relating to these three categories. Specifically, the deficiencies in these categories would include, but not be limited to, slope erosion, deterioration and/or functional failure of drainage facilities, and deterioration of guardrail and signs. With these items as with the previous items the evaluation is being made with regard to physical integrity, safety, and aesthetics. Our investigation will determine if terrain, weather, and the maintenance investment are significant variables in evaluating the maintenance in these categories. Up to this time very little work has been done in these three categories because it was believed that the activity categories where the larger investments in maintenance are made should be given the most consideration during the early part of the study.

WEIGHTING INFLUENCE AREAS AND ACTIVITY CATEGORIES

In the foregoing, the major influence areas, the activity categories, and various other factors relating to these items have been discussed. Figure 5 shows the areas of influence and the related activity categories. The "Recordable Conditions" which apply to the various areas and activities are shown by the code letters already explained, used in making the field survey.

CONDITION CODE: GOOD = 1, FAIR = 2, POOR = 3, CRITICAL = 4

4 EXISTING 7 8 12 13 — REVISED 16 17 21 — 22 — 23 — 24

BRIDGE NUMBER: 28 — 30 CO. — ROUTE — SLM-L/R 33 — ROUTE — SLM-L/R 37 — HWY. SYSTEM: ___ 39 — FED. AID SYSTEM: ___ 42 — YEAR BUILT: ____ 64

DIV. ___ BR. TYPE: ____ O/A LGTH. _____ NO. OF SPANS: ___ OVER OR UNDER: ____

SUPERSTRUCTURE: — REMARKS: — TYPE COND.

1. DECK SLAB: REINF. CONC.=1, TIMBER STRIP=2, TIMBER PLANK=3, FILLED STL. GRID=4, OPEN STL. GRID=5, CORRUGATED STL.=6, BUCKLE PL.=7, CHECKER PL.=8, JACK ARCH=9, OTHER=0 — 65
2. WEARING SURFACE: CONC.=C, BITUMINOUS=B, OTHER=O — 67
3. CURBS & MEDIAN: CONC.=C, STL.=S, TIMBER=T, OTHER=O — 69
4. WALKWAYS: SEE DECK SLAB FOR TYPE CODE — 71
5. RAILINGS: CONC.=C, STL.=S, TIMBER=T, CONC. & ALUMINUM=A, OTHER=O — 73
6. JOISTS: STL.=S, TIMBER=T — 75
7. FLOORBEAMS: STL.=S, CONC.=C, TIMBER=T — 77
8. FLOORBEAM CONNECTIONS: ROD=R, PLATE=P, ANGLE=A — 79
9. LONGITUDINAL BEAMS or GIRDERS: STL.=S, CONC.=C, PRESTRESSED CONC.=P, TIMBER=T — 81
10. TRUSS ALIGNMENT: STL.=S, TIMBER=T — 83
11. HIP VERTICALS: — 85
12. END POSTS: STL.=S, TIMBER=T — 86
13. TOP CHORDS: STL.=S, TIMBER=T — 88
14. BOTTOM CHORDS: STL.=S, TIMBER=T — 90
15. WEB MEMBERS–VERTICAL: STL.=S, TIMBER=T — 92
16. DIAGONAL: — 94
17. PORTALS: STL.=S, TIMBER=T — 96
18. SWAYBRACING: STL.=S, TIMBER=T — 98
19. LATERAL BRACING: STL.=S, TIMBER=T — 100
20. CROSS FRAMES or DIAPHRAGMS: STL.=S, TIMBER=T, CONC.=C — 102
21. DECK EXPANSION DEVICES: STL.=S, OTHER=O — 104
22. BEARINGS: ROCKERS=R, BOLSTERS=B, ROLLERS=N, PLATES=P, ELASTOMERIC=E, OTHER=O — 106
23. DRAINAGE SYSTEM: THRU CURBS=T, SCUPPERS=S, SCUPPERS WITH DOWNSPOUTS=D, OTHER=O — 110
24. ARCHES: CONC.=C, STL=S, MASONRY=M, TIMBER=T — 112
25. MOVABLE BRIDGE MACHINERY: BASCULE=B, VERTICAL LIFT=V, SWING=S — 114
26. SUSPENSION BRIDGE CABLE or CHAIN BENTS: — 116
27. SUSPENSION BRIDGE TOWERS: STL=S, MASONRY=M — 117
28. SUSPENSION SYSTEMS MAIN: CABLE=C, EYEBAR=E — 119
29. SUSPENDER: — 121
30. PAINT: SHOW YEAR LAST PAINTED IN LEFT & CENTER BLOCKS — 123
31. RESPONSE TO LIVE LOAD: EXCESSIVE DEFL. & VIB.=E, SATISFACTORY=S — 126

SUBSTRUCTURE:

40. ABUTMENTS: WALL=W, SPILL-THRU=S, GRAVITY=G — 127
41. BACKWALLS: CONC.=C, MASONRY=M, OTHER=O — 129
42. WINGWALLS: CONC.=C, MASONRY=M, OTHER=O — 131
43. BRIDGE SEATS – ABUTMENT: CONC.=C, MASONRY=M, TIMBER=T, STL=S — 133
44. PIER: — 135
45. PIERS: COLUMN=C, WALL=W, T-TYPE=T, CAPPED PILE=P, OTHER=O — 137
46. SUSPENSION BRIDGE ANCHORAGES: CONC.=C, MASONRY=M — 141
47. PILING: STL.=S, TIMBER=T, CAST-IN-PLACE=C, PRECAST CONC.=P — 143

GENERAL:

