Bus Maintenance Performance Indicators: Historical Development and Current Practice

GEORGE LIST AND MARK LOWEN

Choosing the right performance indicators to control the quality of vehicle maintenance has been and continues to be a problem of concern to the transit industry. Transit operators today see increasing pressure to obtain greater use from their existing equipment, a goal that can only be achieved by closer attention to the maintenance function. The purpose of this paper is to report the results of a recent survey sponsored by American Public Transit Association (APTA) regarding bus maintenance performance indicators and to compare those results with other surveys and related projects that have been conducted in the past. Generally, the survey shows clear points of agreement among the maintenance managers. Roadcalls are the predominant initial point of focus, followed by a search for cause (e.g., drivetrain performance) and a monitoring of costs, labor, and vehicle condition (i.e., inspections). Individual indicators ranking high on the list include miles per gallon, miles per quart of oil, miles per roadcall, periodic roadcalls, maintenance cost per mile and repeat work. There are differences of opinion, however, as shown by the list of 656 free form indicators submitted and ranked by the respondents. Compared to other lists of indicators, the survey shows close similarities with those developed recently, and marked differences with those developed some 30 years ago by the APTA [then known as the American Transit Association (ATA)]. Among the recent surveys, all show roadcalls to be of primary importance along with costs, labor productivity, and quality control (through inspection programs). Compared to the indicators developed by the ATA, there is still a clear overlap, but the indicators deemed important then do not rank in the top 10 today.

The transit industry has been working earnestly in recent years to improve the quality of its bus maintenance. Among all the issues being addressed, the monitoring problem has been of particular concern. It is especially important now because of cutbacks in federal support for the acquisition of new buses and belt tightening by state and local governments. Transit operators see increasing pressure to obtain greater use from their existing equipment—a goal that can only be achieved by closer attention to the maintenance function.

In this paper, the results of a recent survey [sponsored by the American Public Transit Association (APTA)] designed to identify the bus maintenance performance indicators in current use are presented, and these results are compared with other surveys and related projects that have been conducted in the past.

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TRANSIT PARS

The search for bus maintenance performance indicators stretches back at least 35 years to 1951, when at the annual meeting of the American Transit Association (now the APTA), a panel of association operating company executives presented a proposal to establish a set of transit pars, measures of industry performance intended to help management test the adequacy of revenues and the efficiency of their enterprises *(1)*.

Based on meetings, correspondence, and special conferences, the committee's 1952 report identified two types of measures; the first type was revenue based, such as the percentage of operating revenues devoted to maintenance, repair, and servicing; the second type was to be supporting yardsticks, ratios of one operating statistic to another, intended to guide managers in pinpointing the reason for good or bad par performance. As the 1952 report indicated:

> [The supporting yardsticks] are special types of ratios based, in almost every case, on statistics other than revenue. In the opinion of the Committee, the principal purpose of such supplementary ratios [is] to provide management and department heads with additional criteria: For judging the efficiency of operation; to assist in pinpointing sources of trouble in phases of the overall operation which may need special attention; provide an answer to the basic question of whether revenue is too low or expenses too high; and possibly for other specific purposes that may develop in the use of pars (*1*, p. 6).

Although the committee could see that the spectrum of possible yardsticks was virtually unbounded, it restricted itself to measures that would be helpful in a limited number of situations, such as testing the efficiency of the organization responsible for maintaining the vehicles (*1*, p. 7).

SUPPORTING YARDSTICKS

Development of a mature set of supporting yardsticks for maintenance as well as purchases and stores spanned 6 years from 1951 to 1957. The 1952 report of the Transit Pars Committee mentioned five yardsticks pertaining to maintenance (*1*, p. 6):

- Number of thousands of seat-miles operated per vehicle failure;
- Number of seat-miles operated per maintenance personnel work-hour;
- Number of maintenance workers per maintenance executive, administrative, and supervisory personnel;
- Number of maintenance workers per purchases and stores personnel; and
- Number of all transportation maintenance workers to general office workers.

> But when the subject of transit pars and supporting yardsticks was advanced to the regional session of the Mechanical Division in Washington, D.C. in May of 1953, considerable resistance was encountered among the superintendents of equipment there present. There was an apparent reluctance to enter into this activity, which some members present considered a tool of management with which to harass the mechanical departments; a dubious one not based upon fair measures of mechanical department activities and processes (2, Appendix A, p. 1).

A few of the people present felt cooperation was better than resistance, and because of this a Committee on Supporting Yardsticks within the Mechanical Division was appointed for 1953–1954. The 1953 Report of the Committee on Transit Pars indicated the following (*3*, p. 4):

> The Committee does not consider it advisable at this time to submit any. . . .ratio. . . .as [a] recommended. . . 'yardstick' or to develop a critical value for such [a] 'yardstick'. Certain of the ratios discussed, as for example investment-to-revenue and maintenance man-hours per 1,000 vehicle miles, are regarded as useful criteria by many members of the Committee; but there were too many unresolved questions concerning both the definition of terms and what the critical value of each ratio should be to permit unified Committee action on any of the yardsticks considered.

However, during the years 1954 to 1957 a consensus emerged. The 1954 report (*4*, p. 14) cites three important measures: maintenance wages per pay-hour, maintenance pay-hours per 1,000 veh-mi, and maintenance pay-hours per scheduled vehicle. A fourth, pay-hours of maintenance personnel to vehicle-hours, is listed as being discontinued because it lacked significance in comparison to maintenance pay-hours per 1,000 veh-mi. Additionally, eight other indicators were cited as being potentially useful: the proper amount of normal inventory and the use of materials in maintenance (for purchases and stores); hours of direct labor per vehicle-mile, a servicing efficiency measure, time standards, expected component lifetimes, a reasonable bad-order ratio for mechanical division purposes, and separate indicators for nonvehiclar maintenance activities (e.g., buildings, track, and catenary). In 1955, the pars report listed the first approved yardsticks.

Yardsticks for maintenance (2, Appendix A, p. 3) were as follows:

- 1.0 man-hr per bus-day for servicing labor; and
- 18.0 equivalent man-hr per 1,000 veh-mi for maintenance, repair, and overhaul (MR&O), including repairs to damaged vehicles. (Contract work was converted to man-hours using 1 man-hr for every $5.00 of contract work.)

Yardsticks for stores (2, p. 6) were as follows:

- 60 man-hr per bus-year for administrative personnel; and
- $425 of inventory per bus.

