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Rapid Transit Car Maintenance Research Needs

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Final Report

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16. Abstract

This report identifies those car maintenance research needs that (in the judgment of the participating rail transit operators and suppliers) would produce results that would be applicable industry wide. Those research products should assist the operators to realize maximum benefits from each car maintenance budget dollar.

The objectives of this rapid transit industry car maintenance assessment were to:

- define the major research and development needs of the rail transit operators.
- identify those research candidates for which an industry consensus exists, and
- develop an industry ranking of consensus candidates.

Specific research needs were categorized in six major areas: (1) data management/analysis, (2) maintenance practices, procedures and standards, (3) human resources, (4) physical resources, (5) car system design, and (6) policy. Specific proposed projects are described in the report.

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PREFACE

This Assessment of rapid rail car maintenance practices and determination of maintenance research needs was conducted by The Decision Group, Inc., under the auspices of the U.S. Department of Transportation's Urban Mass Transportation Administration's Office of Systems Engineering. Jeffrey G. Mora of the Urban Mass Transportation Administration and Santo J. Gozzo of U.S. Department of Transportation, Transportation Systems Center, provided direction and guidance as the UMTA and TSC project managers. At DGI, this study was managed and directed by Ronald E. Morris.

This study team is indebted to the American Public Transit Association (APTA) representatives of the rail transit systems and Railway Progress Institute (RPI) and its members (representing the transit supply industry) who served on the Rail Maintenance Liaison Board and ensured that findings and recommendations were consistent with the general opinions and views of the transit industry.

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INTRODUCTION

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- to define the major research and development needs of the rail transit operators,
- to identify those research candidates for which an industry consensus exists, and
- to develop an industry ranking of consensus candidates.

BACKGROUND

Car maintenance departments play a pivotal role in determining the level and quality of rapid transit service by ensuring that a full schedule of safe, clean, dependable cars are available each day. Surveys of public transit users have consistently disclosed that service schedule adherence is a major consideration. Service schedule adherence, as a measure of car dependability, reflects car maintenance policies and practices.

This report identifies those car maintenance research needs that (in the judgment of the participating operators and suppliers) would produce results that would be applicable industry wide. Those research products should assist the operators to realize maximum benefits from each car maintenance budget dollar.

STUDY APPROACH

The approach selected to achieve the stated objectives was tailored to ensure that the products of this study; i.e., the research candidates, would completely and accurately reflect the rapid transit operators' expressed needs -- from an industry-wide perspective.

Identification of the research that would benefit rapid transit car maintenance operations involved configuration and comparison of *Generalized* and *Optimized Scenarios*. Each of these comprises the ownership (life cycle) cost elements attributable to car maintenance. A rapid transit operator's annual car maintenance budget is essentially the sum of those cost elements. The *Generalized Scenario* represents the most common industry practices and was validated against the current practices of three rapid transit operators selected because of their excellent car maintenance capabilities:

- Chicago Transit Authority (CTA)
- Southeastern Pennsylvania Transportation Authority (SEPTA)
- Toronto Transit Commission (TTC)

The *Optimized Scenario* which incorporates proven exemplary practices is Appendix B. The differences between each most common and exemplary practice were examined. From these examinations were developed a basic list of research candidates. (See Exhibit 1. The 28 Industry-Consensus Research Candidates).

PERFORMANCE MEASUREMENT INDICATORS

Car maintenance resource data was obtained from each participating operator with the understanding that the data would be disclosed only among the project research staff. Analysis of that data made possible development of the performance measurement indicators (PMI) that are listed in Exhibit 2. Those PMI's provide the basis for determining the relative benefit/cost indices for each of the 28 research candidates. Exhibit 3, *Benefit/Cost Rating Matrix,* offers the decision maker a graphic measure of the potential value to rapid transit operators of the products of each of the 28 research candidates.

THE RESEARCH CANDIDATES

Industry-wide car maintenance research needs were developed from:

- two working sessions with representatives of the participating operators (the APTA Car Maintenance Liaison Board), APTA personnel, and supplier representatives,

- contractor conferences with line managers and supervisors responsible for, and key personnel in support of the rapid railcar maintenance operations at eleven North American transit authorities during nineteen site visits, and

- analysis of transit industry car maintenance policies, practices, resources and constraints from World War II to the present time.

The participating operators and suppliers determined that the 28 research candidates listed in Exhibit 1 address the industry's major car maintenance research needs.

The ability of a typical rapid transit operation to maintain its revenue fleet can be measured in terms of the six functional areas:

- Data Management and Analysis
- Practices, Procedures & Standards
- Human Resources Utilization
- Physical Resources Management
- Car System Design
- Policy

Category A: Data Management & Analysis

A1 CARSHOP COMPUTERIZED MANAGEMENT & CONTROL INFORMATION SYSTEM(CMCIS)

A2 SCHEDULING CAR SUBSYSTEMS REPLACEMENT ON THE BASIS OF FAILURE DATA

A3 COST TRADEOFF ANALYSES OF EARLY REPLACEMENT OF INEFFICIENT CAR-CARRIED PRODUCT DESIGNS

Category B: Practices, Procedures & Standards

B1 SPECIFICATIONS FOR THE PURCHASING, REPAIR & REBUILDING OF CAR SYSTEM ELEMENTS

B2 PRE-INSTALLATION INSPECTION OF CAR-CARRIED EQUIPMENT

B3 DISCIPLINED DIAGNOSTIC APPROACHES

B4 METHODS, PROCEDURES AND PERFORMANCE STANDARDS

B5 FAILURE MANAGEMENT

B6 AN INDUSTRYWIDE MAINTENANCE EXPERTISE INFORMATION DISSEMINATION SYSTEM

B7 MANAGEMENT OF REVENUE SERVICE TESTING OF ALTERNATIVE CAR-CARRIED PRODUCTS

Category C: Human Resources

C1 EMPLOYEE QUALIFICATION ASSURANCE

C2 INCENTIVES/RECOGNITION OF EXCEPTIONAL PERFORMANCE

C3 THE INFLUENCE OF FORMAL TRAINING ON FLEET UTILIZATION

C4 THE INTERACTIVE ROLES OF CAR MAINTENANCE ENGINEERS AND SHOP OPERATIONS

Category D: Physical Resources

D1 MATERIALS STORES MANAGEMENT

D2 CAR INSPECTION/MAINTENANCE FACILITIES' FUNCTIONAL WORKFLOWS

D3 INDUSTRYWIDE AWARENESS OF MULTIPLE SOURCES FOR MATERIALS STORES ITEMS BELOW THE SERVICE-EVALUATED PRODUCT LEVEL

D4 COST TRADEOFF ANALYSIS OF A LOGISTICAL SUPPORT "PIPELINE" VS THE TRADITIONAL MATERIALS STORES APPROACH

Category E: Car System Design

E1 CAR MAINTENANCE DEPARTMENT INFLUENCE ON NEW CAR DESIGN

E2 IMPROVED AIR COMFORT SUBSYSTEM REQUIREMENTS

E3 WINTERIZATION OF RAPID RAILCAR PNEUMATIC SUBSYSTEMS

E4 MULTIPLEX TRAINLINING OF SUBSYSTEM STATUS INFORMATION

E5 SOLID STATE/AC PROPULSION TECHNOLOGY DEPLOYMENT

E6 SERVICE-EVALUATED PRODUCTS LIST (SEPL) MAINTENANCE

E7 GREATER UNIFORMITY OF CAR-CARRIED EQUIPMENT AND ELEMENTS

Category F: Policy

F1 THE ESSENTIAL SUBSTANCE OF A CAR MAINTENANCE PHILOSOPHY

F2 BUDGETARY RESOURCES ALLOCATION PRACTICES WITHIN THE TRANSIT INDUSTRY

F3 THE ECONOMIC IMPLICATIONS OF PROGRESSIVE MAINTENANCE VS THE MAJOR OVERHAUL

EXHIBIT 1. THE 28 INDUSTRY-CONSENSUS RESEARCH CANDIDATES

N-1 Capital & Operating figures for all/or for only certain Car Inspection/Maintenance Facilities (CIMF) -- per car.

