Detroit Downtown People Mover Maintenance Data: An Overview

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The Detroit Downtown People Mover (DPM) has been in operation since August 1987. The 1989 maintenance data of DPM were reviewed, and an attempt was made to determine the relationship between various entities of the DPM maintenance system. Peak failure was observed during December, so winter might have played a significant role in the life cycle of components. Almost equal numbers of repairs were made for each train, with one exception. The train control component was the component most frequently repaired.

The Detroit Downtown People Mover (DPM) has been in operation since August 1987. The DPM is operated and maintained under a set of rules different from those governing other mass transit systems, such as bus, subway, and so forth. The maintenance record of DPM during 1989 is reviewed, and interesting nomenclature associated with DPM maintenance is highlighted.

BACKGROUND

The Detroit Transportation Corporation (DTC) owns and operates the DPM. Construction began in October 1983 on the 2.9-mi (4.6-km), $200.3 million project with 80 percent federal and 20 percent state funding. When the project was opened for revenue service in July 1987, it became the second of its kind in a North American city (Miami's was the first). The DPM, which is one of the most technologically advanced transportation systems in the world, has 13 stations (*1*).

The vehicles on the single-track loop system run in one direction (counterclockwise). Round-trip time is approximately 14 min, with 2- to 3-min headways. The DPM operates 7 days a week. Its operating hours are as follows:

Day	*Hours*
Monday–Thursday	7:00 a.m.–11:00 p.m.
Friday	7:00 a.m.–midnight
Saturday	9:00 a.m.–11:00 p.m.
Sunday	Noon–8:00 p.m.

A computerized control center operates the rail system, monitoring the location of each vehicle at all times. Linear induction motors propel the cars. Each car accommodates 34 passengers seated and 66 standing. DTC currently owns 12 trains.

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ORGANIZATIONAL STRUCTURE OF DPM

The day-to-day management of DPM is carried out by the Operation and Maintenance (O&M) division. The O&M division consists of three subdivisions. The breakdown of personnel by subdivision is given in Table 1.

Maintenance of DPM is performed mostly by O&M personnel. The cost averages approximately $450,000 per month, an annual rate of about $5.5 million (*2*). The trains are subject to routine maintenance monthly or every 4,000 mi (whichever comes first). However, in the absence of detailed information on vehicle miles traveled by each train before failure, various analyses were conducted on a monthly basis only. The ratio of scheduled routine maintenance to unexpected maintenance is 3.5 to 1 (*3*).

Maintenance activities are mostly scheduled and monitored by the maintenance scheduling department of the O&M division. The maintenance facility is located next to Times Square Station and includes two maintenance bays each capable of holding three trains for all vehicle maintenance; an automatic train control laboratory with first-, second-, and some third-level repair equipment; and an electronics laboratory with test setups for fare collection, vehicle doors, closed circuit television, on-board communication, and propulsion. General work areas for steam cleaning, welding, and drilling are also provided. The facility runs 24 hr per day and consists of three shifts: 7:30 a.m.–3:30 p.m. (Shift 1), 3:30 p.m.–11:30 p.m. (Shift 2), and 11:30 p.m.–7:30 a.m. (Shift 3).

Most repairs other than services warranted by the manufacturer are performed in-house. The location of various maintenance activities is shown in Figure 1.

RELATIONSHIP BETWEEN DPM AND DIFFERENT ACTIVITIES

A people mover may be classified into one of three types: active (operative and in service), transitional (operative and in service by means of a redundant system), or failed (not in operation because of prime or redundant system failure). The day-to-day status of a train in relation to the maintenance facility can be described as follows:

1. An "active" people mover is in service.
2. When a problem arises, the maintenance facility is informed. Switch to redundant system if possible and keep running, or tow the failed system to the maintenance facility.