By 1956 *(5)*, the figure of 1.0 man-hr per bus-day was adjusted downward to 0.90 and the figure of 18.0 equivalent man-hours per 1,000 veh-mi for MR&O was adjusted upward to 18.5. Further, two new tentative maintenance yardsticks were established:

- 2.8 maintenance department supervisory and clerical man-hours per 1,000 bus-mi; and
- 30.0 total supervisory, clerical, servicing, and equivalent MR&O man-hours per 1,000 bus-mi.

Also, yardsticks for purchases and stores were as follows:

- 50 man-hr per bus-year for purchases and stores administrative labor (instead of 60);
- $325 in inventory per bus owned; and
- An annual inventory turnover ratio of 2.0.

As given in the following list, the 1957 report *(6)* summarized the performance indicators from the transit pars and presented further adjustments to the yardstick values.

- Motor bus maintenance

  0.90 man-hr per bus-day for servicing;
  18.5 equivalent MR&O man-hr ($5.00/hr for contract work) per 1,000 veh-mi;
  2.65 man-hr of supervisory and clerical labor per 1,000 veh-mi;
  30.0 equivalent man-hr, overall, per 1,000 veh-mi; and
  A spares ratio of 6 percent.

- Purchasing and stores

  50.0 purchasing and stores administrative man-hours per bus;
  $325 inventory per bus;
  2.50 annual turnover rate (tentative); and
  $19.50 of materials disbursed per 1,000 veh-mi (tentative).

MORE RECENT LISTS

More recently, other lists have been developed. Section 15 is one example *(7, 8)*; the recent survey by Maze *(9)* is another; and the APTA-based survey presented here is a third. Lists have also been developed by various analysts such as Hauser *(10)*, Fowler *(11)*, and Foerster et al. *(12–15)*.

To review briefly, the present Section 15 database *(7)* includes three maintenance-related indicators: vehicle-miles per maintenance dollar, vehicle-miles per roadcall, and revenue vehicles per maintenance employee. Although the statistics themselves have been criticized as unreliable *(16)*, so far no one has decided that they should be eliminated. Recently, these indicators have been under careful review, and a new group of indicators presented in the following list has been proposed for the Section 15 database *(8)*. They include measures of mechanic labor hours and maintenance performance in addition to an improved set of roadcall measures.

- Roadcalls (may be broken down based on effect: service disruption versus no service disruption)

  Maintenance-related,
  Other mechanical, and
  Nonmechanical.

- Mechanics' labor-hours worked in inspection, maintenance, and repair

  Hours devoted to revenue vehicle inspection and maintenance, and
  Hours devoted to accident or vandalism repairs to vehicles.

- Maintenance performance

  Average weekday vehicles available for peak service
  Average weekday spare vehicles available for peak service
  Average weekday vehicles out of service for maintenance
  Quarts of oil added between normal oil changes
  Average engine life to first overhaul
  PM inspections performed on schedule (±1,000 mi)
  PM inspections more than 1,000 mi late

- Externalities affecting maintenance

  Vehicle-miles on city streets;
  Vehicle-miles on highway and freeways;
  Existence of facilities for heavy repairs (yes/no);
  Existence of facilities for major component rebuilds (yes/no);
  Peak vehicles equipped with lifts;
  Peak vehicles with air conditioning;
  Local terrain (flat, hilly, mixture); and
  Local climate (hot, cold, severe weather).

Maze *(9)* distributed questionnaires containing the following list of performance indicators to 120 transit properties:

Maze (9)

Miles per roadcall
Regular and overtime labor-hours per month
Repeat repairs per month
Repeat breakdowns per month
Cost per vehicle-mile
Cost per vehicle
Roadcalls per vehicle per month
PM inspections scheduled versus performed (per week)
Percent of PM inspections performed within a prescribed interval
Labor cost per vehicle-mile
Fuel and oil cost per bus (by bus model)
Material cost per vehicle-mile
Average age of the major components in each bus
Number of open maintenance work work orders
Labor hours per PM inspection (by type of inspection)
Labor-hours per repair
Percent of maintenance work identified during inspections
Average mileage overage for overdue inspections
Labor cost per bus (by bus model)
Stockouts per month
PM labor-hours as a percent of total labor-hours
Cost per bus-mile (by bus model)
Labor-hours required to complete the maintenance backlog
Value of the parts inventory
Parts cost per bus (by bus model)
Maintenance jobs in the backlog
Work orders per bus (by bus model)
Miles per bus (by bus model)
Actual labor hours to complete closed work orders versus total labor-hours
Average time per open work order
Parts cost per month versus the value of the parts inventory
Labor cost versus material cost
Labor hours backlogged
Actual versus standard hours for work performed
Value of the parts inventory (by bus subsystem)
Parts room overhead cost versus value of inventory

Hauser (10)

Cost per mile
Percent runs missed
Miles between roadcalls
Breakdown of maintenance staff by category (percentages and ratios)
Coaches per mechanic
Coaches per fueler, cleaner, hosteler, utilityman, and tireman
Coaches per garage
Hoists and pits per 100 coaches
Square feet of garage per coach
Distribution of garage workspace
Service stalls per 100 coaches
Square feet per work stall
Hoists and pits per 100 coaches
Dollars of inventory per coach in the active fleet
Spares ratio
Miles per bus
Average age of the fleet

Fowler (11)

Total mechanical roadcalls
Miles between roadcalls
Roadcalls broken down by category
Number of nontraceable problems
Labor cost per mile
Parts cost per mile
Total cost per mile without fuel or lubricants
Total cost per mile with fuel and lubricants
Costs (labor, parts, total, per mile) by component
Buses being repaired (by garage)
Buses awaiting repair (by garage)
Buses awaiting parts (by garage)
Assigned labor hours
Straight versus overtime labor hours
Labor hours worked (from repair orders)
Labor hours assigned per 1,000 bus-mi
Labor hours paid per 1,000 bus-mi

Labor-hours worked per 1,000 bus-mi
Buses out of service due to maintenance (by cause)
Catch-up maintenance man-hours
Inspections due (by category)
Inspections accomplished (by category)
Inspections overdue
Lapse time and labor-hours per inspection (by category)
Materials/parts cost per inspection (by category)
Inspection labor cost (by category)
Cost of the preventive maintenance program
Tire mileage (new, used, by size)
Damaged tires

The managers were asked to score the indicators on a scale from worthless to vital. Also, they were asked to score each indicator's value to top management as opposed to the maintenance manager. Ninety-two of the questionnaires were returned. Miles per roadcall scored as the most valuable performance indicator; total regular and overtime maintenance labor-hours per month ranked second; the number of repeat repairs in the same month ranked third; and the number of repeat breakdowns in the same month ranked fourth. However, the rankings of these indicators were 4.33, 4.25, 4.25, and 4.25 out of 5 respectively, so it is difficult to say how meaningful the rankings were. As Maze *(9)* indicates:

> Our findings on desirability of various performance indicators are very mixed. It seems those most favored are those most commonly kept (e.g., miles per road call, maintenance cost per mile, etc.). Other indicators which are considered vital by some maintenance managers are considered worthless by others (*9*, cover letter).