N-2 Personnel allocated at or assigned to all or only certain CIMF -- per car

N-3 CIMF employee hours -- per car (All employees actually located at that/those sites)

N-4 Mean distance between repairs (MDBR) (unscheduled maintenance actions)

N-5 Number of road failures/car

N-6 Availability Index (Average no. of cars daily available for scheduled revenue service/active revenue fleet size)

N-7 Ratio of: Total no. of CIMF employee hours to the average annual mileage of a car in scheduled revenue service

N-8 Ratio of: All CIMF employee hours to perform ONLY SCHEDULED car inspection & maintenance to the no. of shop CIMF employee hours to perform both SCHEDULED AND UNSCHEDULED car inspections & maintenance (These are all hours including all uncontrollable; i.e., contractually defined time)

N-9 Ratio of: Materials stores stockage & replenishment costs to the mean distance between unscheduled maintenance actions

N-10 Ratio of: Total no. of CIMF equivalent labor hours*at all or only certain CIMF to the total no. of unscheduled maintenance actions at those CIMF

N-11 Ratio of: Total no. of foremen at all or only certain CIMF to the no. of cars maintained by those CIMF

N-12 Ratio of: Materials stores stockage & replenishment costs to active fleet size

N-13 Ratio of: Total no. of CIMF equivalent labor hours*to the no. of cars maintained by those CIMF

(*i.e., equals value of contracted-out work)

EXHIBIT 2. THE PERFORMANCE MEASUREMENT INDICATORS (PMI)

THE 28 RESEARCH CANDIDATES--BY CATEGORY

NCDR PMI No.	Desired Effect	EVALUATION CRITERIA / PROBABLE EFFECTS OF RESEARCH PRODUCTS	A Data Management & Analysis 1	A 2	A 3	B Practices, Procedures & Standards 1	B 2	B 3	B 4	B 5	B 6	B 7	C Human Resources Utilization 1	C 2	C 3	C 4	D Physical Resources Management 1	D 2	D 3	D 4	E Car System Design 1	E 2	E 3	E 4	E 5	E 6	E 7	F Policy 1	F 2	F 3
1	▼	CIMF CAPITAL & OPERATING COSTS/CAR	▼	▼	△	▼	▼	◇	▼	◇	▼	◇	▼	◇	◇	▼	△	▼	▼	◇	▼	◇	▼	◇	▼	▼	▼	►	►	◇
2	▼	CIMF STAFFING/CAR	▼	◇	◇	◇	◇	▼	◇	◇	◇	◇	▼	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	►	►	◇
3	▼	CIMF LABOR HOURS/CAR	▼	◇	▼	◇	◇	▼	◇	◇	◇	◇	▼	▼	▼	◇	◇	▼	◇	◇	▼	◇	▼	▼	▼	▼	◇	►	◇	▼
4	▲	MEAN DISTANCE BETWEEN UNSCHEDULED MAINTENANCE ACTIONS	▲	▲	▲	▲	▲	▲	▲	▲	◇	▲	▲	▲	▲	▲	▲	◇	▲	◇	▲	▲	▲	◇	▲	▲	▲	▲	►	▲
5	▼	NO. UNSCHEDULED MAINTENANCE ACTIONS /CAR	▼	▼	▼	▼	▼	◇	▼	▼	◇	◇	▼	◇	▼	▼	▼	◇	▼	▼	▼	▼	▼	◇	▼	▼	▼	►	◇	▼
6	▲	AVAILABILITY INDEX (CARS AVAILABLE/FLEET SIZE)	▲	▲	▲	▲	▲	▲	▲	▽	◇	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	►	►	▲
7	▼	CIMF LABOR HOURS/REVENUE CAR MILES	▼	▼	▼	▼	▼	▼	▼	▼	▼	◇	▼	▼	▼	◇	◇	▼	◇	◇	▼	◇	▼	▼	▼	▼	◇	►	◇	▼
8	▲	SCHEDULED MAINTENANCE LABOR HOURS/ SCHED. + UNSCHED. MAINT. LBR.HRS.	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◇	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◇	▲
9	▼	MATERIALS STORES S & R COSTS/ UNSCHEDULED MAINTENANCE ACTIONS	▼	◇	▼	▼	▼	▼	▼	▼	◇	◇	▼	▼	▼	▼	▼	◇	▼	▼	▼	▼	▼	◇	▼	▼	▼	▼	▼	△
12	▼	MATERIALS STORES S & R COSTS/ ACTIVE REVENUE FLEET SIZE	▼	◇	▼	▼	▼	▼	▼	◇	◇	◇	◇	◇	◇	▼	▼	◇	▼	▼	▼	▼	▼	◇	▼	▼	▼	▼	◇	▼
13	▼	CIMF EQUIVALENT LABOR HOURS/ NO. OF CARS MAINTAINED THERE	◇	◇	▼	▼	◇	◇	▼	◇	◇	▼	▼	◇	▼	▼	◇	▼	◇	◇	▼	▼	◇	◇	▼	▼	◇	►	◇	◇
	▼	MATERIALS STORES STOCKAGE & REPLENISHMENT (S & R) COSTS	▼	△	▼	▼	▼	◇	▼	◇	▼	▼	◇	▼	▼	◇	▼	◇	▼	▼	▼	△	△	△	◇	▼	▼	►	►	►
	▲	EFFECT ON LIFE CYCLE COSTS	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◇	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	►	◇	▲
	▲	EFFECT ON RIDERSHIP	►	►	►	►	►	►	►	►	►	▲	▲	◇	▲	▲	▲	◇	◇	►	▲	▲	►	◇	▲	▲	▲	▲	◇	►
	■	RETURN ON INVESTMENT (BENEFITS > OWNERSHIP COSTS)	■	▣	■	■	▣	▣	▣	□	▣	■	▣	□	□	■	▣	□	■	▣	■	□	■	□	□	■	□	▣	□	□

KEY

▲	INCREASE (ANNUAL), DESIRED
▼	DECREASE (ANNUAL), DESIRED
△▽	INCREASE/(ANNUAL), *UNDESIRED* DECREASE
▲	DESIRED EFFECT
►	WOULD ACT TO STABILIZE OR SUSTAIN AT EXISTING LEVEL
◇	NO PREDICTABLE EFFECT

BENEFITS WOULD MARKEDLY EXCEED RD&D COSTS AND WOULD BE RECOGNIZABLE AND TANGIBLE

■	DURING FIRST OPERATIONAL YEAR
▣	WITHIN 2 TO 3 YEARS
□	WITHIN 4 TO 5 YEARS

EXHIBIT 3. BENEFIT/COST RATING MATRIX

Since the 28 research candidates translate into opportunities for improvement in one or more of these six areas, Exhibit 1 presents each research candidate in the most appropriate functional area. Exhibit 4 is the format for profiling each research candidate. Each has been described (in Appendix A) in sufficient detail to provide readers with a basis for evaluation. Exhibit 5 summarizes for each candidate the resources required to conduct the research and the timeframe within which products of that research would produce tangible benefits.

The basic list of research candidates was submitted to the participating operators for evaluation, preliminary ranking, and the addition of any operator-initiated candidates that would make the list a complete representation of the industry's car maintenance research needs.

FINDINGS

Five opportunities to improve car maintenance effectiveness were identified as key to any research program. Listed according to relative importance to the industry, they are the needs for:

1. A computer-assisted data recording, usage, and analytical capability at each car inspection/maintenance facility (CIMF) and under the direct operational control of the CIMF General Superintendent

2. Industrywide, frequent one-on-one communications and site visit exchanges among car maintenance line personnel; especially General Superintendents

3. Industrywide adoption of a codified statement of the essential substance of a rapid transit car maintenance philosophy

4. Development of a comprehensive employee qualification program, and demonstration of the benefit/cost implications of such a resource to a typical rapid transit operator

5. Substantive assistance to the rapid transit operators to promote accelerated movement toward:

   a. greater use of interchangeable elements of their new car system designs on both an operator-specific and an industrywide basis, and

   b. development of multiple sources for replacement elements of car-carried equipment.

RECOMMENDATIONS

<u>The Essential Research</u>

The nature of the research proposed herein is for the most part directed toward formalizing and disseminating knowledge that would benefit policy level and car maintenance line management and support staff officials at any domestic rapid transit operation.

Research Candidate ____________

Category:

Title:

THE PURPOSE OF THIS RESEARCH

POTENTIAL BENEFITS

Timeframe — Research Products would produce tangible benefits ......

__________ during first operational year
__________ within 2 to 3 years
__________ within 4 to 5 years

Detail

SECONDARY IMPLICATIONS

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

THE RECOMMENDED RESEARCH

Project Form

Products

APPROACH

RESOURCES REQUIREMENTS

Calendar Time ____________ months

Professional Time ____________ labor months

Computer Processing ___yes _____ no

EXHIBIT 4. PROJECT PROFILE FORMAT FOR RESEARCH CANDIDATES

Research Candidate No.	Professional Time (labor months)	Computer Processing	Project Duration (calendar months)	Potential Benefits Timeframe (yrs) 1	2 to 3	4 to 5
A1	60	yes	20	■		
A2	20	yes	6		■	
A3	40	yes	12	■		
B1	36	yes	12	■		
B2	24	no	9		■	
B3	36	no	12		■	
B4	48	no	12		■	
B5	30	no	10			■
B6	24	no	6		■	
B7	18	no	6	■		
C1	36	no	12		■	
C2	15	no	6			■
C3	30	yes	8			■
C4	15	no	6	■		
D1	32	no	10		■	
D2	30	no	8			■
D3	12	no	6	■		
D4	20	no	8		■	
E1	10	no	4	■		
E2	Refer to "STARS" budget					■
E3	10	no	4	■		
E4	36	yes	8			■
E5	Refer to "STARS" budget					■
E6	10	no	6	■		
E7	36	no	12			■
F1	18	no	8		■	
F2	30	yes	12			■
F3	30	yes	8			■

EXHIBIT 5. RESOURCES REQUIREMENTS/PAYBACK TIMEFRAMES

Eight of the twenty-eight consensus initiatives comprise the essence of a research program addressing the industry's car maintenance research needs and are responsive to the stated findings:

A1 CARSHOP COMPUTERIZED MANAGEMENT & CONTROL INFORMATION SYSTEM

B6 DEVELOPMENT OF AN INDUSTRYWIDE MAINTENANCE EXPERTISE INFORMATION DISSEMINATION SYSTEM

D2 CATALOGING BEST RAPID TRANSIT CAR INSPECTION/MAINTENANCE FACILITIES' FUNCTIONAL WORKFLOWS

F1 ESTABLISHMENT OF THE ESSENTIAL SUBSTANCE OF A CAR MAINTENANCE PHILOSOPHY

C1 DEVELOPMENT OF A COMPREHENSIVE EMPLOYEE QUALIFICATION ASSURANCE PROGRAM

E7 REDUCTION OF MATERIALS STORES INVENTORY INVESTMENT THROUGH GREATER UNIFORMITY OF CAR-CARRIED EQUIPMENT AND ELEMENTS

D3 PROVIDING FOR AN INDUSTRYWIDE AWARENESS OF MULTIPLE SOURCES FOR MATERIALS STORES ITEMS BELOW THE SERVICE-EVALUATED PRODUCT LEVEL

E6 SERVICE-EVALUATED PRODUCTS LIST MAINTENANCE

The professional staff resources to perform these eight essential research projects have been estimated at from 15 to 17.5 labor years. Each is profiled in Appendix A.

I INTRODUCTION

This report provides the basis for a comprehensive rapid rail car maintenance research program plan, the products of which should:

1. be responsive to industry-wide needs -- as expressed by the rapid transit operators,

2. assist the operators to enhance the cost effectiveness of their car maintenance operations, and

3. assist the operators to maintain their revenue fleets in a safe, dependable condition throughout useful economic lives that equal or exceed their design lives.

The objectives of this car maintenance assessment study of the rapid transit industry were:

- to determine the major research and development needs of the car maintenance managers,
- to identify those research candidates for which an industry consensus exists, and
- to develop an industry ranking of consensus candidates.

Completion of the proposed research and dissemination of the products of that research will benefit rapid transit operators by assisting those operators to:

- achieve and sustain car maintenance capabilities at a level approaching optimal fleet availability,
- develop car maintenance master plans to ensure cost effective scheduling of preventive and normal maintenance,
- justify consistent allocation of adequate budgeted resources to implement the annual plan, and
- provide the basis for an informed awareness of the influence of car maintenance on scheduled service dependability and on total ownership costs of a rapid transit car fleet.

II BACKGROUND

Car maintenance departments play a pivotal role in determining the level and quality of rapid transit service by daily ensuring that a full schedule of safe, clean, dependable cars are available for revenue service. Surveys of public transit users have consistently disclosed that service schedule adherence is a major consideration in the decision to use mass transit. Service schedule adherence, as a measure of car dependability, is a reflection of car maintenance policies and practices.

Subsequent to the transition of urban rail transportation from private to public ownership during the post-World War II years, the resources annually allocated for maintenance of revenue fleets in many instances became inadequate to ensure that the useful economic life of each car-type would equal or exceed its design life. A transit authority's image and ridership depend more upon the authority's commitment to maintenance than upon any other single factor. However, while the inflation rate was soaring to record levels, the car maintenance share of a typical rapid transit operating budget entered a decline that was to last until the quality of scheduled service dependability became intolerable.

A pattern of underfunding car maintenance inevitably increases the total ownership (life cycle) costs for a revenue fleet. While attractive in the near term, the offsetting effect is to shorten the useful economic life of the undermaintained fleet. The capital cost elements of the car ownership equation are thereby increased beyond the cumulative reductions (supposed savings) in annual budget funds. Typical effects of a pattern of inadequate car maintenance budgets are:

- premature retirement of undependable revenue cars that can no longer be cost effectively maintained, and
- oversizing the replacement carbuy in anticipation of similar post-midlife dependability problems with the (under-maintained) replacement cars.

III STUDY APPROACH

GENERAL

The approach selected to achieve the stated objectives was tailored to ensure that the products of this study; i.e., the research candidates, would completely and accurately reflect the rapid transit operators' expressed needs from an industry-wide perspective.

Identification of the research that would benefit rapid transit car maintenance operations involved configuration and comparison of *Generalized* and *Optimized Scenarios*. *The Generalized Scenario* represents the most common industry practices; the *Optimized Scenario** incorporates proven exemplary practices. The differences between each most common and exemplary practice were examined. From these examinations was developed a basic list of research candidates.

Research candidate rank ordering was approached from two perspectives: qualitative and quantitative. The participating operators established a qualitative ranking. Examination of the relative influence of the products of each research candidate upon ownership cost elements established the quantitative ranking.

IDENTIFYING INDUSTRY RESEARCH NEEDS

Determining industry-wide needs for new knowledge of new technology that would enable rapid transit operators to improve the effectiveness of their car maintenance operations was a four step process:

Step One

Using the individual car maintenance practices of each North American rapid transit operator as the basis for determining which practices are typical, a *Generalized Scenario* representative of industry practices was developed. The composite in this instance reflected the most common -- not the most effective -- practices.

The *Generalized Car Maintenance System Scenario* was validated against the current practices of three rapid transit operators selected because of their excellent car maintenance capabilities:

- Chicago Transit Authority (CTA)
- Southeastern Pennsylvania Transportation Authority (SEPTA)
- Toronto Transit Commission (TTC)

CTA is noted for the quality of its car maintenance operations which is reflected by CTA's car availability record (ratio of: the number of cars ready for scheduled revenue service to fleet size). SEPTA has reversed a worsening decline in car availability while establishing a reputation for resourcefulness and maintenance know-how. SEPTA's rapid and light rail car rebuilding programs have demonstrated a cost effective alternative to premature retirement of revenue cars. TTC has for decades enjoyed an unrefuted reputation throughout the transit community for car maintenance effectiveness and scheduled service dependability.

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* *The Optimized Scenario* is Appendix B

Step Two

The next step was to synthesize an *Optimized Car Maintenance System Scenario.* An *Optimized Scenario* is a conceptual representation of best proven practices. Each proven practice must also be translatable from the operator which refined its effectiveness. Unreasonable capital investment on the part of the adaptees would be unacceptable.

Synthesize is used here instead of *conceptualize* because the optimized scenario must be practicable, feasible, affordable, and reasonable.

Practicable relates to the technology, man-machine design efficiency and institutional readiness to accept change.

Feasible addresses the world as it is; e.g., taking into account labor agreements, existing work practices, and employee qualifications.

Affordable simply recognizes that everything has a price which must inevitably be paid.

Reasonable, addresses the pragmatic nature of public funding allocation practices.

Step Three

The third step was to determine how each proven, exemplary practice that characterizes the *Optimized Scenario* differs from the more common form of that practice in the *Generalized Scenario.* The basic list of research candidates was developed by defining the research required to assist operators to improve existing practices.

The *Generalized* and the *Optimized Scenarios* comprise the ownership cost elements attributable to car maintenance. A rapid transit operator's annual car maintenance operating budget is essentially the sum of those cost elements.

Relying on the cumulative knowledge and experience within the transit community, the implications of translating each research candidate into a funded research project, completing that project, and making the research products available to the rapid transit operators were predicted and quantified. These implications address:

- car availability, and
- the useful economic life of the revenue fleet.

Car Dependability translates into service schedule adherence.

Step Four

Step Four involved the eight rapid transit operators selected as a representative sample. The North American rapid transit operators are listed below:

•	BART *	Bay Area Rapid Transit District (San Francisco)
	BRRTS	Baltimore Regional Rapid Transit System
•	CTA	Chicago Transit Authority
	GCRTA	Greater Cleveland Regional Transit Authority
•	MBTA	Massachusetts Bay Transportation Authority
•	MARTA	Metropolitan Atlanta Rapid Transit Authority
	MDCTA	Metropolitan Dade County Transit Authority
•	NYCTA	New York City Transit Authority
•	PATCO	Port Authority Transit Corporation (NJ-PA)
	PATH	Port Authority Trans-Hudson Corporation (NJ-NY)
•	SEPTA	Southeastern Pennsylvania Transportation Authority
	TTC	Toronto Transit Commission (Ontario, Canada)
•	WMATA	Washington Metropolitan Area Transit Authority (DC)

The basic list of research candidates was submitted to the participating operators for evaluation, preliminary ranking, and the addition of any operator-initiated candidates that the participants felt would make the list a complete representation of the industry's major car maintenance research needs.

RANKING INDUSTRY RESEARCH NEEDS

Efforts were made to rank the research candidates:

- to reflect the transit industry's judgment regarding the value of the products of each research project to the industry as a whole, and
- according to benefit/cost indices.

The first is the qualitative approach; the second is quantitative.

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*
• indicates a participating operator/member of the APTA Car Maintenance Liaison Board.

The Qualitative Approach

The basic list of research candidates was submitted to the participating operators and suppliers for evaluation, culling and expansion to include other major car maintenance research needs. Uniform identification, selection and ranking criteria were provided to each participant to ensure coherent development of a research plan.

