THE ECONOMICS OF PREVENTIVE MAINTENANCE

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HOW MUCH PREVENTIVE MAINTENANCE?

How do we know when we have made the best possible use of the funds available for highway and street maintenance? Is it when we allocate 20 percent of the budget to preventive maintenance activities such as sealing asphalt surfaces and blading gravel shoulders? Is 20 percent enough, or is it too much? The answer, of course, is that we don't know. We have no basis of fact to supplement our judgments about the economics of asphalt sealing or shoulder work, or any other maintenance activity.

What Is Known

We do have some facts regarding revenues and costs. As illustrated in Figure 1, since 1972 there has been a downward trend in total highway receipts, and the trend applies not only to current dollars but to dollars adjusted by the consumer price index.

On the cost side of the picture (Figure 2), we know that maintenance costs have nearly doubled since 1965, and that construction costs are far outpacing the consumer price index. Both revenue and cost trends are expected to continue, in spite of the temporary stability in prices.

So far as physical maintenance is concerned, we know that some combination of maintenance activities will extend the useful life of a facility beyond the point we could expect if no maintenance were performed. Patching potholes and repairing edge failures add to the life span of any surface. The same surface, sealed or resealed on a regular basis, may last two or three times as many years as a similar surface that is not sealed.

We also know that maintenance is expensive, but it is not as costly as the price we have to pay to reconstruct a facility or to build a new one. Over a period of 25 years, for example, we may spend $40,000 to maintain a certain bridge—one that has a replacement cost which