In addition, Maze reports that only 8 of the 36 indicators were considered worthwhile by everyone. The eight were miles per roadcall, regular and overtime maintenance labor-hours per month, number of repeat repairs in the same month, maintenance cost per vehicle-mile, maintenance cost per vehicle, roadcalls per vehicle per month, maintenance labor cost per vehicle-mile, and average fuel and oil cost per bus model versus the total fleet. All 8 ranked in the top 11 indicators. The respondents also suggested some 35 other performance indicators, suggesting that perhaps some useful measures had been omitted.

There have been further lists developed by analysts for the purpose of conducting various investigations. Hauser's *(10)* list was based on the supporting yardsticks discussed previously to describe what a successful maintenance operation should be. His list reflects a heavy emphasis on work quality, costs, physical resource capacity utilization, and labor utilization and distribution.

Fowler *(11)* believed his list of data items should be included in a maintenance management information system. Although this is not a list of indicators per se, it does give a clear picture of what a maintenance manager needs to know in order to manage effectively. The list includes measures of overall bus performance, labor utilization, deferred maintenance, costs, roadcalls, preventive maintenance, and tire performance. For example, the roadcall indicators include total mechanical roadcalls per unit time, miles between mechanical roadcalls, a breakdown of roadcalls by cause, and the number of nontraceable problems.

Foerster et al. *(12–15)* developed a list of performance indicators based on a series of bus maintenance management case studies. In one of the case studies *(13)*, the general superintendent of maintenance and the special projects administrator said (*13*, p. 14):

> The maintenance division uses the following performance indicators:
>
> Roadcalls per week,
> Average miles per roadcall,
> Missed runs per week,
> Number of late outs,
> Number of buses out of service, and
> Spare ratio.
>
> In addition, maintenance cost per mile is used during the budget process, although it is not one of the indicators used on a regular basis. They look for trends in the indicators; for some they have limits they try to adhere to. According to the general superintendent, the most important indicators are those concerned with roadcalls, particularly average miles per roadcall.

Between this and two other case studies *(14, 15)* presented in Table 1, 15 performance indicators were cited. They included roadcalls (per week, per month, and per mile), cost measures (per mile, per hour, and budget adherence), vehicle component performance (especially, fuel and oil consumption), overall bus performance (out-of-service buses, spares ratio, missed runs, late outs, availability, general bus appearance), and labor (in this case, buses per maintenance employee).

THE 1985 APTA SURVEY

In July 1985, the American Public Transit Association's (APTA's) Bus Maintenance Management Subcommittee elected to conduct its own survey of maintenance managers to determine what indicators they used to monitor maintenance performance and what skills they considered most important for first-line maintenance managers *(17)*. Each respondent was asked to answer four questions using the form shown in Figure 1: (a) list the 10 most important performance indicators you use to monitor maintenance performance; (b) describe the characteristics of your transit system in terms of average road speed, frequency of stops, ambient temperature, and five other criteria; (c) list the five most important skills your first-line supervisors need to do their job effectively; and (d) provide a breakdown of your fleet based on size (the percentage of buses under 35 ft long, 35 to 40 ft long, and articulated).

Responses

One hundred two properties submitted responses, of which 100 are included in this analysis. These represent a diversity of system types ranging from those where all buses are under 35 ft long to others where over 25 percent of the fleet is articulated. They encompass approximately 32,000 buses or 50 percent of all North American transit buses, with fleets ranging from small (under 50) to large (over 4,000). They are located primarily in the United States with a few from Canada and one from Guam.

TABLE 1 PERFORMANCE INDICATORS FROM THREE CASE STUDIES *(13–15)*

Indicator	CENTRO Syracuse, NY			Gary Public Trans. Corp		Spokane Trans. Auth.		
	G-M	AGM	M-M	G-S	H-M	DTO	S-M	LDM
Roadcalls per week or month	x	1	1	1	1	x	1	2
Cost per mile	x	2	3		3	1	3	x
Fuel and oil consumption						3		1
Appearance of the bus	1							
Out-of-service buses (% of fleet)	x		x			x	2	x
Spares (% of fleet)		3	x		2			x
Cost per hour						2		
Oil consumption				2				
Availability of buses	2							
Budget Adherence	3		x					
Fuel consumption				3				
Missed runs per week or month	x					x	x	
Late outs	x	x	x					
Buses per maintenance employee				x	x			x
Roadcalls per mile			x				x	

Key

G-M:	General Manager	1:	most important
AGM:	Assistant General Manager	2:	second most important
M-M:	Maintenance Manager	3:	third most important

Standardized Indicators

Rather than asking the respondents to rank a number of possible indicators, the committee believed it would be better to let the respondents create their own entries, hoping to eliminate any biases that might be generated by including some indicators and potentially omitting others. The committee recognized that this meant the responses would all be in free format, making it difficult to mechanize the summary process without some form of interpretation and categorization. But the benefits of having direct input were felt to outweigh the costs of interpreting the responses.

Once the responses were received, it was evident that the categorization process would be quite straightforward. Only the 126 indicators presented in the following list were required to capture all of the entries cited in the survey responses. They fall naturally into several groups: cost, factors of production (as related to the maintenance function), maintenance activities, interface with operations, and miscellaneous. For the first three, subcategories help to add additional clarity (i.e., for types of costs, factors of production, and types of maintenance activities, respectively).