The Quantitative Approach

Complementing the qualitative approach was the research analysis directed toward quantifying the costs of performing the proposed research and of the implications potential in each funding allocation option (the benefit/cost indices.) The quantification process took the form of:

- examining each Car Maintenance Scenario as a whole,
- identifying each constituent ownership cost element,
- determining the interdependency among cost elements and the nature of these interactions,
- obtaining and examining the annual car maintenance budgets and actual expenditure records of the eight participating operators for the same recent year,
- converting operator-specific car maintenance resources data into a uniform format that addresses each car maintenance cost element, (See Appendix C)
- analyzing costs attributable to each element identified in the two Car Maintenance Scenarios,
- normalizing operator-specific cost data, developing car maintenance performance measurement indicators (PMI), and applying those PMI as a means of relating operator-specific resources allocation practices and revenue fleet conditions on an operator-to-operator and an operator-to-industry basis,
- defining the implications potential in an operator's adoption of the products of each research candidate on the basis of the PMI's.

Performance Measurement Indicators

Before the relative effectiveness of the tangible benefits derived from the allocation, management and consumption of available resources could be determined for dissimilar operations, measurement criteria had to first be established. Since benefits are a measure of performance effectiveness, normalized car maintenance cost data were selected as performance measurement indicators. (See Appendix D, *Normalization Format For Comparison Of Operator-Specific Car Maintenance Resources Data.)*

IV THE RESEARCH CANDIDATES

GENERAL

Industry-wide car maintenance research needs were developed from:

- two working sessions with representatives of the participating operators (the APTA Car Maintenance Liaison Board), APTA personnel, and supplier representatives,

- contractor conferences with line managers and supervisors repsonsible for, and key personnel in support of the rapid railcar maintenance operations at eleven North American transit authorities during nineteen visits, and

- analysis of transit industry car maintenance policies, practices, resources and constraints from World War II to the present.

The proposed research, which addresses the major industry-wide need for car maintenance was identified. Those major needs took the form of the 28 discrete initiatives, or research candidates, listed in Exhibit 1. Exhibit 2 is the format for profiling each research candidate. Each has been described (in Appendix A) in sufficient detail to provide reviewers with an understanding of:

- the specific research need which is addressed,

- the benefits that the industry should derive from adaptation of the research products and the timeframe for those benefits to become apparent,

- the implications of performing this research and/or deploying the products thereof,

- a description of the form and scope of the required research effort, and

- estimated resource requirements to accomplish the research effort. These estimates include the professional time of federal employee participants/monitors.

Exhibit 3 is a quick-look reference chart listing the resources requirements and potential benefit payback timeframes for each research candidate.

FUNCTIONAL GROUPING

The ability of a typical rapid transit operator to maintain its revenue fleet can be measured in terms of the six functional areas:

1. Data Managemant and Analysis,
2. Practices, Procedures & Standards,
3. Human Resources Utilization,
4. Physical Resources Management,
5. Car System Design, and
6. Policy.

Category A: Data Management & Analysis

A1 CARSHOP COMPUTERIZED MANAGEMENT & CONTROL INFORMATION SYSTEM(CMCIS)

A2 SCHEDULING CAR SUBSYSTEMS REPLACEMENT ON THE BASIS OF FAILURE DATA

A3 COST TRADEOFF ANALYSES OF EARLY REPLACEMENT OF INEFFICIENT CAR-CARRIED PRODUCT DESIGNS

Category B: Practices, Procedures & Standards

B1 SPECIFICATIONS FOR THE PURCHASING, REPAIR & REBUILDING OF CAR SYSTEM ELEMENTS

B2 PRE-INSTALLATION INSPECTION OF CAR-CARRIED EQUIPMENT

B3 DISCIPLINED DIAGNOSTIC APPROACHES

B4 METHODS, PROCEDURES AND PERFORMANCE STANDARDS

B5 FAILURE MANAGEMENT

B6 AN INDUSTRYWIDE MAINTENANCE EXPERTISE INFORMATION DISSEMINATION SYSTEM

B7 MANAGEMENT OF REVENUE SERVICE TESTING OF ALTERNATIVE CAR-CARRIED PRODUCTS

Category C: Human Resources

C1 EMPLOYEE QUALIFICATION ASSURANCE

C2 INCENTIVES/RECOGNITION OF EXCEPTIONAL PERFORMANCE

C3 THE INFLUENCE OF FORMAL TRAINING ON FLEET UTILIZATION

C4 THE INTERACTIVE ROLES OF CAR MAINTENANCE ENGINEERS AND SHOP OPERATIONS

Category D: Physical Resources

D1 MATERIALS STORES MANAGEMENT

D2 CAR INSPECTION/MAINTENANCE FACILITIES' FUNCTIONAL WORKFLOWS

D3 INDUSTRYWIDE AWARENESS OF MULTIPLE SOURCES FOR MATERIALS STORES ITEMS BELOW THE SERVICE-EVALUATED PRODUCT LEVEL

D4 COST TRADEOFF ANALYSIS OF A LOGISTICAL SUPPORT "PIPELINE" VS THE TRADITIONAL MATERIALS STORES APPROACH

Category E: Car System Design

E1 CAR MAINTENANCE DEPARTMENT INFLUENCE ON NEW CAR DESIGN

E2 IMPROVED AIR COMFORT SUBSYSTEM REQUIREMENTS

E3 WINTERIZATION OF RAPID RAILCAR PNEUMATIC SUBSYSTEMS

E4 MULTIPLEX TRAINLINING OF SUBSYSTEM STATUS INFORMATION

E5 SOLID STATE/AC PROPULSION TECHNOLOGY DEPLOYMENT

E6 SERVICE-EVALUATED PRODUCTS LIST (SEPL) MAINTENANCE

E7 GREATER UNIFORMITY OF CAR-CARRIED EQUIPMENT AND ELEMENTS

Category F: Policy

F1 THE ESSENTIAL SUBSTANCE OF A CAR MAINTENANCE PHILOSOPHY

F2 BUDGETARY RESOURCES ALLOCATION PRACTICES WITHIN THE TRANSIT INDUSTRY

F3 THE ECONOMIC IMPLICATIONS OF PROGRESSIVE MAINTENANCE VS THE MAJOR OVERHAUL

EXHIBIT 1. THE 28 INDUSTRY-CONSENSUS RESEARCH CANDIDATES

Research Candidate ___________

Category:

Title:

THE PURPOSE OF THIS RESEARCH

POTENTIAL BENEFITS

Timeframe — Research Products would produce tangible benefits ......

__________ during first operational year
__________ within 2 to 3 years
__________ within 4 to 5 years

Detail

SECONDARY IMPLICATIONS

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

THE RECOMMENDED RESEARCH

Project Form

Products

APPROACH

RESOURCES REQUIREMENTS

Calendar Time ____________ months

Professional Time ____________ labor months

Computer Processing ___yes _____ no

EXHIBIT 2. PROJECT PROFILE FORMAT FOR RESEARCH CANDIDATES

Research Candidate No.	Professional Time (labor months)	Computer Processing	Project Duration (calendar months)	Potential Benefits Timeframe (yrs) 1	2 to 3	4 to 5
A1	60	yes	20	■		
A2	20	yes	6		■	
A3	40	yes	12	■		
B1	36	yes	12	■		
B2	24	no	9		■	
B3	36	no	12		■	
B4	48	no	12		■	
B5	30	no	10			■
B6	24	no	6		■	
B7	18	no	6	■		
C1	36	no	12		■	
C2	15	no	6			■
C3	30	yes	8			■
C4	15	no	6	■		
D1	32	no	10		■	
D2	30	no	8			■
D3	12	no	6	■		
D4	20	no	8		■	
E1	10	no	4	■		
E2	Refer to "STARS" budget					■
E3	10	no	4	■		
E4	36	yes	8			■
E5	Refer to "STARS" budget					■
E6	10	no	6	■		
E7	36	no	12			■
F1	18	no	8		■	
F2	30	yes	12			■
F3	30	yes	8			■

EXHIBIT 3. RESOURCES REQUIREMENTS/PAYBACK TIMEFRAMES

Since the 28 research needs translate into opportunities for improvement in one or more of these six areas, Exhibit 1 presents each research candidate in the most appropriate functional area.

TRANSIT INDUSTRY RANKING

Qualitative/Judgmental

To provide the decision makers with a rational basis for allocating limited resources, the basic list (14 of the complete final list) of 28 research candidates were rank ordered to reflect the judgment of the 8 participating rapid transit operators.

Each participant was requested to provide his professional judgment as to the relative value to the rapid transit industry on-the-whole of the products of each research candidate by classifying each candidate in one of 3 categories observing the following criteria:

- Category I • Most Important (Industry must have. Research project results would decidedly contribute to greater car maintenance effectiveness.)
- Category II • Very Important (A definite need within the industry. Research product results would contribute to greater car maintenance effectiveness in the near term.)
- Category III • Important, if funding available after funding Categories I & II projects. (Research project results would contribute to greater car maintenance effectiveness over the long term.)

There was no limit placed on the number of candidates that could be placed in any given category.