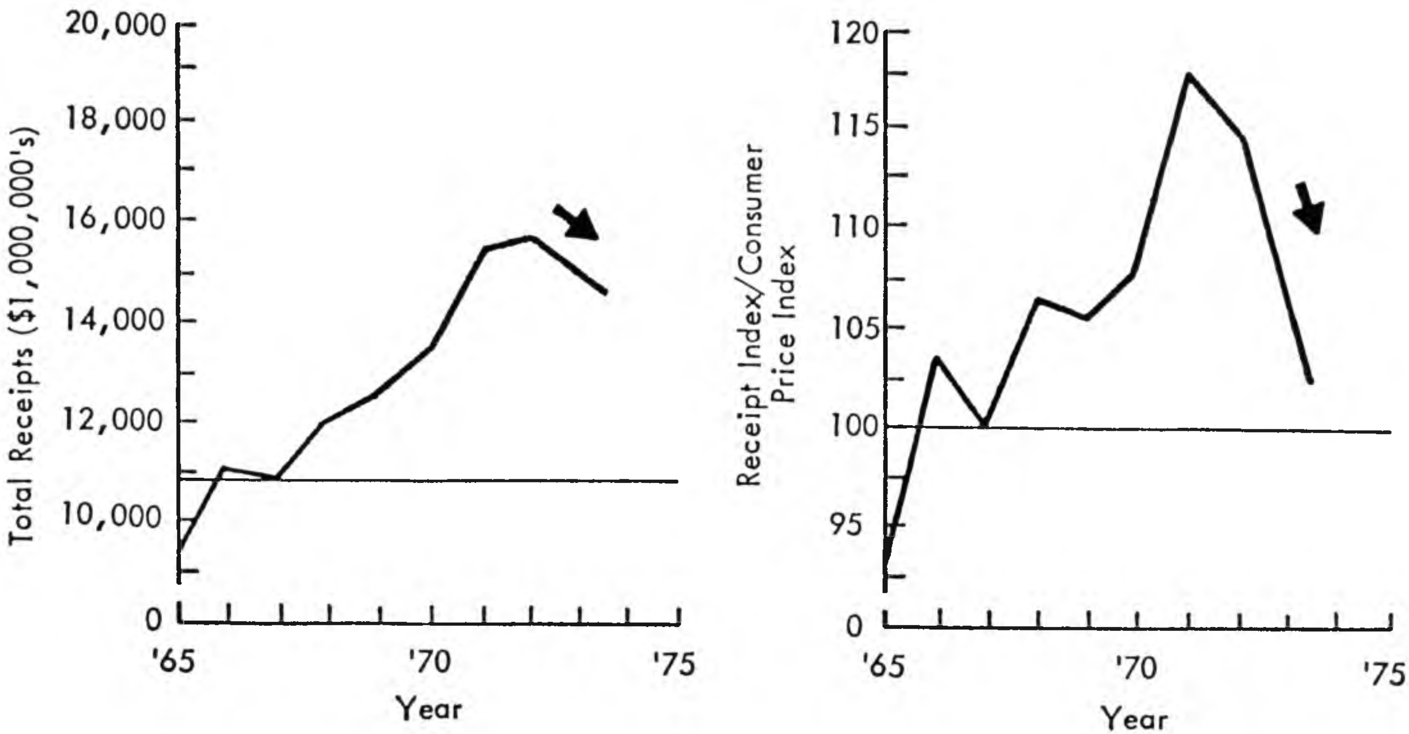

Figure 1. Trends in State Highway Receipts (From Highway Statistics, FHA, 1965-1974. Base Year is 1967)

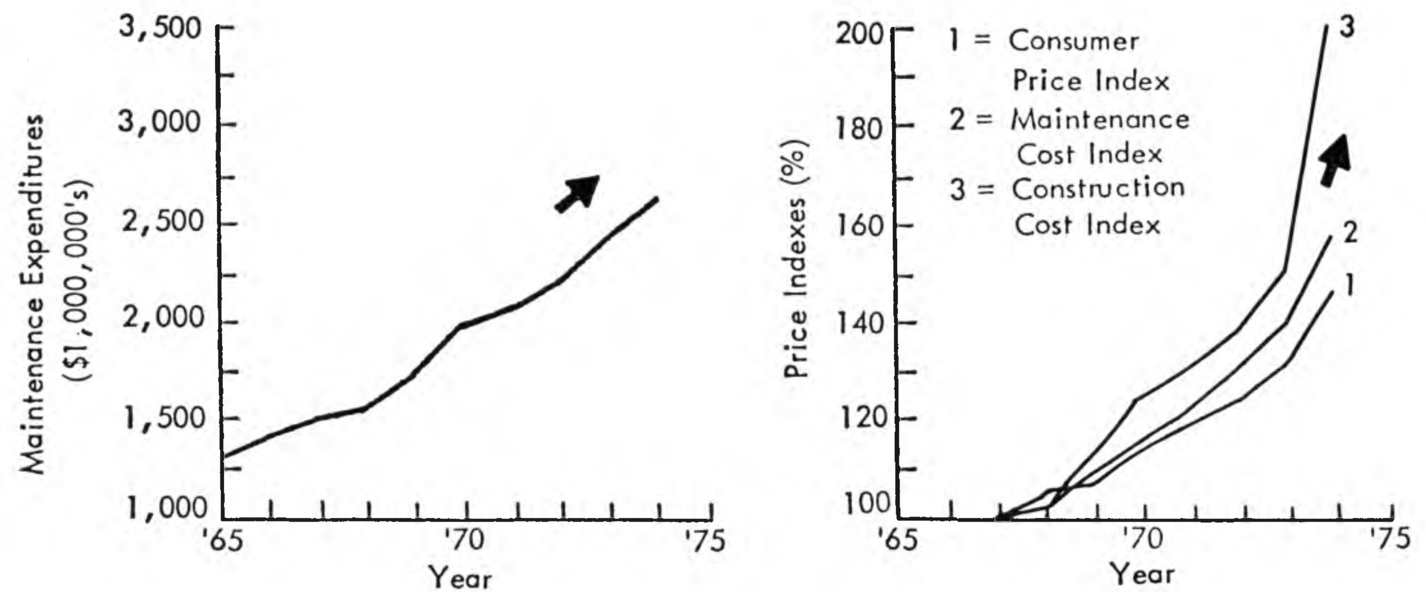

Figure 2. Trends in State Highway Maintenance Expenditures (From Highway Statistics, FHA, 1965-1974. Base Year is 1967)

is many times the cumulative maintenance expense. We use the same logic to justify preventive maintenance of other facilities: the total cost of a 25-year street maintenance program that includes preventive activities will be lower than the cost of a program that is limited to repair work. But we don't know how much lower.