COSTS

Operating
- Overall
  - Budget performance — BDG PERF
  - Maintenance cost per bus — M $/B
  - Maintenance cost per mile — M $/MI
  - Management cost per mile — MGMT $/MI
  - Mechanical operating costs per mile — MC OP $/MI
  - Periodic costs (unspecified) — PER $
  - Periodic costs for corrective maint. — PER $ CORR

Periodic costs for prevent. maint.	PER $ PM
Repair costs	REP $
Labor Costs	
Actual time versus pay time	ACT T/PD T
Direct vs. indirect vs. paid time	DIR/IND/PD
Pay time versus reported time	PD T/RP T
Periodic labor costs	PER L $
Workmens compensation claims filed	WKMN COMP
Parts Cost	
Parts cost per mile	PRT $/MI
Periodic material costs	PER MT $
Periodic value of inventory	PER $ IV
Tire cost per mile	TIRE $/MI
Value of inventory per active fleet	$ IV/B
Warranty Billing	WARR BILL
Capital Investments	
Average age of fleet	FL AGE
Number of bays per fleet size	# BY/FL
Size of spare fleet to total fleet	S FL/TO FL
FACTORS OF PRODUCTION	
Labor	
Absenteeism	ABSENT

AMERICAN PUBLIC TRANSIT ASSOCIATION
MAINTENANCE PERFORMANCE INDICATORS SURVEY 20
Maintenance Management Subcommittee
Bus Equipment and Maintenance Committee

11-4

I. What are the most important performance indicators you use to monitor maintenance performance? You can list up to ten; please list them in order, from most to least important.

most important
(1) Miles between Road Call
(2) Repeat Road Call
(3) Percentage of P.M.'s completed
(4) Miles Per gallon - Fuel
(5) Miles Per Quart - Oil
(6) Mfg's Component Rebuild Hours
(7) Q.A. Program
(8)
(9)
least important (10)

II. Please mark the appropriate box that best describes your transit system:

(1)	Average Road Speed	__ under 20 MPH	/ 20-40 MPH	__ over 40 MPH
(2)	Frequency of Stops	/ under 6/mile	__ 6-10 Miles	__ over 10 Miles
(3)	Average Ambient Temperature	__ under 70°F	/ 70-90°F	__ over 90°F
(4)	Terrain	/ flat	__few grades	__ many grades
(5)	Road Surface Condition	/ smooth	__few potholes	__many potholes
(6)	Street Litter Condition	__ light	__moderate	/ heavy
(7)	Air-conditioned Buses % of Fleet	__ under 25%	__25-75%	/ over 75%
(8)	Buses Over 10 Years Old - % of Fleet	__ under 25%	/25-75%	__ over 75%

III. What do you see as being the most important skills your first line supervisors need to do their job better?

(1) Extensive Bus Maintenance Experience
(2) Ability to communicate
(3)
(4)
(5)

IV. Please indicate the % of your fleet in the following bus lengths:

Under 35 feet 0 %
35-40 feet 100 %
Articulated 0 %

Please return no later than November 15, 1985 to:

John J. Schiavone
Manager-Bus Technology
American Public Transit Association
1225 Connecticut Avenue, N.W.
Washington, D.C. 20036

FIGURE 1 Survey form.

Adequate supervision	OK SUP
Labor accountability	L ACCOUNT
Maintenance labor time per mile	M L T/MI
Morale of mechanics	MCH MORALE
Number of buses per maint. worker	# B/M W
Number of buses per maint. sup. pers.	# B/SP P
Number of buses per maint. svc. pers.	# B/SV P
Number of buses per mechanic	# B/MCH
Number of maint. workers per mile	# M W/MI
Ratio of overtime to total time	OT T/TO T
Time allocation	T ALLOCAT
Time guide	T GUIDE
Total labor time	TO L T
Total overtime required	OV
Training of shop personnel	TRG SHP P
Training of supervisory personnel	TRG SUP P
Work force alignment	WF ALIGN
Vehicle Fleet	
Average availability	AVG AV
Average avail. as percent of demand	AVG AV/DEM
Historical data by bus or bus type	HIS DATA/B
Number of days down per bus	# DY DN/B
Number of down buses	# DN B
Number of repeat fail. by bus type	# RPT/TYPE
Total down time	TO DN T
Spare Parts	
Inventory turnover rate	IV TURN
Number of stockouts	STOCK
Parts availability	PRT AV
Scrap bin	SCRAP BIN
Vehicle Components	
Drive Train	
Engine life	ENG LF
Fluid consumption (unspecified)	FLU CNS
Fuel consumption	MPG
Oil analysis	OIL ANAL
Oil consumption	MPQ OIL
Transmission fluid consumption	MPQ TRAN
Transmission life	TRAN LF
Other Components	
Air conditioner availability	A-C AV
Brake life	BR LF
Lift failure	LIFT FAIL
Miles per brake reline	MI/BR REP
Tire life	TIRE LF
Wheelchair reliability	WLCHR REL
General	
Component life (unspecified)	PRT LF
Failure trends	FAIL TREND
Miles on changed-out components	MI C-O PRT
Miles on rebuilt components	MI REB PRT
Part reliability	PRT RELIAB
Periodic defects reported	PER DEF RP
Shop Facilities	
Cleanliness of shop	SHP CLN
Lift availability	LIFT AV

MAINTENANCE ACTIVITIES

General	
Adequate safety programs	OK SAFE
Comp. with other transit agencies	AGENCY COM
Gen. qual. of maint. work	GEN QUAL W
Production	PROD
Repeat work	RPT W
Scheduled/unscheduled work	SCH/USCH W
Shop retention time	SHP RET T
Work done on time	W DONE O/T
Work order comparison	W ORD COM
Work volume through shop	W THRU SHP
Roadcalls	
Miles per failure	MI/FAIL
Miles per mechanical roadcall	MI/RC MC
Miles per nonmechanical roadcall	MI/RC NMC
Miles per repeat roadcall	RPT RC
Miles per roadcall (unspecified)	MI/RC TL
Miles per tow-in	MI/TOW IN
Miles per service interruption	MI SV INT
Mechanical/nonmechanical roadcalls	MC/NMC RC
Number of accidents	ACCID
Number of roadcalls per PM interval	RC/PM
Periodic repeat roadcalls	PER RPT RC
Periodic roadcalls	PER RC
Periodic service interruptions	PER SV INT
Roadcalls with mechanic on street	RC W/MCH
Inspections	
Adequate PM program	OK PM
Correct diagnosis/troubleshooting	OK DIAGNOS
Defects uncovered during PM	DEF PM
Miles per PM inspection	MI/PM
Overdue PM inspections	LA PM
Performance after inspections	PERF>INSP
Periodic A/C inspections	PER A-C
Periodic bus inspections	PER B INSP
Results of (State) safety inspect.	SAVE INSP
Supervisory spot-checks	SUP INSP
Light Repairs	
Appropriate replacement of part	OK PRT REP
Overdue brake adjustments	LA BR ADJ
Percent of fleet cleaned on schedule	% SCH CLN
Periodic brake adjustments	PER BR ADJ
Periodic bus cleanings	PER CLN
Proper servicing of fleet	OK SV
Heavy Repairs	
Backshop backlog	SHP BACKLG
Miles/major overhaul	MI/MAJ OV
Miles/major repair	MI/MAJ REP
Time to rebuild a component	T/REB PRT
Unit repair production	REP PROD