A corporate ranking for each research candidate was determined according to the following numerical value scheme:

Each Category I vote = 5 points

Each Category II vote = 3 points

Each Category III vote = 1 point

An indeterminate or ambiguous ranking was scored as three points.

An X vote for deletion was unscored.

Attempts to obtain participant evaluation of those candidates augmenting the basic list produced unclear responses. For this reason, the complete list of 28 research candidates groups the candidates into the most appropriate functional area. This arrangement does not attempt to reflect industry rank ordering.

Chapter V of this report titled, FINDINGS AND RECOMMENDATIONS, presents that essential car maintenance research that accurately reflects the participating operators' determination as to substance and relative need.

Quantitative

Car maintenance resources data* was requested from each of the participating operators (with the understanding that the data would be disclosed only among the project research staff) and with the intent to derive normalized cost data ratios (NCRD) as industry wide performance measurement indicators (PMI). While that cost data does not appear in this report, it was used to develop normalized cost data ratios (NCDR).

Normalized cost data ratios have two immediate applications: the first is to provide the basis for determining the relative benefit/cost indices for each of the 28 research candidates. The second is to provide each rapid transit operator with performance measurement indicators (PMI's) in five different reference frames:

- The complete sample of 8 rapid transit operators
- Seven of the 8-operator sample, with NYCTA excluded
- The 4 older operators (CTA, MBTA, NYCTA, SEPTA)
- Three of the older operators, with NYCTA excluded
- The 4 newer operators (BART, MARTA, PATCO, WMATA)

This approach neither suggests nor implies direct comparability of NCRD/PMI data except by transit authority employees with firsthand knowledge of the similarities and differences that characterize the operations being compared. This approach recognizes that each operator is best equipped to make a determination as to whether other operators have revenue cars of similar complexity, and whether they have old or modern maintenance equipment, facilities, etc.

Exhibit 5, *Benefit/Cost Matrix,* offers decision makers a graphic measure of the potential value of the products of each of the 28 research candidates.

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* 1. Exhibit 4 is a listing of the performance measurement indicators (i.e., the normalized cost data ratios).

2. Appendix C consists of the: Data Request Format, Explanatory Notes, and Computer Programming Instructions which were developed to provide a uniform format for recording operator-specific budget data.

N-1	Capital & Operating figures for all/or for only certain Car Inspection/Maintenance Facilities (CIMF) -- per car
N-2	Personnel allocated at or assigned to all or only certain CIMF -- per car
N-3	CIMF employee hours -- per car (All employees actually located at that/those sites)
N-4	Mean distance between repairs (MDBR) (unscheduled maintenance actions)
N-5	Number of road failures/car
N-6	Availability Index (Average no. of cars daily available for scheduled revenue service/active revenue fleet size)
N-7	Ratio of: Total no. of CIMF employee hours to the average annual mileage of a car in scheduled revenue service
N-8	Ratio of: All CIMF employee hours to perform ONLY SCHEDULED car inspection & maintenance to the no. of shop CIMF employee hours to perform both SCHEDULED AND UNSCHEDULED car inspections & maintenance (These are all hours including all uncontrollable; i.e., contractually defined time)
N-9	Ratio of: Materials stores stockage & replenishment costs to the mean distance between unscheduled maintenance actions
N-10	Ratio of: Total no. of CIMF equivalent labor hours*at all or only certain CIMF to the total no. of unscheduled maintenance actions at those CIMF
N-11	Ratio of: Total no. of foremen at all or only certain CIMF to the no. of cars maintained by those CIMF
N-12	Ratio of: Materials stores stockage & replenishment costs to active fleet size
N-13	Ratio of: Total no. of CIMF equivalent labor hours*to the no. of cars maintained by those CIMF

(*i.e., equals value of contracted-out work)

EXHIBIT 4. THE NORMALIZED COST DATA RATIOS/PERFORMANCE MEASUREMENT INDICATORS

THE 28 RESEARCH CANDIDATES--BY CATEGORY

NCDR/PMI No.	Desired Effect	PROBABLE EFFECTS OF RESEARCH PRODUCTS / EVALUATION CRITERIA	A Data Management & Analysis			B Practices, Procedures & Standards							C Human Resources Utilization				D Physical Resources Management				E Car System Design							F Policy		
			1	2	3	1	2	3	4	5	6	7	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	1	2	3
1	▼	CIMF CAPITAL & OPERATING COSTS/CAR	▼	▼	△	▼	▼	◊	▼	◊	▼	◊	▼	◊	◊	▼	△	▼	▼	◊	▼	◊	▼	◊	▼	▼	▼	►	►	◊
2	▼	CIMF STAFFING/CAR	▼	◊	◊	◊	◊	▼	◊	◊	◊	◊	▼	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	►	►	◊
3	▼	CIMF LABOR HOURS/CAR	▼	◊	▼	◊	◊	▼	◊	◊	◊	◊	▼	▼	▼	◊	◊	▼	◊	◊	▼	◊	▼	▼	▼	▼	◊	►	◊	▼
4	▲	MEAN DISTANCE BETWEEN UNSCHEDULED MAINTENANCE ACTIONS	▲	▲	▲	▲	▲	▲	▲	▲	◊	▲	▲	▲	▲	▲	▲	◊	▲	◊	▲	▲	▲	◊	▲	▲	▲	▲	►	▲
5	▼	NO. UNSCHEDULED MAINTENANCE ACTIONS /CAR	▼	▼	▼	▼	▼	◊	▼	▼	◊	◊	▼	◊	▼	▼	▼	◊	▼	▼	▼	▼	▼	◊	▼	▼	▼	►	◊	▼
6	▲	AVAILABILITY INDEX (CARS AVAILABLE/FLEET SIZE)	▲	▲	▲	▲	▲	▲	▲	▽	◊	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	►	►	▲
7	▼	CIMF LABOR HOURS/REVENUE CAR MILES	▼	▼	▼	▼	▼	▼	▼	▼	▼	◊	▼	▼	▼	◊	◊	▼	◊	◊	▼	◊	▼	▼	▼	▼	◊	►	◊	▼
8	▲	SCHEDULED MAINTENANCE LABOR HOURS/ SCHED. + UNSCHED. MAINT. LBR.HRS.	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◊	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◊	▲
9	▼	MATERIALS STORES S & R COSTS/ UNSCHEDULED MAINTENANCE ACTIONS	▼	◊	▼	▼	▼	▼	▼	▼	◊	◊	▼	▼	▼	▼	▼	◊	▼	▼	▼	▼	▼	◊	▼	▼	▼	▼	▼	△
12	▼	MATERIALS STORES S & R COSTS/ ACTIVE REVENUE FLEET SIZE	▼	◊	▼	▼	▼	▼	▼	◊	◊	◊	◊	◊	◊	▼	▼	◊	▼	▼	▼	▼	▼	◊	▼	▼	▼	▼	◊	▼
13	▼	CIMF EQUIVALENT LABOR HOURS/ NO. OF CARS MAINTAINED THERE	◊	◊	▼	▼	◊	◊	▼	◊	◊	▼	▼	◊	▼	▼	◊	▼	◊	◊	▼	▼	◊	◊	▼	▼	◊	►	◊	◊
	▼	MATERIALS STORES STOCKAGE & REPLENISHMENT (S & R) COSTS	▼	△	▼	▼	▼	◊	▼	◊	▼	▼	◊	▼	▼	◊	▼	◊	▼	▼	▼	△	△	△	◊	▼	▼	►	►	►
	▲	EFFECT ON LIFE CYCLE COSTS	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	◊	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	►	◊	▲
	▲	EFFECT ON RIDERSHIP	►	►	►	►	►	►	►	►	►	▲	▲	◊	▲	▲	▲	◊	◊	►	▲	▲	►	◊	▲	▲	▲	▲	◊	►
	■	RETURN ON INVESTMENT (BENEFITS > OWNERSHIP COSTS)	■	▣	■	■	▣	▣	▣	□	▣	■	▣	□	□	■	▣	□	■	▣	■	□	■	□	□	■	□	▣	□	□
			1	2	3	1	2	3	4	5	6	7	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	1	2	3
			A			B							C				D				E							F		

KEY

- ▲ INCREASE (ANNUAL), DESIRED
- ▼ DECREASE (ANNUAL), DESIRED
- △▽ INCREASE/(ANNUAL), *UNDESIRED* DECREASE

- ▲ DESIRED EFFECT
- ► WOULD ACT TO STABILIZE OR SUSTAIN AT EXISTING LEVEL
- ◊ NO PREDICTABLE EFFECT

BENEFITS WOULD MARKEDLY EXCEED RD&D COSTS AND WOULD BE RECOGNIZABLE AND TANGIBLE:

- ■ DURING FIRST OPERATIONAL YEAR
- ▣ WITHIN 2 TO 3 YEARS
- □ WITHIN 4-TO-5 YEARS

V FINDINGS AND RECOMMENDATIONS

GENERAL

The nature of the research proposed herein is for the most part directed toward formalizing and disseminating knowledge that would benefit policy level and car maintenance line management and support staff officials at any domestic rapid transit operation. Key to any research program to assist the operators to enhance and improve the overall effectiveness of their revenue fleet maintenance capabilities are the five dominant issues discussed as FINDINGS.