The Need for Better Answers

Mathematical models have been used for some time to try to quantify the costs and savings associated with preventive maintenance. And several computer programs have been developed to calculate the theoretical payoffs of hypothetical maintenance strategies. A few state highway departments also have designed "pavement management systems." These systems usually involve comprehensive pavement ratings, extensive reporting of the work performed on each station or segment of the road network, and detailed cost analyses.

The mathematical models and the pavement management systems are generating considerable amounts of data, and some day they will provide better answers regarding the economics of preventive maintenance. The problem is that we need better answers today. We need to have facts concerning the way maintenance should be managed and the costs and benefits of performing individual activities.

MAINTENANCE MANAGEMENT SYSTEMS

Some of the facts can be supplied by existing maintenance management systems similar to the one implemented by the Indiana State Highway Commission. Figure 3 illustrates part of Indiana's system.

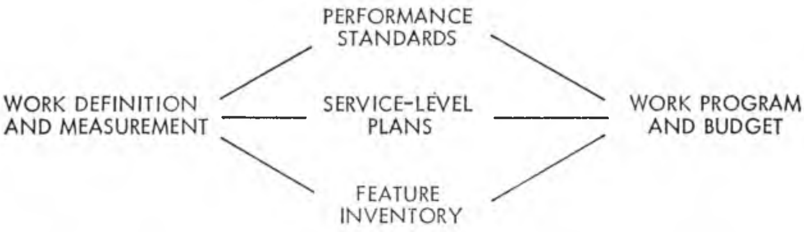

Figure 3. Selected Elements of the ISHC Maintenance Management System

The same basic elements have been applied to maintenance operations in many cities and counties. The design (or development) process is relatively simple.

Activities and Standards

The process starts with the work itself. Maintenance is defined in terms of activities and a unit of measure is established for each activity.

For example, asphalt sealing is described in specific terms and cubic yard or square yard or mile is used as the basis for measuring work and results.

Performance standards are developed, activity by activity. Each standard identifies: (1) performance criteria that describe the conditions under which work should be done, (2) a general work procedure and a listing of the resources to be used when performing the activity, and (3) the results expected, in terms of average daily production or productivity. Given a specific performance criteria and work procedure, the standard for asphalt sealing might indicate that ten men, four dump trucks, two rollers, a chip spreader, and a distributor should be able to seal an average of two miles per day.

Inventories and Service Levels

Physical inventories are taken of the facilities being maintained. The inventories define the nature and scope of maintenance responsibilities by geographical area or district.

At this point, an initial service level is established for each activity and applied to the appropriate inventory value. For example, for asphalt sealing the initial service level might be a five-year frequency—an annual rate of 0.2 mile per mile of highway or street. This frequency, when applied to an appropriate inventory value of say 250 miles, defines the annual amount of sealing to be done: 0.2×250, or 50 miles.

Can the five-year frequency be justified on economic grounds? It depends on the facts we had when the frequency was set. For the time being, we will assume that it represents our best judgment as to the amount of preventive maintenance it will take to extend the useful life of the surface.

Work Programs and Budgets

The 50 miles of sealing to be done are put in terms of the number of days it will take to complete the work. The total quantity divided by the average daily production from the performance standards provides the answer: $50 \div 2 = 25$. The total cost of the work is calculated by multiplying the number of days of work by the cost per day, based on the standard complement of manpower, equipment, and materials. In this example, a daily cost of $4,100 translates into an annual cost of $102,500, for 50 miles (and 25 days) of asphalt sealing.

The same kinds of calculations are made for essentially all other activities, to develop a work program and budget similar to that illustrated in Figure 4.