INTERFACE WITH OPERATIONS

Cleanliness complaints	CLN CMP
Complaints about maintenance work	CMP M W
Operator reported defects	OP DEF
General appearance	GEN APP
Meeting goals	O-T PERF
Number of late starts	LA STARTS
Number of no-go's	# NOGO
Number of replace. buses dispatched	# REP B DES
Passenger complaints	PAX CMP
Percent (or number) of trips missed	% MISS TRP

TABLE 2 DIFFERENCES BETWEEN PRIORITY RANKING AND OVERALL POPULARITY RANKING

	PRIORITY LEVEL ON THE SURVEY FORM			
INDICATOR	FIRST	SECOND	THIRD	TOTAL
	Entries by Priority Level			
INDICATOR A	70	10	5	85
INDICATOR B	10	35	60	105
INDICATOR C	20	50	25	95
None	0	5	10	15
TOTAL	100	100	100	300
	Cumulative Entries by Priority Level			
INDICATOR A	70	80	85	85
INDICATOR B	10	45	105	105
INDICATOR C	20	70	95	95
None	0	5	15	15
TOTAL	100	200	300	300

MISCELLANEOUS

Maintenance time per mile on sup. veh.	T/SP V MI
Meeting goals (unspecified)	GOAL
Miles per bus	MI/B
Missed injection (?)	MISS INJE
MPG for support veh. per service mile	SP MPG/MI
Periodic mileage	PER MI
Periodic transfers	PER TRANSF

Ranking Methodology

Usually, the process of ranking is simple and straightforward, particularly if the items to be ranked are given a single-dimensional score by the respondents. But here, the process is not quite as simple because the respondents have created their own indicators, listing only as many as they felt were important, and listing them in rank order. Hence, a difference can exist between the relative importance of an indicator and the number of times it is listed. Consider the hypothetical situation presented in Table 2, where a group of 100 respondents has listed three indicators in varying orders (i.e., priority rankings) such that one indicator (A) is dominant in the top-priority slot, but fails to be significant thereafter. A second indicator (B) is not mentioned often at either the first- or the second-priority slots, but represents almost all of the entries at the third-priority slot, and a third (C) is mentioned most often in the second-priority slot. Although an aggregate Indicator B is listed most often (i.e., has the most entries), Indicator A ranks first because it dominates the other two at the top-priority level. Moreover, Indicator C falls ahead of Indicator B because it accumulates high-level entries faster than Indicator B. However, it is clear that Indicator B is widely accepted, appearing more times on the various lists than any other. Indicator C is next most popular, followed by Indicator A. Hence, an understanding of each indicator's importance requires two dimensions: the first considering the rates at which the indicators accumulate entries across the priority levels and the second considering the breakdown of total entries. Each is important.

Analysis of the Results

Of the 1,000 entries that were possible (100 respondents times 10 entries each), 656 were provided, an average of about 6 per respondent. Twenty-six respondents listed 10 and seven more respondents provided at least 8. (This in itself is an important finding because it shows that managers typically use only a limited number of indicators to monitor performance.)

The respondents clearly give roadcall indicators top priority. Half of them list a roadcall indicator first (Table 3); 18 list one second and 12 list one third (Table 4). Overall, 99 of the entries (15 percent) involve a roadcall indicator.

After roadcalls, drivetrain indicators accumulate entries faster than any other group (Table 5), ranking them second. In

TABLE 3 BREAKDOWN OF 98 TOP-PRIORITY INDICATOR CANDIDATES

Indicator	Main Category	Sub-Category	Number of Occurances
Maintenance dollars per bus mile	COST	Overall	7
Maint. cost op. dollars per bus mile	COST	Overall	1
Periodic labor cost	COST	Labor cost	1
Number of buses per maintenance worker	FACTORS	Labor factor	1
Maintenance labor hours per bus mile	FACTORS	Labor factor	1
Average availability	FACTORS	Vehicle overall	4
Total down time	FACTORS	Vehicle overall	1
Fluid consumption	FACTORS	Component (DTRAIN)	1
Miles per gallon	FACTORS	Component (")	5
Miles per quart of oil	FACTORS	Component (")	3
Oil analysis	FACTORS	Component (")	1
Failure trends	FACTORS	Component (general)	1
Repeat work	MAINT ACT	Overall	4
Work orders completed	MAINT ACT	Overall	2
Adequate safety programs	MAINT ACT	Overall	1
Miles per roadcall (unspecified)	MAINT ACT	Roadcalls	25
Periodic roadcalls (e.g. per month)	MAINT ACT	Roadcalls	15
Miles per failure	MAINT ACT	Roadcalls	6
Miles per roadcall, mechanical cause	MAINT ACT	Roadcalls	4
Defects found during inspection	MAINT ACT	Inspections	2
Deferred preventive maintenance	MAINT ACT	Inspections	2
Miles between inspections	MAINT ACT	Inspections	2
Periodic brake inspections	MAINT ACT	Inspections	1
Miles between major overhauls	MAINT ACT	Major repairs	1
Part availability	MAINT ACT	Inventory manag.	1
Percent missed trips	INTERF OP	-	2
General appearance	INTERF OP	-	1
On-time performance	INTERF OP	-	1
Operator defects	INTERF OP	-	1

Note: DTRN = drivetrain

TABLE 4 COUNTS OF CANDIDATES BY INDICATOR CATEGORY AND PRIORITY LEVEL

	PRIORITY LEVEL ON THE SURVEY FORM										
CATEGORY	FIRST	SECOND	THIRD	FOURTH	FIFTH	SIXTH	SEVENTH	EIGHTH	NINETH	TENTH	TOTAL
COSTS											
Overall costs	8	10	10	11	2	3	3	2	3	2	54
Labor costs	1			2	2	4	2	1			12
Parts costs		3	2	3	1	1	3	1		1	15
Capital invest				1	1			1	2	1	6
Warranty billings								1			1
SUBTOTAL	9	13	12	17	6	8	8	6	5	4	88
FACTORS OF PRODUCTION (FOR MAINTENANCE)											
Labor	2	11	8	10	7	7	5	3	10	5	68
Comp.(drivetrain)	10	18	22	17	18	10	11	9	4		119
Comp.(other)		2		1	2	8	1	2	1	4	21
Comp.(general)	1	1	3	4	4	1		1		1	16
Vehicles	5	6	6	10	3	3	2	4			39
Facilities				1		1		1		1	4
SUBTOTAL	18	38	39	43	34	30	19	20	15	11	267
MAINTENANCE ACTIVITIES											
Overall	7	11	6	6	6	5	6	3	1	3	54
Light repairs			2	1	2	2		2			9
Roadcalls	50	18	12	5	7	3	1	2	1		99
Inspections	7	7	11	8	4	2	4			2	45
Heavy repairs	1	1	2	1	2	2	1	1			11
Inventory manag.	1		2		2	4	2	1	1		13
SUBTOTAL	66	37	35	21	23	18	14	9	3	5	231
INTERFACE W/OPER	5	8	8	8	10	4	7	2	5	4	61
MISCELLANEOUS		2	2	1	1	1	1		1		9
BLANK	2	2	4	10	26	39	51	63	71	76	344
GRAND TOTAL	100	100	100	100	100	100	100	100	100	100	1000