TABLE 1 PERSONNEL BREAKDOWN BY DIVISION (3)

Division	Subdivision	Total Staff in Subdivision	No.	Category
Operation and Maintenance	Operations	15	1	Manager
			5	Supervisors
			9	Control Operator
	Maintenance	39	1	Manager
			5	Supervisors
			13	Electronic Technicians
			10	Mechanical Technicians
			8	Utility Worker
			1	Maintenance Schedule
			1	Date Clerk
	Administration	7	1	Manager
			1	Supervisor
			3	Store Keeper
			1	Accounting
			1	Administrator

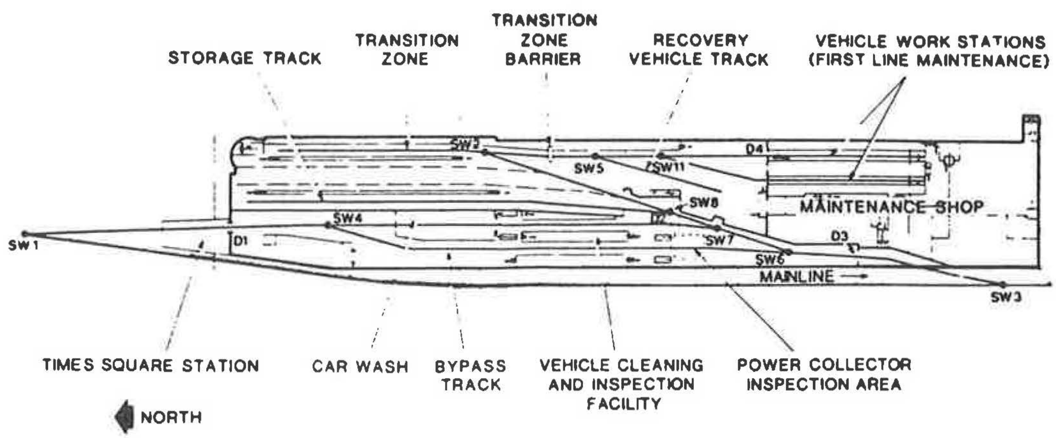

FIGURE 1 DPM maintenance facility.

3. A quick-repair person (QRP) is on the train while the train is still running.
4. The QRP inspects the failed item and if possible repairs or replaces it.
5. If the QRP cannot repair or replace the failed item on the train, the train is still running on a redundant system.
6. At the end of the day, the train returns to the service station for preventive maintenance.
7. In the maintenance facility each train is categorized as follows: requires preventive maintenance to be scheduled during Shifts 1, 2, or 3; failed components to be repaired internally during Shifts 1, 2, or 3; or failed component is warranted and will be repaired by the manufacturer.
8. Repair work is being documented.
9. Train is returned to service.

A schematic diagram of the day-to-day DPM activities is presented in Figure 2.

DESCRIPTION OF DPM MAINTENANCE SYSTEM

DPM maintenance data are stored in a mainframe computer. Typical maintenance data include work order number, train number (there are 12 trains providing daily service), date work was performed, shift during which the work was performed, name of the mechanic, and codes representing the type of work that was performed (reason, item, and action codes). For example, C is a reason code indicating corrective maintenance, BM is a component code indicating battery monitor, and R is an action code indicating repaired. Therefore, C BM R means that a defective or malfunctioning battery monitor was repaired on the vehicle shown in the train number field.

The O&M division keeps track of repair work by assigning codes given in Tables 2 to 5.

REVIEW OF 1989 DPM MAINTENANCE DATA

Maintenance records of DPM were obtained from DTC. Type of component failure, train number, shift, and repair action information were coded and keyed into the computer. SPSS software was used to determine the relationship between various elements of DPM maintenance activities. Characteristics of DPM maintenance data are presented and discussed in the following sections.

Frequency of Repairs by Month

During 1989, 5,374 repairs were done on the 12 trains. Numbers of repairs by month and by train are shown in Figures 3 and 4 and Table 6. The data indicate that the month with the largest number of repairs was December (727, or 13.3 percent of all repairs), followed by August (666, or 12.4 percent). The month with the smallest number of repairs was February