FINDINGS

1. **The pivotal influence of car inspection and maintenance facility record keeping -- and management and timely analysis of those records data -- upon the cost effectiveness of car maintenance operations is not generally recognized within the transit industry.**

2. **Improved, frequent, one-on-one communications among rapid transit operator car maintenance line management personnel would probably do as much or more to improve car maintenance effectiveness than would any of the research recommended herein, with the exception of research candidates:**

A1 CARSHOP COMPUTERIZED MANAGEMENT & CONTROL INFORMATION SYSTEM, and

F1 ESTABLISHMENT OF THE ESSENTIAL SUBSTANCE OF A CAR MAINTENANCE PHILOSOPHY.

3. **A concise, codified statement of the basic, essential substance of a rapid transit car maintenance philosophy would provide policy level officials at all domestic transit authorities with a universal guide -- a set of minimum standards. Such a guide would form the basis for a** commitment to ensure:

- scheduled service dependability,
- programmed, preventive maintenance of the revenue fleet, and
- the assured availability of qualified personnel.

A coherent policy would be premised on recognition of the interdependence of performance goals for revenue service and fleet maintenance operations. To illustrate: the number of road failures (equipment malfunctioning or failures during scheduled revenue service that negatively affect schedule adherence or ride quality) experienced on an average day is the dominant indicator of car maintenance effectiveness. If a revenue fleet has not been sized to include an adequate number of spares (quantity daily available for programmed inspection and maintenance beyond that required to "make the line"; i.e., provide full service during peak periods), a preventative maintenance program cannot be adhered to -- despite the availability of adequate car maintenance resources.

4. Training is a vital industry-wide need. A labor intensive industry, public transit must recognize employee qualification resources as an investment. The value of continuing employee education and training is without question beneficial.

5. Non-interchangeability of similar elements of car-carried equipment among different carbuys of a given operator and among the car system designs of most operators is costly in that:

- the benefits inherent in economy-of-scale, replacement parts production cannot be achieved,
- market size and traditional buying practices act to inhibit the entry of new vendors into the marketplace, and
- identification and awareness of qualified "second sources" for replacement parts are too often limited to the operator who made that determination.

RECOMMENDATIONS

The Essential Research

Eight of the twenty-eight industry consensus initiatives comprise the essence of a research program that addresses the industry's car maintenance research needs. They are listed below according to the relative value of their products to the operators:

A1 CARSHOP COMPUTERIZED MANAGEMENT & CONTROL INFORMATION SYSTEM

B6 DEVELOPMENT OF AN INDUSTRYWIDE MAINTENANCE EXPERTISE INFORMATION DISSEMINATION SYSTEM

D2 CATALOGING BEST RAPID TRANSIT CAR INSPECTION/MAINTENANCE FACILITIES' FUNCTIONAL WORKFLOWS

F1 ESTABLISHMENT OF THE ESSENTIAL SUBSTANCE OF A CAR MAINTENANCE PHILOSOPHY

C1 DEVELOPMENT OF A COMPREHENSIVE EMPLOYEE QUALIFICATION ASSURANCE PROGRAM

E7 REDUCTION OF MATERIALS STORES INVENTORY INVESTMENT THROUGH A GREATER UNIFORMITY OF CAR-CARRIED EQUIPMENT AND ELEMENTS

D3 PROVIDING FOR AN INDUSTRYWIDE AWARENESS OF MULTIPLE SOURCES FOR MATERIALS STORES ITEMS BELOW THE SERVICE-EVALUATED PRODUCT LEVEL

E6 SERVICE-EVALUATED PRODUCTS LIST MAINTENANCE

The professional staff resources to perform these eight essential research projects have been estimated at from 15 to 17.5 labor years. The objectives of Project D2 might well be accomplished as a "piggyback", no-cost product of Project B6.

The nature of the research proposed herein is for the most part directed toward formalizing and disseminating knowledge that would benefit policy level and car maintenance line management and support staff officials at any domestic rapid transit operation.

THE PERFORMANCE MEASUREMENT INDICATORS

1. The performance measurement indicators (PMI) that have been developed during this study offer a practical basis for each rapid transit operator to compare the relative effectiveness of its car maintenance capability with those of other operators, and against industry-wide indices (normalized car maintenance cost data) within the context of available resources and allocation decisions.

Each operator's unique performance measurement indices should be augmented by four elements of operator-specific characteristics data:

- Year of record
- Active revenue fleet size, total
- Active revenue fleet size, by age
    - Percent under 10 years old
    - Percent 10-20 years old
    - Percent older than 20 years
- Average annual revenue mileage per car.

APPENDIX A

PROFILES of the 28 INDUSTRY-CONSENSUS CAR MAINTENANCE RESEARCH CANDIDATES

Research Candidate A1

Category: Data Management & Analysis

Title: CARSHOP COMPUTERIZED MANAGEMENT & CONTROL INFORMATION SYSTEM (CMCIS)

THE PURPOSE OF THIS RESEARCH

This research candidate would be conducted in two discrete phases.

The purpose of Phase One would be to develop, install, operate and refine within a car inspection/maintenance facility (CI/MF) of a cooperating transit authority, and under the direct control of the appropriate CI/MF general superintendent, a dedicated computerized capability to enhance the operational effectiveness and productivity of that CI/MF.

The purpose of Phase Two would be to develop and validate at an operating car inspection/maintenance facility (CI/MF) a computerized capability for generating and maintaining configuration status and service histories of (1) each individual car in the active revenue fleet, and (2) each car-carried critical or high value component.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits during the first operational year of the CMCIS.

Detail — (Phase One)

- Productivity of shop clerical personnel would be markedly increased.
- Car history records could be maintained current on a daily basis with the entry of completed work order data into the computer via desktop terminals.
- Car histories could be "called up" instantly on the visual display unit.
- Scheduled shopping of cars could be programmed on the basis of either mileage or time "trigger thresholds".
- Road failures could be correlated on a fleetwide, carbuy, and/or route-specific basis.
- Service and maintenance histories of each carborne subsystem and major component could be developed and maintained as a piggyback output at no consequential additional cost.
- Warranty monitoring of rehabilitated or procured parts and subsystems should promote greater responsiveness on the part of involved suppliers.

As a minimum, the CMCIS would have the capability to:

- Monitor individual car mileage or time between inspections and maintenance actions,
- Schedule shopping of cars for inspection and preventive maintenance,
- Record completed work order information as significant elements of any number of MIS data files, and
- Generate and maintain complete and current maintenance history and configuration records for each car in the active revenue fleet.

Detail (Phase Two)

- The existence of, ability to computer correlate, and the convenience of a recall/visual display at any computer terminal location would make possible and promote joint/simultaneous analysis of priority equipment problems by the car maintenance engineering staff and CI/MF personnel.

  Realtime recording of modifications to car-carried subsystems and major components would make the:

  - product configuration management, (and)
- car system functional interface management disciplines available to CI/MF manager, the car maintenance engineering staff, and to the new car design project director.

Complete, formatted and readily accessible servicing/failure records would make possible:

- trend analysis of equipment performance as basis for -
  - product improvement,
  - establishing and modifying preventive inspection/maintenance actions, and
  - identifying incipient failures;
- materials consumption activity -
  - to be recorded on a realtime basis,
  - to influence, on a realtime basis, on materials store stockage levels and on procurement pipeline activity,
  - activity to update stockage level threshold trigger values;

- performance measurement of shop employees,
- maintenance of the Service-Evaluated Products List (SEPL) on a realtime basis; and
- effective oversight of products under warranty.

SECONDARY IMPLICATIONS (Phase One)

Planned and in-place computer systems of domestic transit authorities are for the most part large-scale omnibus designs intended primarily to serve the budgeting and accounting functions. Therefore, it is generally believed among transit authority policy-level management that these systems can be expanded to adequately meet the requirements of Car Inspection/Maintenance Facility (CI/MF) General Superintendents.

A federally-subsidized research project in cooperation with a willing Transit Authority is the only way to demonstrate the low cost and simplicity of installing a computerized replacement for essentially all handwritten and typed CI/MF production schedules, work orders, labor, materials, and car history records data.

Completion of this research project is an essential prerequisite to commencement of project activity on research candidates A2, A3, B3, B4 and D1.

SECONDARY IMPLICATIONS (Phase Two)

- All Car Inspection/Maintenance Facilities (CI/MF) must adopt and rigorously follow a work order control system of allocating and recording the utilization of CI/MF resources.
- This research/demonstration project could most economically be carried out with the cooperation of a rapid transit operator whose revenue fleet consists of its initial car-buy.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

The majority of transit authorities use computers for payroll, accounting, budgeting, and personnel records management functions. Some also monitor motor fuel, electrical power, and materials consumption costs.

In few instances does an operator's management information system (MIS) address the needs of the CI/MF General Superintendent. While he is usually provided with periodic, after-the-fact records or analyses of shop-related operating and budget allocation/expenditure statistics, review of those statistics too often only increases his workload without contributing to his effectiveness.