FORM NO. 601	WORK PROGRAM AND BUDGET		YEAR FY 1976	WORK MANAGEMENT SYSTEM CITY OF PROGRESS							MANAGEMENT UNIT STREET MAINT	CLASS MAJ ST FND	PAGE 1	DATE PREPARED 11-17-75
ACTIVITY NO.	ACTIVITY NAME	INVENTORY MEASURE	INV UNITS	ANNUAL QTY PER INVENTORY UNIT	UNIT OF MEASURE	ANNUAL WORK QUANT	AVERAGE DAILY PROD	NO. OF CREW DAYS	STD CREW SIZE	TOTAL MAN DAYS	COST DISTRIBUTION LABOR	EQUIPMENT	MATERIAL	TOTAL DOLLARS REQUIRED
101	POTHOLE PATCHING	PAVED 2LM	277	2.00	TONS	554	3.0	185	5	925	42,920	9,250	8,695	60,865
102	BUMP REPAIR	RIGID BASE2LM	238	14.00	SQ FT	3332	100.0	33	6	198	8,844	7,194	1,683	17,721
103	REMOVE/REPL RIGD PVT	RIGID BASE2LM	238	5.00	LIN FT	1190	175.0	7	7	49	2,240	2,408	31,990	36,638
104	RESURFACING	RESURFACED LM	20	440.00	TONS	8800	250.0	35	20	700	30,275	21,980	143,500	195,755
105	ASPHALT SEALING	SURF TRT MI	250	0.20	MILES	50	2.0	25	10	250	7,500	7,500	87,500	102,500
201	STREET FLUSHING	STREET MILE	146	14.00	ST MILE	2044	15.0	136	1	136	6,120	7,888	0	14,008
202	CURB SWEEPING	CURB MILE	275	14.00	CURB MI	3850	30.0	128	3	384	17,408	34,304	0	51,712
203	REPLACE CURB & GUTTER	CURB MILE	275	21.80	LIN FT	5995	60.0	100	6	600	27,600	16,100	8,800	52,500
204	LEAF PICKUP	CURB MILE	275	1.00	CURB MI	275	10.0	28	3	84	5,096	3,920	0	9,016
402	LITTER PICKUP	STREET MILE	146	24.00	PASS MI	3504	12.5	280	3	840	36,400	8,120	0	44,520
501	DITCH CLEANOUT	STATION DITCH	687	.20	STATION	137	25.0	5	9	45	1,980	1,220	0	3,200
502	MECH CLEAN INLET	STORM INLET	6000	1.50	INLET	9000	25.0	360	2	720	31,680	46,440	0	78,120
503	MANUAL CLEAN INLET	STORM INLET	6000	.04	INLET	240	10.0	24	2	48	2,112	384	120	2,616
504	REPAIR INLETS	STORM INLET	6000	.02	INLET	120	2.0	60	6	360	16,560	11,220	4,920	32,700
505	CLEAN STM SEWER MAIN	MILE STM SWR	93	158.40	LIN FT	14731	75.0	196	3	588	30,380	31,752	0	62,132
601	ERECT/REPAIR GDRAIL	STA GUARDRAIL	123	4.00	LIN FT	492	75.0	7	5	35	1,624	1,316	2,457	5,397
701	SCRAPE/PLOW STREETS	ROUTE MILE	277	20.00	PASS MI	5540	27.0	205	1	205	8,815	16,810	0	25,625
702	SALTING STREETS	ROUTE MILE	277	27.00	TON SALT	7479	15.0	499	1	499	24,950	37,425	112,275	174,650
703	SNOW REMOVAL-BRIDGES	STRUCTURES	49	28.00	CU YDS	1372	100.0	14	7	98	4,480	2,604	0	7,084
704	SNOW REMOVAL-STREETS	12IN SNOWSTRM	4	600.00	CU YDS	2400	600.0	4	23	92	4,100	1,920	0	6,020
709	OTHER WINTER MAINT	ROUTE MILE	277	2.00	MANHOURS	554	16.0	35	2	70	3,080	1,680	2,345	7,105
801	BRIDGE DECK REPAIR	STRUCTURES	49	16.00	MANHOURS	784	40.0	20	5	100	4,640	3,980	620	9,240
802	BRIDGE RAILING MAINT	STRUCTURES	49	1.00	LIN FT	49	5.0	10	4	40	1,880	570	200	2,650
109	OTHER ROUTINE MAINT	STREET MILE	146	10.00	MANHOURS	1460	24.0	61	3	183	9,699	5,490	7,442	22,631
901	OVERHEAD-SUPERVISION	NO. SUPT'S	3	1400.00	MANHOURS	4200	8.0	525	1	525	51,975	6,825	0	58,800
902	OVERHEAD-CLERICAL	NO. CLERKS	1	1400.00	MANHOURS	1400	8.0	175	1	175	6,825	0	700	7,525
903	OVHD-LEAVE/HOLIDAY	NO. MEN	70	400.00	MANHOURS	28000	8.0	3500	1	3500	154,000	0	0	154,000
	TOTAL REQUIREMENTS							6657		11449	543,183	288,300	413,247	1,244,730
	MAN DAYS DISTRIBUTION REG. DAYS		6999											
				OVERTIME HOURS		33768								