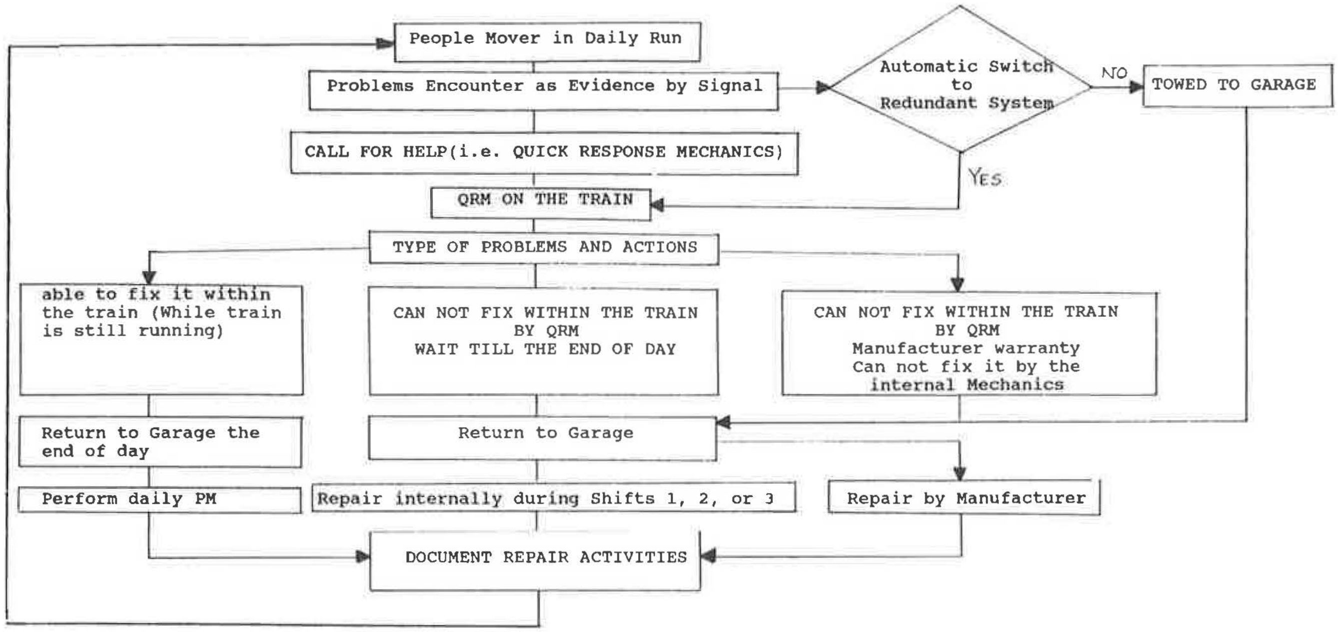

FIGURE 2 Day-to-day status of DPM.

TABLE 2 TRAIN CODE

TRAIN VEHICLE #	CODE
1	V1
2	V2
3	V3
4	V4
5	V5
6	V6
7	V7
8	V8
9	V9
10	V10
11	V11
12	V12

(263, or 4.9 percent), followed by April. In January the train with the highest number of repairs was Train 5. In February, May, and September it was Train 3; in March and April it was Train 10; in June and December it was Train 6; in July and October it was Train 12; in August it was Train 9; and in November it was Train 11.

Frequency of Repairs by Shift

Data were studied to determine whether any relationship exists among numbers of repairs by month, train, and shift. The findings are given in Tables 7 and 8 and in Figures 5 and 6. A review of Tables 7 and 8 indicates that 48 percent of the repairs were done during Shift 3, followed by Shift 1 (39.3 percent) and Shift 2 (12.7 percent). The train with the largest number of repairs was Train 9 (503 repairs), followed by Train 12 (480) and Train 7 (475). The largest percentage of repairs was done during Shift 3 on Train 3, during Shift 2 on Train 2, and during Shift 1 on Train 6. For Shift 3 the month with the most repairs was March, followed by August and December. For Shift 2 it was November, and for Shift 1 it was December.