TABLE 5 CUMULATIVE COUNTS OF CANDIDATES BY INDICATOR CATEGORY AND PRIORITY LEVEL

	PRIORITY LEVEL ON THE SURVEY FORM									
CATEGORY	FIRST	SECOND	THIRD	FOURTH	FIFTH	SIXTH	SEVENTH	EIGHTH	NINETH	TENTH
COSTS										
Overall costs	8	18	28	39	41	44	47	49	52	54
Labor costs	1	1	1	3	5	9	11	12	12	12
Parts costs		3	5	8	9	10	13	14	14	15
Capital invest				1	2	2	2	3	5	6
Warranty billings								1	1	1
SUBTOTAL	9	22	34	51	57	65	73	79	84	88
FACTORS OF PRODUCTION (FOR MAINTENANCE)										
Labor	2	13	21	31	38	45	50	53	63	68
Comp.(drivetrain)	10	28	50	67	85	95	106	115	119	119
Comp.(other)	0	2	2	3	5	13	14	16	17	21
Comp.(general)	1	2	5	9	13	14	14	15	15	16
Vehicles	5	11	17	27	30	33	35	39	39	39
Facilities				1	1	2	2	3	3	4
SUBTOTAL	18	56	95	138	172	202	221	241	256	267
MAINTENANCE ACTIVITIES										
Overall	7	18	24	30	36	41	47	50	51	54
Light repairs			2	3	5	7	7	9	9	9
Roadcalls	50	68	80	85	92	95	96	98	99	99
Inspections	7	14	25	33	37	39	43	43	43	45
Heavy repairs	1	2	4	5	7	9	10	11	11	11
Inventory manag.	1	1	3	3	5	9	11	12	13	13
SUBTOTAL	66	103	138	159	182	200	214	223	226	231
INTERFACE W/OPER	5	13	21	29	39	43	50	52	57	61
MISCELLANEOUS		2	4	5	6	7	8	8	9	9
BLANK	2	4	8	18	44	83	134	197	268	344
GRAND TOTAL	100	200	300	400	500	600	700	800	900	1000

Table 4, 10 respondents list a drivetrain indicator first, 18 list one second, 22 list one third, and 17 list one fourth. This means that drivetrain indicators accumulate entries faster than any other category except roadcalls (Table 5). Overall, 119 entries (18 percent) fall into this category. The main specific indicators are miles per gallon (51 entries) and miles per quart of oil (38 entries).

After drivetrain performance, cost indicators gain entries the fastest. Eight respondents list an overall cost indicator first, 10 list one second, and 10 list one third. Overall, 54 of the 656 entries (8 percent) relate to overall cost. The most common indicator is maintenance cost per mile with 27 entries.

Beyond these three, the category that gains the most top-level entries is inspection program performance, followed by interface with operations; labor performance; overall maintenance performance; vehicle (i.e., indicators of overall vehicle quality); performance of specific components other than the drivetrain (brakes, tires, air conditioning, and wheelchair lifts); and general indicators of vehicle component performance.

The breakdown of total entries shows that the ranking based on popularity is slightly different. As Figure 2 shows, drivetrain performance measures have the most overall entries, followed by roadcalls and labor performance. Despite these differences, however, the 10 top categories are the same in either case, as shown in Table 6. The two indicator categories with the greatest difference in the rankings are overall costs (3 versus 5) and labor performance (6 versus 3).

Other perspectives provide additional insights. When the top 25 individual indicators are ranked according to total entries, miles per gallon ranks first followed by miles per quart of oil and miles per roadcall (Table 7). In Table 8, which lists the three top indicators for each priority level, roadcalls are dominant at first, but cause-related measures then increase in importance, especially miles per gallon and miles per quart of oil. At lower levels, transmission life, absenteeism, and general bus appearance receive top attention. Separately, there are numerous ties for third place, showing a wide diversity of opinion.