Revenue service mileage records are maintained for every rapid transit car on the active fleet roster. Each day the number of miles that each car has operated in scheduled service is recorded. Depending on the data management system adopted by the transit authority, the daily service mileage may be:

- manually added to each car's hard copy performance record, or
- entered into a computerized performance record by use of punch cards or computer terminals, or
- entered automatically into a computerized performance record via a computer program tied into automatic train car identification systems.

Whether manual or ADP, each Transit Authority's revenue service mileage records are designed to isolate and identify all cars which have accumulated sufficient revenue mileage/time since a previous datum event to ensure that those cars are shopped for scheduled inspections and preventive maintenance or for planned overhaul action.

Operational activities within Car Inspection/Maintenance Facilities (CI/MF) are, for the most part:

- scheduled,
- formalized (work orders),
- monitored (car history records review and analysis),
- recorded,
- assimilated, and
- correlated

by shop clerks working with a combination of handwritten and typed first generation paperwork. As an affordable alternative, desktop-generation computer systems have in recent years demonstrated their time/effort superiority. In addition to operational economies, desktop computers offer the capability to correlate, compare, and selectively recall information.

The older rapid transit operators all depend for the most part on handwritten shop records as the basis for developing and maintaining:

- service and maintenance histories and car system configurations of individual cars in the active revenue fleet,
- installation, inspection, repair and failure histories of critical and high value products which are elements of car-carried subsystem and major components,
- the extent of different design configurations of each major car-carried component throughout the revenue fleet.

As a consequence:

- design deficiencies of products that had been improperly engineered for the end-use application cannot be readily tracked or identified at the incipient failure stage,
- materials stores stockage levels and procurement actions cannot be related with any appreciable degree of confidence to the actual configurations of either the cars scheduled for shopping or of the car-carried equipment to be serviced. The economics and operational ease resulting from recent advances in computer technology -- especially, miniaturization, simplified programming and data entry, and adjunct visual displays -- make installation of a computerized car system history management capability in every Car Inspection/Maintenance Facility (CI/MF) not only affordable, but probably at a lower cost than the much less efficient manual system.

THE RECOMMENDED RESEARCH

Project Form (Phase One)

Developmental research/systems study in a deployment demonstration application.

Project Form (Phase Two)

A combined developmental research systems study and deployment demonstration at a CI/MF of a cooperating rapid transit operator.

Products (Phase One)

- An in-place operating CMCIS in that CI/MF of the cooperating operator at which site this project will have been conducted
- Procedural knowledge of the planning, scheduling, logistical and resources requirements to (1) expand the prototype CMCIS throughout all the Car Inspection/Maintenance Facilities (CI/MF) of the cooperating transit operator, and (2) install a similar CMCIS at other CI/MF's at any other transit authority.

Products (Phase Two)

An operating, validated car system history management capability; i.e., a computerized capability to initially generate and thereafter maintain on a realtime basis:

- car system configuration status for every car in the active revenue fleet
- the configuration status of each car-carried product that the rapid transit operator deems to be critical or high value

- service and maintenance histories of:
  - •• each revenue car,
  - •• each critical/high value car-carried product.

APPROACH (Phase One)

1. Develop, install and operate a prototype CMCIS in a Car Inspection/ Maintenance Facility.
2. Demonstrate the role of the CMCIS in improving the effective utilization of shop personnel, plant and equipment resources.
3. Provide empirical capital and operating costs data.
4. Identify quantifiable and qualitative economies which directly result from a fully operational CMCIS.
5. Evaluate the relative effectiveness of a general superintendent's function with and without a CMCIS which:
   - is under his direct control, and
   - is dedicated to enhancing his ability to carry out his assigned role and responsibilities.

APPROACH (Phase Two)

1. Develop procedures and computer programs:

   a. Establish data collection procedures for:

   - initial recording and formatting of raw data,
   - controlling/monitoring data recording,
   - transferring raw data into machine language,
   - inputting to computer,
   - programming for computer creation of -
     - •• servicing
     - •• failure
     - •• configuration (modification recordings)

   files for each car-carried subsystem and major component.

b. Acquire and install requisite computer system elements; notably CI/MF terminals for inputting work order data.

c. Train and inform all involved employees.

d. De-bug the system.

2. Demonstrate the car system (car-carried products) histories management capability (CSHMC) at the CI/MF of a cooperating rapid transit operation.

   a. Operate the CSHMC for a full six month demonstration period

   b. Maintain demonstration phase diary from the separate perspectives of:

      - CI/MF General Superintendents
      - Materials Stores Management,
      - Shop Foremen.

   c. Track all costs associated with planning for, installing, debugging and operating the system during the demonstration period.

3. Publish a generalized car system history management system (CSHMS) design and implementation plan that could readily be adapted by any rapid transit operator:

   a. Modify procedures and computer hardware and software as indicated by the demonsration phase experience;

   b. Present the resources requirements associated with:

      - introduction of the generalized CSHMC capability to a typical CI/MF, and
      - first year operating costs of the CSHMC;

   c. Publish a complete description of the generalized CSHMC together with a comprehensive detailed action plan that any rapid transit operator could follow in budgeting, planning for, adapting, installing and operating a CSHMC.

RESOURCES REQUIREMENTS

Phase One

Calendar Time ____8____ months

Professional Time ____24____ labor months

Computer Systems Hardware, Peripheral Equipment & Supplies Costs Range:

____$10,000____ to ____$25,000____

Phase Two

Calendar Time ____12____ months

Professional Time ____36____ labor months

Computer Processing _x_ yes____ no

Research Candidate A2

Category Data Management & Analysis

Title SCHEDULING CAR SUBSYSTEMS REPLACEMENT ON THE BASIS OF FAILURE DATA

THE PURPOSE OF THIS RESEARCH

To develop a procedure that, utilizing any transit authority's rapid transit car inspection, repair and failure data, would make it possible to predict the timeframe within which each car system major component would probably fail.

POTENTIAL BENEFITS

Timeframe Research products would produce tangible benefits within 2 to 3 years.

Detail

- Car system major components could be replaced prior to that time/usage threshold beyond which an unacceptable percentage (to be established separately as a matter of policy by each transit authority) of failures would probably occur during revenue service.
- As a result:
  - Fewer Road failures would be experienced.
  - Each major component could be restored to the condition which fully satisfies the using transit authority's technical specifications at less cost and in less time than would otherwise be the case if the unit had been run to failure.
  - Materials stores inventory levels of replacement car system major components could be budgeted for in a timely manner and procured according to a schedule that takes into account the prevailing lead time.
  - Contracting/shopping out provisions for car system major component renewal could be planned, budgeted, implemented and monitored in an orderly, cost efficient manner.

SECONDARY IMPLICATIONS

Research Candidate A1 is an essential prerequisite. The product of this research project will benefit only those transit authorities that also adopt and rigorously observe a commitment to renew each car system major component no later than its empirically-determined failure threshold.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

Pre-World War II rapid transit cars had been simple in design. While considered relatively slow by present standards (standards that measure performance in terms of top speed), those cars nevertheless mirrored the scheduled service times of their complex successors. While those simpler car designs -- which reached the pinnacle of engineered efficiency in the Presidents' Conference Committee (P.C.C.) car -- could be completely maintained in-house, the more complex equipment to satisfy the post-war compulsion for modern designs (read: "superior") imposed upon car maintenance departments the requirements for more elaborate tooling, higher levels of technical competence, and additional shop space.

Largely because of the depression era decline in profitability among domestic transit operators, the practice of restoring each major component of a car system on the basis of wear patterns and performance degradation records -- and to thereby avoid geometrically-scaled increasing maintenance costs -- was discarded. Preventive maintenance was deferred because ridership and the fare structure barely covered operating costs.

Following the changeover to public ownership, the consequences of years of deferred maintenance were assessed. The new owners found themselves with two options:

- Completely overhaul each salvageable car, or
- Sell or scrap those cars considered beyond economic rehabilitation.

While a general overhaul can restore a car system to a level of performance dependability that approaches that of the cars at the time they became the newest members of the active revenue fleet, overhaul of all cars of a given procurement contract is, at best, an inefficient practice:

- Each car must be removed from scheduled service for a minimum of one month's time.
- Each car system major component is replaced regardless of that major component's condition.
- Car inspection/maintenance facility (CI/MF) space, which had been scaled to provide normal support of the revenue fleet according to a preventive maintenance schedule, must be intruded upon for the overhaul program.
- CI/MF labor forces, the manning levels of which had been justified by the mission to provide normal support to the revenue fleet, must be augmented to carry out the overhaul program.
- CI/MF labor forces cannot readily be augmented by competent new personnel -
  - Since training is an uncertain or discontinued function among the older rapid transit oprators, staff augmentation becomes an "iffy" consideration.

- •• Following completion of the overhaul program, would it be politically expedient to dismiss the excess workers?

THE RECOMMENDED RESEARCH

The Project Form   A combination developmental research/deployment demonstration.

Products

An in-place operating computerized system for (1) correlating and analyzing Car Inspection/Maintenance Facilities' (CI/MF) records of inspection, maintenance & failure data for each major component of a typical rapid transit car system, and (2) predicting (in the realm of using operator-specified probability and level of confidence indices) the timeframe within which each major component would probably fail.