TABLE 3 REASON CODE

CODE	DESCRIPTION
P	PREVENTIVE MAINTENANCE (PM)
C	CORRECTIVE MAINTENANCE
I	INCORRECT MAINTENANCE
R	ROUTINE MAINTENANCE
Z	SUBSEQUENT FAILURE
J	COMSYST NO RESPONSE
B	INTERMITTENT FAILURE
N	SCHEDULED PM INSPECTION
D	TESTING INDUCED
W	WAYSIDE INDUCED
K	PATRON INDUCED
T	TRAIN INDUCED
M	MODIFICATION
H	ALARM
G	INFO/DATA
O	STARTER
V	VANDALISM
X	ACCIDENT
S	SEASONAL
F	FAILURE
A	ACCESS
E	TIMEOUT
L	LOOSE
Q	GROUND FAULT

TABLE 4 ACTION CODE

Code	DESCRIPTION
F	FINISHED
I	INSPECT
R	REPAIR
C	CLEAN
T	TEST
M	MODIFY
P	ASSIST
Q	INSTALL
L	LUBRICATE
E	EXCHANGE
A	ADJUST
X	RESET
H	HOLD
K	TAG OUT
D	DATA DUMP
N	NO FAULT FOUND
G	SPECULATION
U	UNFINISHED
I	INVENTORY
B	BLEED SYSTEM
W	AWAITING PARTS
O	RIDE VEHICLE

TABLE 5 COMPONENT CODE

CODE	NAME OF COMPONENT
BM	BATTERY MONITOR
CB	CARBODY
CM	COMMUNICATION
CP	COUPLER
DB	DISC BRAKE
DC	CONVERTER
ED	END DOORS
EL/IL	EXTERIOR/INTERIOR LIGHTING
HA	HVAC
HM	HEALTH MONITOR
L	INTERIOR LIGHTING
PC	POWER COLLECTOR
PD	PASSENGER DOOR
PR	PROPULSION
PV	PARTIAL VEHICLE INSPECTION
TB	TRACK BRAKE
TC	TRAIN CONTROL
TR	TRUCK
VE	VEHICLE ELECTRONICS

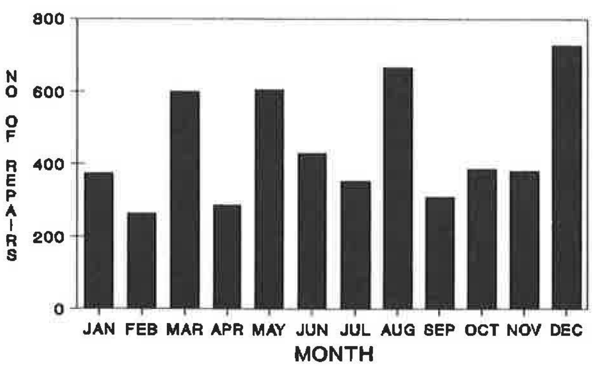

FIGURE 3 Frequency of repairs by month, 1989 DPM maintenance data.

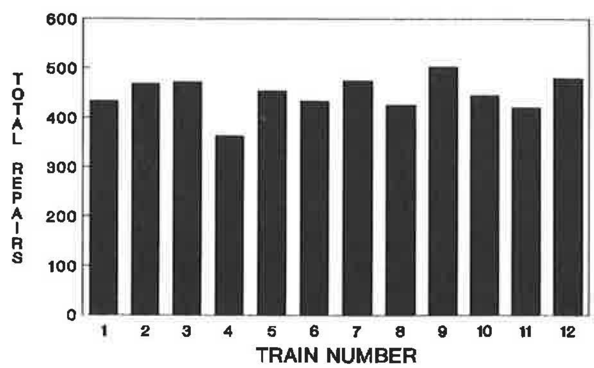

FIGURE 4 Frequency of repairs by train, 1989 DPM maintenance data.