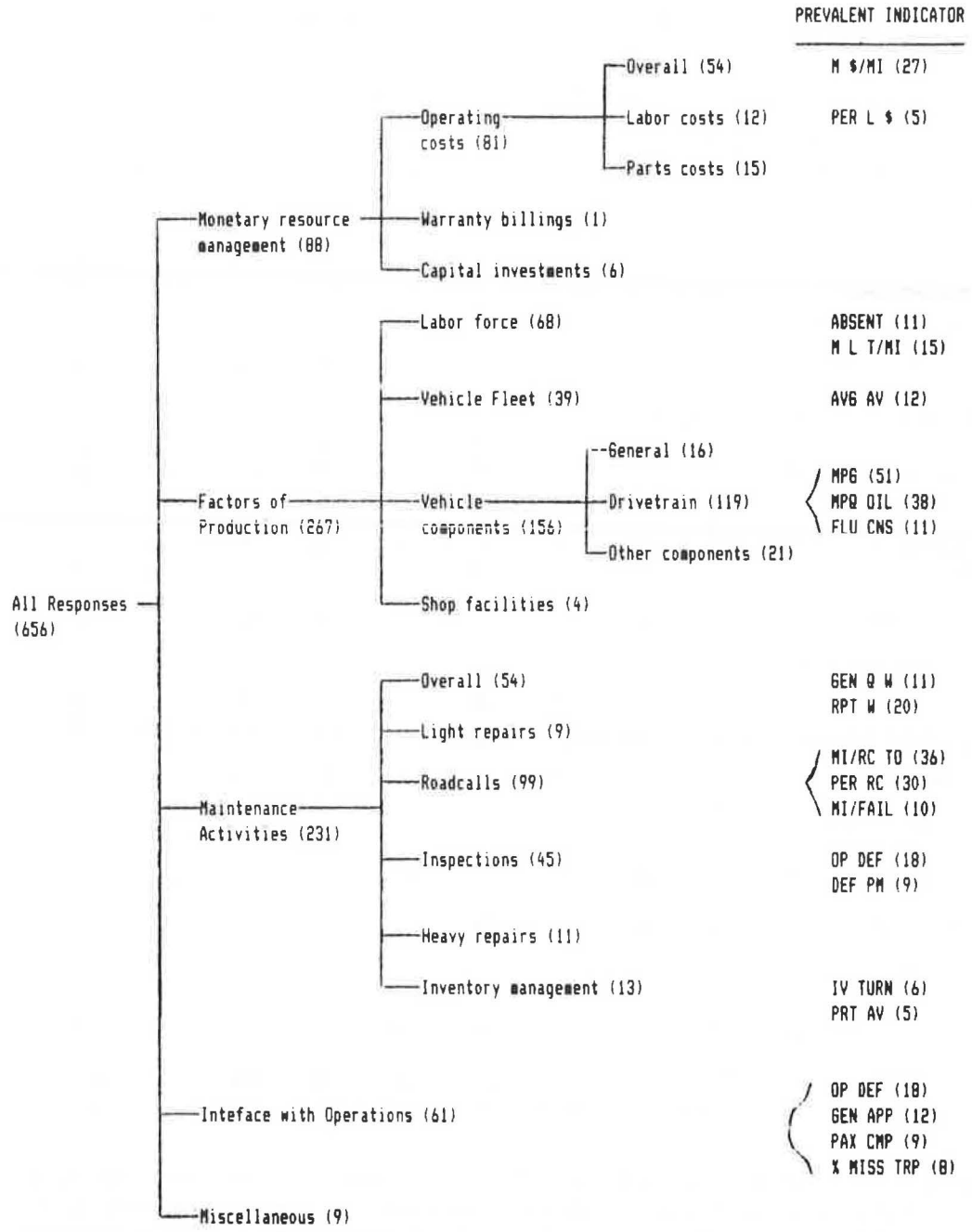

FIGURE 2 Breakdown of 656 indicator candidates.

Other observations (Tables 2–8) are as follows:

- Although labor is not a Priority Level 1 concern, it does have deep-rooted importance. At Priority Level 9, where only 29 entries are given, 10 of them relate to labor indicators. Manpower ratios were discussed intensively at the Bus Maintenance Workshop held in Houston, Texas, March 5–7, 1985 (*18*, pp. 4–5).
- The separate costs of labor and parts are not major indicators, even though total cost receives significant attention.
- Inspection-related indicators are listed frequently only at Priority Levels 3 and 4.
- The adequacy of investment in shop capacity is not given much attention despite Hauser's *(10)* intense focus on this area.
- Heavy repairs and inventory management never receive major attention.

Consistency Across Environments

One can theorize that the value of certain performance indicators should be sensitive to the system's operating environment. With this in mind, the survey included two questions that were used to test this idea. Question 2 (Figure 1) asked the respondent to describe his environment in terms of average road speed, stopping frequency, average ambient temperature, grades, potholes, street litter, percent of buses air conditioned, and percent of buses over 10 years old. Question 4 asked the

TABLE 6 RANKING OF INDICATOR CATEGORIES

Category	Ranking based on Accumulated Entries	Ranking based on Overall Entries
Roadcalls	1	2
Drivetrain performance	2	1
Overall costs	3	5
Inspection program perf.	4	7
Interface with operations	5	4
Labor performance	6	3
Overall maint. performance	7	6
Vehicles (quality)	8	8
Comp. (specific, but not drivetrn)	9	9
Comp. (generalizations)	10	10

TABLE 7 TOP 25 FUNDAMENTAL INDICATORS

Abbreviation	Meaning	Number of Entries
MPG	Miles per gallon	51
MPQ OIL	Miles per quart of oil	38
MI/RC TO	Miles per roadcall (unspecified)	36
PER RC	Periodic roadcalls (e.g. per month)	30
M $/MI	Maintenance cost per mile	27
RPT W	Repeat work	20
OP DEF	Operator reported defects	18
LA PM	Inspection (PM) backlog	15
M L T/MI	Total labor man-hours per bus mile	15
AVG AV	Average bus availability	12
GEN APP	General bus appearance	12
FLU CNS	Fluid consumption	11
ABSENT	Absenteeism	11
GEN QUAL W	General quality of maintenance work	11
MI/FAIL	Miles between failures	10
PAX CMP	Passenger complaints	9
DEF PM	Defects discovered during inspections	9
# DN B	Number of inoperative buses	8
OV	Overtime	8
MI/RC MC	Miles per roadcall - mechanical cause	8
% MISS TRP	Percentage of trips missed	8
M $/B	Maintenance cost per bus	7
PRT $/MI	Parts cost per mile	7
BR LF	Brake life	7
OIL ANAL	Oil analysis	7

Note: These top 25 account for 395 of the 656 entries (60%)

TABLE 8 THREE TOP FUNDAMENTAL INDICATORS FOR EACH RANK ORDER POSITION

Rank and Indicator	Entries	Rank and Indicator	Entries
FIRST		SECOND	
Miles per roadcall	25	Miles per gallon	11
Periodic roadcalls	15	Miles per qt of oil	7
Maint. cost per mile	7	Maint. man-hrs per mi	6
THIRD		FOURTH	
Miles per gallon	11	Miles per gallon	7
Periodic roadcalls	8	Op ident. defects	6
Miles per qt of oil	7	Maint cost per mile	6
FIFTH		SIXTH	
Miles per qt of oil	10	Miles per gallon	5
Miles per gallon	6	Inventory turnover	3
Three-way tie	3	Nine-way tie	2
SEVENTH		EIGHTH	
Fluid consumption	9	Transmission life	3
Complaints about work	4	Miles per gallon	2
Seven-way tie	2	No. of disabled buses	2
NINTH		TENTH	
Absenteeism	5	General appearance	3
Maint cost per mile	3	Brake life	2
All the rest	1	Overtime	2

TABLE 9 PERCENTAGE USE OF ROADCALLS AS THE TOP-PRIORITY PERFORMANCE MEASURE BASED ON SYSTEM FLEET CHARACTERISTICS

Fleet Characteristic	Number of systems	Systems using Roadcalls	Percent
All buses 35-feet long or shorter	7	4	57%
51-99% of the fleet 35-foot or shorter	11	7	64%
11-50% of the fleet 35-foot or shorter	17	6	35%
1-10% of the fleet 35-foot or shorter	14	7	50%
100% of the fleet between 35 and 40 feet	27	11	41%
1-10% of the fleet is articulated buses	16	9	56%
over 10% of the fleet is articulated	8	6	75%
Total responses	100	50	50%

respondent to break down the bus fleet in terms of small (under 35 ft long), full-sized (35 to 40 ft long), and articulated buses.