Figure 4. Typical Work Program and Budget

The work program and budget can be recalculated to provide indications of the relationships between service levels and costs: a sealing frequency of once every five years will cost $102,500; once every four years will cost $128,125; once every ten years will cost $51,250; and so on. And the mix of activities can be justified to reflect analyses of the costs and benefits associated with each activity.

PREVENTIVE MAINTENANCE: COSTS AND BENEFITS

Analyses of the costs and benefits of work is a logical extension of the system framework outlined above. The real issue, of course, is whether or not the benefits of a preventive maintenance activity justify the cost. In the sealing example, our best judgment indicated that a five-year frequency provides optimum benefit. But that may not be true.

In the diagram in Figure 5, we may be operating at point "C"—a point at which the benefits are marginal in relation to the costs. The same analysis applies to other activities: as the amount of work efforts (and costs) increase the benefits increase—point "A" in the diagram. But when point "B" is reached, any additional work efforts will add more to the total costs than to the benefits.

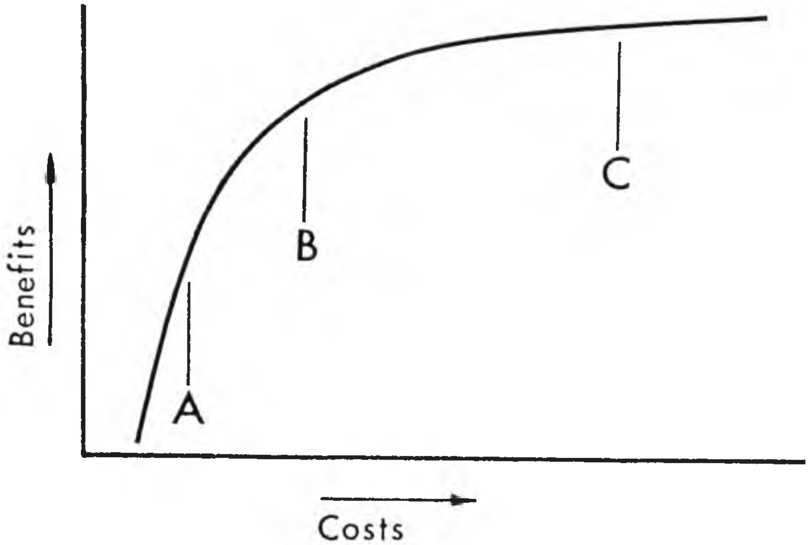

Figure 5. Typical Cost-Benefit Curve

Demonstration Laboratory

The problem is to find point "B" for each maintenance activity. One approach is to establish a physical "demonstration area" in which maintenance is performed under controlled conditions and observations and measurements are made regarding the costs and benefits of each major kind of work. The geographical area itself contains a small sample of all maintainable facilities. One or two parts of a maintenance district (or city or county) are satisfactory, so long as the total area is reasonably representative of all facilities.

Measuring Costs and Benefits

The cost side of the equation is relatively easy to establish. In most highway and street agencies, all that is needed is a simple modification of cost collection procedures, to make sure that the cost of work in the demonstration area is recorded properly.

Obtaining reasonable measurements of the benefits of each major activity is more difficult, but not overpowering. The approach that one agency will be using involves three broad steps:

1. *Criteria.* The traditional reasons for performing maintenance will be used as a basis for evaluating maintenance work in the demonstration area. Five factors are involved: traffic safety, preservation of investment, esthetics, public comfort, and user cost. The relative importance of each factor will be established by assigning numerical values, such as 0.9 for traffic safety and 0.7 for user cost.