TABLE 6 REPAIR FREQUENCY FOR 1989 BY TRAIN AND MONTH

Train#	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1	33	9	47	15	53	33	33	78	18	30	38	46	433
2	30	22	54	27	50	38	43	34	40	26	20	84	468
3	14	54	69	13	78	19	20	53	41	36	27	48	472
4	21	13	39	31	31	32	20	44	32	27	20	53	363
5	44	30	39	27	37	38	36	37	28	30	41	67	454
6	39	19	27	24	43	50	20	57	24	23	22	86	434
7	34	28	65	26	47	47	28	48	25	37	28	62	475
8	40	20	54	31	36	31	15	57	18	37	19	68	426
9	26	20	41	25	64	35	36	101	19	27	35	74	503
10	13	18	88	31	60	39	22	42	18	39	19	56	445
11	38	8	40	14	54	35	33	60	13	24	62	40	421
12	41	22	36	21	51	33	47	55	32	49	50	43	480
Total (%)	373 (6.9)	263 (4.9)	599 (11.1)	285 (5.3)	604 (11.2)	430 (8.0)	353 (6.6)	666 (12.4)	308 (5.7)	385 (7.2)	381 (7.1)	727 (13.5)	5374

TABLE 7 DPM REPAIRS FOR 1989 BY MONTH AND SHIFT

Month	Shift 1 No. (%)	Shift 2 No. (%)	Shift 3 No. (%)	Total
January	110(29.5)	14(3.8)	249(66.8)	373
February	54(20.5)	23(8.7)	186(70.7)	263
March	160(26.7)	81(13.5)	358(59.8)	599
April	108(37.9)	58(20.4)	119(41.8)	285
May	328(54.3)	29(4.8)	247(40.9)	604
June	228(54.3)	21(4.9)	181(42.1)	430
July	156(44.2)	51(14.4)	146(41.4)	353
August	218(32.7)	101(15.2)	347(52.1)	666
September	106(34.4)	55(17.9)	147(47.7)	308
October	177(46.0)	68(17.7)	140(36.4)	385
November	138(36.2)	117(30.7)	126(33.1)	381
December	328(45.1)	65(8.9)	334(45.9)	727
Total	2111(39.3)	683(12.7)	2580(48.0)	5374

TABLE 8 REPAIR FREQUENCY FOR 1989 BY TRAIN AND SHIFT

Train	Shift 1 No. (%)	Shift 2 No. (%)	Shift 3 No. (%)	Total
1	155(35.8)	65(15)	213(49.2)	433
2	191(40.8)	69(16.7	208(44.4)	468
3	147(31.1)	63(13.3)	262(55.5)	472
4	148(40.8)	49(13.5)	166(45.7)	363
5	183(40.3)	48(10.6)	223(49.1)	454
6	210(48.4)	34(7.8)	190(43.8)	434
7	167(35.2)	60(12.6)	248(52.2)	475
8	173(40.6)	57(13.9)	196(46.0)	426
9	181(36.0)	67(13.3)	255(50.7)	503
10	194(43.6)	49(11.0)	202(45.4)	445
11	173(41.1)	56(13.3)	192(45.6)	421
12	189(39.4)	66(13.8)	225(46.9)	480
Total	2111(39.3)	683(12.7)	2580(48.0)	5374

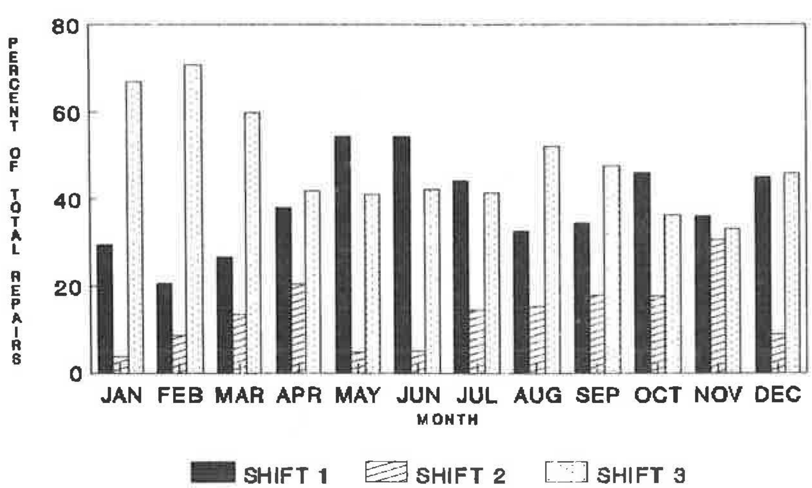

FIGURE 5 Repairs by month and shift, 1989 DPM maintenance data.