50. STREAM CHANNEL – WATERWAY: SHOW IN LEFT BLOCK, UNRESTRICTED=U, RESTRICTED=R; SCOUR: SHOW IN TYPE BLOCK, SCOURED=Y, NOT SCOURED=N; ALIGNMENT: SHOW IN CONDITION BLOCK — 145
51. BANK PROTECTION: SHOW IN TYPE BLOCK: ADDITIONAL PROTECTION NEEDED=Y, NO=N — 148
52. CULVERTS: BOX=B, ARCH=A, SLAB TOP=S, PIPE=P — 150
53. APPROACH GUARDRAIL: DEEP BEAM=D, CABLE=C, WOVEN=W, OTHER=O — 152
54. APPROACH EMBANKMENT: SHOW IN TYPE BLOCK: SETTLED=Y, NOT SETTLED=N — 154
55. APPROACH PAVEMENT: CONC.=C, BITUMINOUS=B, OTHER=O — 156
56. APPROACH ALIGNMENT & GRADE: — 158
57. APPROACH SLABS: SHOW IN TYPE BLOCK: SETTLED=S, NOT SETTLED=N — 159
58. SUMMARY: SATISFACTORY=1, NEEDS HOUSEKEEPING MAINT.=2, MINOR REPAIR=3, MAJOR REPAIR=4 — 161

USE REVERSE SIDE FOR ADDITIONAL DETAILS.

70. INSPECTED BY: ____________ SIGNED — 162 INITIALS — 164 __/__/__ 169 DATE — REVIEWED BY: ____________ SIGNED — INITIALS — __/__/__ DATE

INSPECTION RESPONSIBILITY __________ 170 179

Figure 4. Bridge inspection report.

ACTIVITY CATEGORIES	Ice Snow	Pavement	Shoulders	Vegetation	Structures	Roadside Medians	Drainage	Appurt-enances
Recordable Condition Codes Ref. Pg.	Special	1	2	7	3	8	5	4,6
INFLUENCE AREAS								
Physical Integrity		b X	b,c,g X		a,b,d,e,f X	g	f X	X
Safety	X	a,b,d X	a,c,b,g X	a X	a,b,d,e,f X			f X
Rideability	X	rougho-meter a,b X			a,b X			
Aesthetics		Photo's a,b X	a,b X	Photo's a X		g X		X
Maintenance Investments	X	X	X	X	X	X	X	X

X indicates Influence Areas relating to Activity Category
a,b,c,d,e,f,g - Recordable Condition Codes

Figure 5. Areas of influence versus related activity categories.

As an example in the influence area of safety and under the activity category of pavements the letters a, b, and d refer to the unacceptable pavement conditions obstruction, deterioration, and slipperiness. These are conditions relating to safety.

In Figure 5 an X indicates that the activity category is a factor in the influence area where the X appears. Thus, the activity categories ice and snow, pavement, and structures are factors to be considered in the influence area rideability.

After measures have been established for evaluating the quality of maintenance as it affects each influence area for the elements included in each activity category, the measures must be weighted. This weighting will first reflect the impact of each activity category on a specific influence area. Consider safety for example. The relative impact of pavements, shoulders, structures, vegetation, and appurtenances on the highway user must be appropriately weighted so that a single measure of the quality of maintenance as it affects the safety of the highway user can be determined. Depending on broad highway objectives, weights can be given to the influence areas of physical integrity, safety, rideability, and aesthetics so that a single value of maintenance quality can be generated.

APPLICATION OF THE METHOD AFTER DEVELOPMENT

To apply the method which is now in the development phase, data will be collected on random sample sections of highway as noted earlier. The "Recordable Conditions" for pavement will be compared with the base values resulting from the consultant's correlation work on pavement. Similar comparisons will be made in other activity categories. The values thus obtained will be given the proper weighting factors and quality levels will thus be established for each of the four influence areas. The influence area values will then be weighted to give an overall measure of quality. This procedure will be used in each of the 12 divisions to indicate the quality of maintenance achieved in each. Consideration will be given to applying the results of this study in the budgeting of maintenance funds. If factors such as age, construction, and weather prove to be of sufficient importance in their effect on the cost of maintenance in achieving a minimum quality standard then maintenance funds could be adjusted to meet the requirements imposed by such factors.

SUMMARY

The objective of this presentation has been to describe what is presently being done in Ohio to develop a method to measure the quality of highway maintenance and the level of services to the highway user. We have elected to use statistical methods because of the savings offered thereby in both the development and continued use of the new method for evaluating maintenance. Statistical sampling is being used in the development of the method and it will be used in the application of the method.

We have engaged Tallamy, Byrd, Tallamy and MacDonald as consultants on this work and they are now engaged in the statistical analysis of the data that have been collected during the past six months. We have utilized department field engineers and other maintenance personnel in the collection of our input data for two important reasons:

1. The additional funds for the collection of field data by personnel outside the department were not available; and
2. Use of department personnel accomplished the desirable benefits of introducing our people to the idea of measuring maintenance quality and gave them initial training in inspection procedures which they will be involved with after the method is developed and put to use.

Roughometer readings were at first made by the consultant primarily as a control measure. The department has a regular full-time crew operating a BPR roughometer owned by the department. This crew and equipment was used to run the roughness on a 3,000-mile sample of highway for use in developing the new method.

When the necessary parameters and their relationships have been established by Tallamy, Byrd, Tallamy and MacDonald, a computer program will be established so that data can be processed on the department's IBM 360/50 computer system. Once each year a random selection of sample highway sections will be generated using these computer facilities. A "Recordable Condition," roughometer, and photographic survey will then be made on the sample sections. Data collected from these surveys will be processed by the computer and a determination made on the quality of maintenance on Ohio highways. By this means, a more consistent quality of maintenance will be possible throughout the state and a means will be available for deciding the types of maintenance activities to emphasize in order to maximize the utility of the maintenance investment.