2. *Facility Ratings.* Evaluations will be made of the levels of service being provided throughout the demonstration area. For some combinations of activities and facilities, such as roadside litter pickup, the ratings will be based on observations and judgments. For other combinations, such as asphalt sealing and reshaping shoulders, objective measurements will be used. Skid resistance, traffic accident counts, and surface-shoulder drop-off are good possibilities.

3. *Composite Scores.* The service-level evaluations will be applied to the values established for the various criteria, activity by activity. The result, a composite rating, will establish the general shape of the cost-benefit curve for each activity or category of activity.

The results of adopting certain service levels—by performing work at various frequencies and in various quantities—will be displayed in tabular form and in diagrams similar to the one in Figure 6. In this illustration, the optimum frequency for shoulder reshaping (point "B") is about two times per year. This work performed once a year results in a relatively low rating, and once-a-month performance results in a rating that is very little above that for a semi-annual frequency.

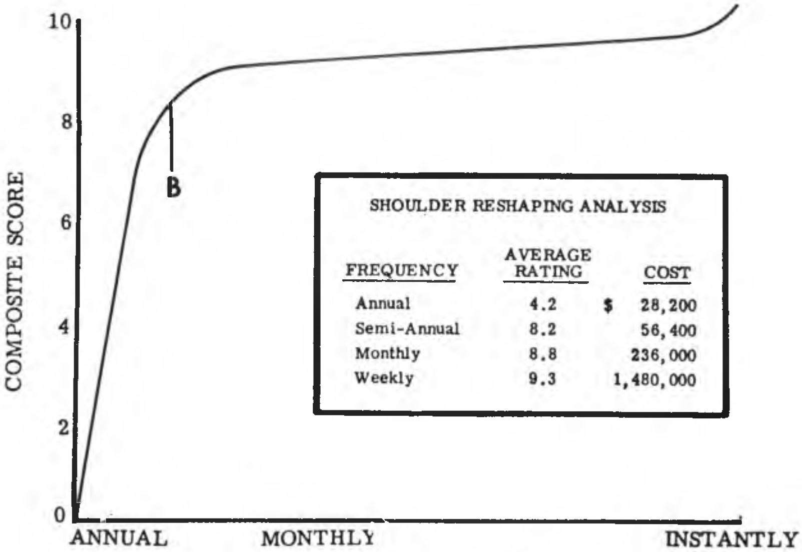

Figure 6. Typical Cost-Benefit Display

The next logical step, and one of the main reasons for using this process, is to identify the trade-offs between preventive maintenance and repair-rehabilitation work. Theoretically, the total cost of a maintenance work program will be minimized when the cost of preventive maintenance equals the cost of repair-rehabilitation work. As a practical matter, the distinction between the two kinds of work frequently is too fuzzy to achieve a perfect balance. But the end result will still be useful, partly because optimum service levels are being identified activity by activity, and partly because the nature of maintenance is such that a perfect balance would occur only by coincidence.

FURTHER THOUGHTS AND CONCLUSIONS

The demonstration-area approach to establishing measurements of maintenance costs and benefits is somewhat unique:

- It provides a comparatively simple way of evaluating the economics of work. There are no complex mathematics or voluminous records needed to obtain reasonably accurate data—a real plus for most county and local agencies.
- Simple ratings, instead of theoretical dollar values, are used to identify the benefits of various service levels.

- The process avoids the degree of perfection and expense associated with computerized models and comprehensive pavement management systems.
- For many highway and street agencies, the process is a simple extension of their maintenance management systems.

Within a year or so, research now getting underway will begin providing the facts needed to supplement the judgments being made about the economics of several preventive maintenance activities. By the time the next budget has to be prepared, reasonable service-level ranges will be identified for 80 to 90 percent of the workload. And, for some activities such as reshaping gravel shoulders and litter pickup, the range will be quite narrow.

Comparable research, already performed on a smaller scale, also suggests that within two to three years the economics of all but a few activities will be identified, at least in one agency. Additional time will be required to narrow the service level ranges for some kinds of work, including major rehabilitation and overlays.

We are convinced that almost any kind of preventive maintenance extends the useful life of highway and street facilities, and we know that, in an indirect manner, a demonstration area will help answer questions about the economics of specific service levels. When these questions are answered, so are the questions as to how well we are using the funds available for highway and street maintenance.