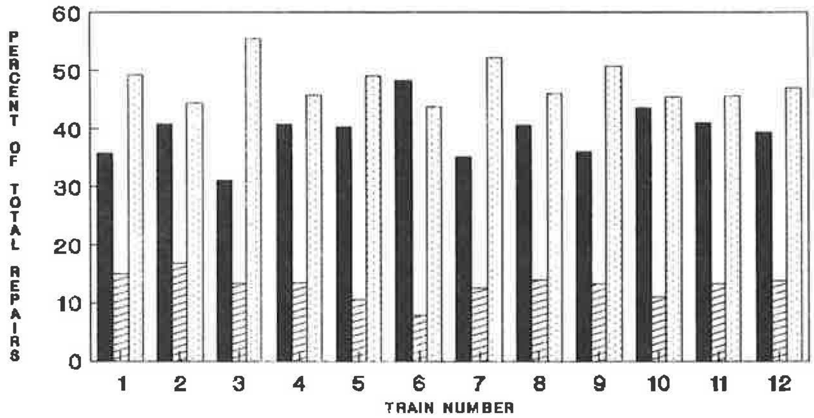

FIGURE 6 Repairs by train and shift, 1989 DPM maintenance data.

Component Failure by Train, Shift, and Month

Maintenance data were stored in 19 component categories in the data base (see Table 5). The data were reviewed to determine the number of repairs by component type. The findings of this analysis are presented in Tables 9 and 10 and in Figure 7. A plot of component type versus mean time between failures is shown in Figure 8. Tables 9 and 10 and Figure 8 indicate that TC was the component that failed most frequently (1,078 times), followed by PR (913 times) and TR (562 times). The shortest mean time between failures was observed for TC (0.58 weeks), followed by PR (0.68 weeks). In Shift 1, TC was repaired or replaced 456 times. TC was also the most frequently failed component in Shift 2. In Shift 3 PR was the most frequently failed component (552 times). TC was responsible for most of the failures on Trains 1 (112, or 25.9 percent), 2 (97, or 20.7 percent), 3 (79, or 16.7 percent), 4 (77, or 22.2 percent), 6 (78, or 18.0 percent), 7 (102, or 21.5 percent), 8 (76, or 17.8 percent), 10 (93, or 20.9 percent), 11 (87, or 20.7 percent), and 12 (122, or 25.4 percent). PR was the most frequently failed component for Trains 5 (99, or 21.8 percent) and 9 (140, or 27.8 percent).

SUMMARY OF FINDINGS

The DPM is an "activity center circulation" system, significantly different from a conventional line-haul transit facility in its use (*3*). Using the year of data, various relationships among the elements of maintenance activities were reviewed and analyzed for this unique transportation system. The conclusions are as follows:

1. The month with the largest number of repairs was December (727), mostly in Shifts 1 and 3, followed by August (666). The largest number of repairs may be in December because of severe winter weather conditions.
2. The shift with the largest number of repairs was Shift 3 (48 percent). This appears logical because most of the trains are not in service during Shift 3.

TABLE 9 REPAIR FREQUENCY FOR 1989 BY COMPONENT TYPE AND SHIFT

Component-Type	Shift 1 No. (%)	Shift 2 No. (%)	Shift 3 No. (%)	Total No. (%)
BM	52(35.1)	19(13.3)	74(51.7)	145(2.7)
BP	0	0	2(100)	2(0.0)
CB	65(60.2)	11(10.2)	32(29.6)	108(2.0)
CM	38(21.8)	45(25.9)	91(52.3)	174(3.2)
CP	103(56.3)	13(7.1)	67(36.6)	183(3.4)
DB	188(37.1)	39(7.7)	280(55.2)	507(9.4)
DC	66(51.6)	19(14.8)	43(33.6)	128(2.4)
ED	39(50.6)	10(13.0)	28(36.4)	77(1.4)
HA	160(44.9)	47(13.2)	149(41.9)	356(6.6)
HM	18(27.7)	15(23.1)	32(49.2)	65(1.2)
PC	21(30.4)	0(0.0)	48(69.6)	69(1.3)
PD	93(24.8)	42(11.2)	240(64.0)	375(7.0)
PR	302(33.1)	59(6.5)	552(60.5)	913(17.0)
TB	67(48.6)	13(9.4)	58(42.0)	138(2.6)
TC	456(42.3)	280(26.0)	342(31.7)	1078(20.1)
TR	262(46.6)	36(6.4)	264(47.0)	562(10.5)
VE	107(61.1)	18(10.3)	50(28.6)	175(3.3)
EL/IL	74(23.2)	17(5.3)	228(71.5)	319(5.9)
Total	2111(39.3)	683(12.7)	2580(48.0)	5374