Although intuitive correlations between these characteristics appear to hold true, there is little evidence that they affect the choice of maintenance indicators. For example, the breakdown of Priority Level 1 indicators appears to be the same regardless of operating environment. Roadcalls account for about 50 percent of the Priority Level 1 indicators regardless of the fleet composition (Table 9). Other breakdowns by fleet size and environmental characteristics fail to show any obvious trends, with the conclusion that environmental factors do not play a major role in determining what indicators are important.

DISCUSSION

Comparing the present results with the studies discussed earlier, one is struck by both similarities and differences. The phrase that appears to apply most clearly is "The more things change, the more they stay the same." For example, although 35 years have passed since the supporting yardsticks were developed, they are still in use today albeit to a lesser degree. Also as was true 35 years ago, although some indicators seem to rank higher than others, diversity of opinion is still the norm.

While all nine of the pars indicators can be found in the lists submitted by the survey respondents, comparison with the 10 top-ranked individual indicators presented in Table 7 shows that the supporting yardsticks match only those ranked 9th and 10th, none higher. Miles per gallon is missed as well as miles per quart of oil, miles per roadcall, periodic roadcalls, maintenance cost per miles, repeat work, operator defects, and overdue preventive maintenance. Moreover, the yardsticks lack representation from 5 of the 10 top categories (Table 6). There are no supporting yardsticks for roadcalls, drivetrain performance, overall costs, inspection program performance, interface with operations, or the other two-component (specific and general) performance-related categories. Several explanations are possible. This lack may be an indication of change—that maintenance managers have more reason to focus on roadcalls today than they did in the past. Alternatively, they may be more service-oriented; the buses may be less reliable; or the buses may be more reliable, with the result that preventive maintenance intervals are longer and failures are more difficult to catch before they occur. Another possibility is that 35 years ago maintenance managers knew what factors to watch in order to keep others under control. Also, the committee members may have gotten trapped by trying to specify target values for all yardsticks and found it impossible to identify universally applicable values for indicators such as roadcalls per vehicle-mile; hence, such indicators were dropped from the list. In any event, the old yardsticks do not reflect the indicators in use today.

The newly proposed Section 15 indicators fare considerably better. Equivalents for all nine can be found in Table 2; and collectively, treating them as a supplement to other indicators already available in the Section 15 data, there are matches for the first-, second-, third-, and fourth-ranked indicators presented in Table 7. Moreover, vis-à-vis the top indicator categories presented in Table 6, the Section 15 list includes one or more indicators for each of the four top categories: (a) roadcalls, both total and mechanical; (b) miles per gallon and miles per quart of oil; (c) overall maintenance cost per mile; and (d) percent of preventive maintenance performed on schedule. The categories lacking indicators are interface with operations, labor performance, overall maintenance performance, and either the component-specific or unspecific performance categories. Thus, while the Section 15 list could be expanded further to capture indicators of lower importance, the proposed list is quite good.

Maze's *(9)* indicators also do well. Of the 36 proposed, equivalents for 30 are presented in Table 2. Moreover, there are matches for the 3rd-, 4th-, 5th-, 6th-, 8th-, and 10th-ranked indicators (Table 7), the missing ones being miles per gallon, miles per quart of oil, operator-identified defects and total maintenance labor man-hours per mile. Separately, vis-à-vis the 10 top categories listed in Table 6, the ones lacking representation are drivetrain performance, interface with operations, and specific component performance other than drivetrain (e.g., brakes and air conditioner).

Comparison with Maze's *(9)* survey also highlights two important points. First, by having the respondents score a list of preselected indicators, the survey showed whether the indicators were useful but not whether they would be or were being used. Second, the survey missed indicators that the respondents thought were important. This lack limits the utility of the results.

Hauser's *(10)* list fares the poorest, with matches in Table 6 for only the third-, fourth-, and fifth-ranked indicators. This result may not be because the list was wrong, but rather because the maintenance managers are being too shortsighted about identifying the real source of their performance problems. Hauser believes that too little facility capacity can lead to overtaxation of existing resources, backlogs, and poor-quality work.

Fowler's *(11)* list does better than Hauser's *(10)*. Although it does not have many exact matches in Table 2, ratios based on the list have matches for all but four. Clearly, Fowler's list reflects the industry's current thinking.

Finally, all the indicators identified by Foerster et al. *(12–15)* have matches in Table 1. However, this result is not surprising because the properties that were studied were also surveyed in the work presented here. However, Foerster's short list of 15 indicators captures the ones ranked 2nd, 3rd, 4th, 5th, and 10th (Table 7). Also, as was the case in this survey, roadcalls were found to be the leading indicator used to monitor performance.

IMPLICATIONS FOR RESEARCH AND PRACTICE

The scope of this paper has been limited to the measures that are in prevalent use today. This process may only determine what measures are easiest to obtain and interpret at the maintenance management level, not necessarily those that are the most useful. Better measures may be needed, but the data to support them may presently be too diffcult to obtain, store, and analyze. Roadcall measures are easy to use because the events are well-defined and always recorded. They are also most visible to the public and therefore sensitive from a system's public-image perspective. Labor time standard performance, on the other hand, is far more difficult to capture without some of the more sophisticated maintenance management information

systems now becoming available. Yet, labor time is likely to be an effective means for measuring performance.

A number of questions need to be addressed as extensions to the work presented here.

- How effective are the present indicators?
- How well are they being used?
- Are the indicators fool-proof, or is following some of them (e.g., cost per vehicle-mile) at the expense of others misleading?
- Do they measure what is believed that they measure?
- What other indicators are needed?
- Where can new ideas for indicators be found (e.g., from aircraft maintenance)?
- If target values for the indicators (e.g., yardsticks) are developed, are they transferable between systems or between divisions within the same system?
- Can these 126 indicators be reduced to a small set of comprehensive measures that provide a succinct view of the maintenance performance of a given transit property?
- Can a set of vital indicators be identified that should be monitored all the time, deferring use of the others to times when problems occur?
- How is such a hierarchical structure for the indicators to be developed?

SUMMARY AND CONCLUSIONS

The survey appears to have succeeded in (a) determining what indicators are being used by maintenance managers today, and (b) providing an indication of their relative ranking. The respondents show clear points of agreement, such as the initial focus on roadcalls, followed by a turn inward to search for cause (e.g., drivetrain performance) and to monitor labor and monetary productivity. But the industry is far from consensus, and perhaps that is to be expected. Differences in managerial philosophies appear to stand in the way of an agreement on a single list of indicators and their ranking. In fact, this diversity may be a sign of health, not weakness, in that it shows individual opinion and experimentation are constantly being used to test the validity of old measures and to determine the value of new ones.

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