TABLE 10 REPAIR HISTORY BY COMPONENT TYPE AND TRAIN

TRAIN#	REPAIR FREQUENCY/PERCENT BY COMPONENT TYPE																	
	BM	BP	CB	CM	CP	DB	DC	ED	HA	HM	PC	PD	PR	TB	TC	TR	VE	EL/IL	TOTAL
1	2 .5	-	10 2.3	17 3.9	12 2.8	30 6.9	7 1.6	1 .2	25 5.8	8 1.8	6 1.4	46 10.6	57 13.2	9 2.1	112 25.9	47 10.9	12 2.8	32 7.4	433
2	20 4.3	-	11 2.4	17 3.6	13 2.8	51 10.9	7 1.5	8 1.7	24 5.1	11 2.4	4 .9	43 9.2	73 15.6	10 2.1	97 20.7	38 8.1	16 3.4	25 5.3	468
3	4 .8	-	13 2.8	16 3.4	18 3.8	51 10.8	5 1.1	16 3.4	34 7.2	7 1.5	3 0.6	17 3.6	107 22.7	16 3.4	79 16.7	44 9.3	17 3.6	25 5.3	472
4	11 3.1	-	12 3.3	12 3.3	13 3.6	20 5.5	7 1.9	6 1.9	28 7.7	-	6 1.7	26 7.2	43 11.8	11 3.0	77 21.2	58 16.0	9 2.5	24 6.6	363
5	16 3.5	2 .4	7 1.5	21 4.6	13 2.9	34 7.5	7 1.5	6 1.3	39 8.6	9 2.0	4 .9	31 6.8	99 21.8	12 2.6	68 15.0	44 9.7	16 3.5	26 5.7	454
6	10 2.3	-	7 1.6	11 2.5	21 4.8	57 13.1	14 3.2	3 .7	34 7.8	4 .9	8 1.8	28 6.5	74 17.1	7 1.6	78 18.0	39 9.0	15 3.5	24 5.5	434
7	13 2.7	-	8 1.7	14 2.9	15 3.2	37 7.8	22 4.6	4 .8	26 5.5	7 1.5	4 .8	42 8.8	80 16.8	13 2.7	102 21.5	40 8.4	22 4.6	26 5.5	475
8	29 6.8	-	10 2.3	7 1.6	16 3.8	47 11.0	27 6.3	4 0.9	26 6.1	1 .2	7 1.6	31 7.3	51 12.0	14 3.3	76 17.8	43 10.1	9 2.1	28 6.6	426
9	19 3.8	-	10 2.0	15 3.0	19 3.8	30 6.0	9 1.8	6 1.2	31 6.2	3 0.6	9 1.8	38 7.6	140 27.8	7 1.4	87 17.3	45 8.9	10 2.0	25 5.0	503
10	4 0.9	-	4 0.9	15 3.4	9 2.0	60 13.5	8 1.8	6 1.3	33 7.4	5 1.1	8 1.8	25 5.6	64 14.4	11 2.5	93 20.9	56 12.6	17 3.8	27 6.1	445
11	9 2.1	-	6 1.4	17 4.0	11 2.6	48 11.4	10 2.4	8 1.9	35 8.3	6 1.4	6 1.4	25 5.9	40 9.5	11 2.6	87 20.7	56 13.3	13 3.1	33 7.8	421
12	8 1.7	-	10 2.1	12 2.5	23 4.8	42 8.8	5 1.0	9 1.9	21 4.4	4 0.8	4 0.8	23 4.8	85 17.7	17 3.5	122 25.4	52 10.8	19 4	24 5	480

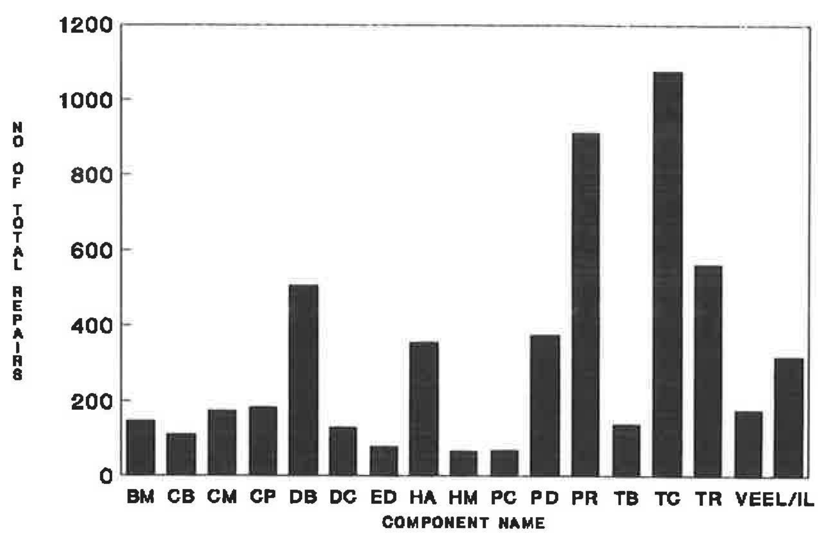

FIGURE 7 Repairs by component type, 1989 DPM maintenance data.

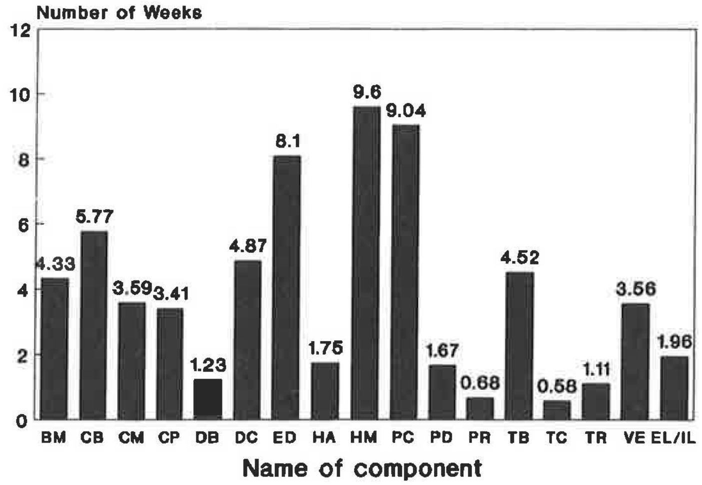

FIGURE 8 Mean time between failures, 1989 DPM maintenance data.

3. Because the smallest number of repairs was done during Shift 2, it is recommended that repairs be limited to Shifts 1 and 3. Thus, as a cost-saving measure, Shift 2 could be eliminated. However, the implications on labor relations should be fully explored before closing Shift 2.

4. Except for Train 4, which had the fewest repairs (363), trains had almost equal numbers of repairs (see Figure 4). Maintenance data for 1989, which is almost 2 years after the initiation of the DPM, were reviewed. Thus, the data represent the steady-state condition of the failure curve. The steady-state condition was evident from the almost equal number of repairs for all trains.

5. TC was the most frequently failed component (1,078 times), followed by PR and TR. Sufficient stocks of these components should be maintained. It is recommended that most emphasis be placed on TC.

Operating cost data could not be obtained. In addition, the time between failure and repair was not kept by the DPM authority, so no attempt was made to study downtime and cost factors.

For further research, it is recommended that the cost of component failure be considered (if cost data are available) and that the most cost-effective maintenance strategy be identified. This could save thousands of dollars, create a positive image of this state-of-the-art technology, and encourage other cities to consider such a circulation system.

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