APPROACH

- Develop a statistically valid analytical procedure for determining the distinctive level of performance at which each car system major component should be replaced as a matter of transit authority-specific policy.

- Establish a procedure which any transit authority could follow to establish a replacement threshold (timeframe) which (1) would be a function of road failure and CI/MF work order records data, and (2) would fall within the zone of failure probability as inferred from the records data.

RESOURCES REQUIREMENTS

Calendar Time	6	months
Professional Time	20	labor months
Computer Processing	x yes ____	no

Research Candidate A3

Category Data Management & Analysis

Title IDENTIFICATION OF INEFFICIENT CARBORNE PRODUCT DESIGNS AND COST TRADE OFF ANALYSES OF EARLY REPLACEMENT

THE PURPOSE OF THIS RESEARCH

To develop a procedure for identifying (on the basis of empirical data) inefficient carborne product designs, and estimating the economic implications of retrofitting qualified alternative products.

POTENTIAL BENEFITS

Timeframe Research products would produce tangible benefits during the first operational year.

Detail

- Scheduled service operational dependability would more closely mirror that of the other car system designs within the active revenue fleet.
- Materials stores investment and activity requirements would more closely mirror those for other car system designs within the active revenue fleet.
- Negative interactive effects on other elements of the total car system design would be mitigated or eliminated.

SECONDARY IMPLICATIONS

Research Candidate A1 is a prerequisite to this research project.

Those inefficient carborne product designs that are identified during the warranty period will, in all probability, be vigorously contested by both the carbuilder and original equipment manufacturer.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

Perhaps the one single factor which has contributed most to the pandemic problem of rapid transit cars having to be "de-bugged" during scheduled revenue service is the industry-wide practice of placing into full-scale production unproven car system designs. In each instance, insufficient time had been allocated to ensure that the new cars could be operated and maintained effectively by the purchaser.

The record of some rapid railcar procurements during the 1960's and 1970's is replete with instances of cars which could not:

- be manufactured profitably,
- be operated efficiently,

- be maintained effectively, or
- offer riders dependable service.

At least four builders are at present or have recently been involved in litigation related to the quality of manufacture or the late delivery of those cars, or both.

Examples of poor car system integration proliferate. Carbuilders have incurred (unbudgeted) costs in the tens of millions for retrofit of defective items, while the Operators cite poor dependability and excessive maintenance requirements for cars presumed to represent the best design available.

A number of causes contribute to the general dissatisfaction with rail transit cars: Lack of proper specification definition, changes by the purchaser during production, inexperienced manufacturing plant workers, and poor quality control all share the focus. A lack of design standardization has led to each new car order including different car systems integration requirements. Political and economic pressures emphasize delivery of cars within the shortest possible time period. This requirement presumes a "best case" scenario. In other words: everything will go as planned and scheduled.

New car system designs that incorporate inefficient major component engineering designs and/or major component designs that cannot efficiently be integrated into the overall car system, impose upon the owning operator:

- a car system with unacceptably low performance dependability,
- disproportionately greater inspection, maintenance and replacement requirements for the inefficient component,
- materials stores/purchasing inventory investment and activity requirements.

THE RECOMMENDED RESEARCH

<u>Project Form</u> Developmental research/systems study

<u>Products</u>

A validated, computerized procedure that any domestic rapid transit operator could adapt and implement without the requirement for significant additional resources commitments to (1) identify, on the basis of empirical data, inefficient carborne product designs, and (2) estimate the economic implications of retrofitting qualified alternative products.

Inadequate data exists to identify inefficient carborne product design and the benefit/cost analysis for their replacement. Corrective maintenance is a follow-up to the failure and repair records of each car. A study should be conducted of all equipment or component failures and breakdowns to determine what action is needed to preclude recurrences. Whenever a breakdown occurs, it should be analyzed as to:

- cause,
- what repairs were made,
- what further action should be taken to assure that the failure will not recur,
- what other products are affected.

To avoid recurrences, the following actions should be taken:

- Redesign the component that failed;
- Eliminate the primary cause of the failure;
- Replace the product that initiated the failure with an improved design;
- Improve preventive maintenance procedures; adjust the frequency and detail of each inspection;
- Review and improve (if necessary) the clarity of operational procedures.

Failure reports should be analyzed at regular intervals to identify incipient trouble areas where improvement appears most needed. It is imperative that corrective maintenance be adopted as a formal procedure. An effective preventive maintenance program should then be instituted.

If recorded in sufficient detail, each failure report could be input into a computer analytical format. In addition to recording failures and corrective actions, the report should also contain:

- revenue service time,
- time required to perform fault diagnosis, inspection and repair,
- identity of involved CI/MF personnel,
- materials required

Car maintenance records should be analyzed to detect trends in car-carried equipment reliability and to define and correlate car-carried equipment failure conditions. This information could be used to determine replacement cycles for carborne equipment.

APPROACH

Establish the procedures and criteria that would enable any transit authority to (1) identify inefficient carborne product designs and (2) perform an economic impact analysis of the relative costs of:

- **retaining the inefficient product on its revenue cars, or**
- **retrofitting (revenue service demonstration indicated) more efficient products as replacement elements.**

RESOURCES REQUIREMENTS

Calendar Time	12	months
Professional Time	40	labor months
Computer Processing	x yes	no

Research Candidate B1

Category Practices, Procedures & Standards

Title SPECIFICATIONS FOR THE PURCHASING, REPAIR & REBUILDING OF CAR SYSTEM ELEMENTS

THE PURPOSE OF THIS RESEARCH

Develop the staffing and procedural requirements that a typical transit authority could follow in establishing an Engineering sub-unit to prepare and maintain up-to-date technical specifications for the procurement, repair and rebuilding of materials, products and services which are essential to the maintenance of the revenue fleet.

POTENTIAL BENEFITS

Timeframe Research products would produce tangible benefits during first operational year.

Detail

Up-to-date uniform technical specifications:

- promote open and fair price competition among qualified vendors or products or services rigorously defined by technical specifications,
- make possible procurements from competitive sources for unit and piece-part replacement,
- enable all qualified sources to price their bids realistically,
- permit design efficiencies proven on the newest cars to be retro-fitted to the older cars,
- permit orderly upgrading of the performance capabilities of older cars,
- act to reduce in-service failures of car-carried equipment because both the transit authority and all re-manufacturing firms (vendors) would have demonstrated specification compliance following rebuilding and prior to installation of the rebuilt equipment onto a revenue car,
- act to ensure the quality of workmanship and performance of both vendors and in-house repair facilities,
- act to minimize individual judgment of repair personnel.

SECONDARY IMPLICATIONS

Research Candidates A3, B1, E6 and E7 are interrelated. This must be recognized when designing and performing research on any of the four.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

The revenue fleets of older transit authorities include revenue car system designs of varying ages which had been procured from different carbuilders under separate contracts over the past 30-years and which incorporate varying evolutionary designs of proprietary products from any of several major subsystem suppliers and carborne generic equipment manufactured by competitive supply firms. Any of these car system components, in turn, is subject to product modifications by either or both the supplier and/or the operator's engineering and shop personnel throughout the useful life of the car system into which each product has been incorporated.

Configuration management is the discipline of ensuring that equipment or hardware meets carefully defined functional, mechanical, and electrical requirements and that any changes in these requirements are rigidly controlled, carefully identified, and accurately recorded.

Configuration management, not only of each car system, but also of each major carborne equipment is therefore an essential, but never-ending process.

Configuration management ensures that the technical specifications which define a product-to-be-purchased are current, complete and correct.

THE RECOMMENDED RESEARCH

Project Form   Developmental research in the form of a systems study.

Products   An action plan which any transit authority could follow to install or contract for the capability to prepare and maintain up-to-date technical specifications for revenue fleet carborne equipment and maintenance support materials.

APPROACH

- Establish a configuration control data library for each car system major component
- Record in detail the typical inspection, use-application, servicing, maintenance and recordskeeping practices and procedures for each car component
- Detail replacement actions at the piece-part level that have proven to extend the useful life and/or improve the performance reliability of the affected major components
- Develop control procedures to ensure specification compliance at the Authority's receiving station for new and rebuilt products.
- Develop form and structure of each car system major component specification

- Disseminate draft specifications among industry reviewers
- Confer with industry reviewers re each draft specification's completeness, internal consistency and readability
- Record, control and evaluate industry reviewer comments on the draft specifications
- Recommend appropriate action re each reviewer comment
- Revise each draft specification as directed by the Chief Mechanical Officer.

RESOURCES REQUIREMENTS

Calendar Time ___12___ months

Professional Time ___36___ labor months

Computer Processing _x_ yes ____ no

Research Candidate B2

Category Practices, Procedures & Standards

Title PRE-INSTALLATION INSPECTION OF CAR-CARRIED EQUIPMENT

THE PURPOSE OF THIS RESEARCH

To develop the economic implications of pre-installation inspection of car-carried equipment.

POTENTIAL BENEFITS

Timeframe Research products would produce tangible benefits within 2 to 3 years.

Detail

- The frequency and number of instances of road failures caused by equipment recently installed on the failed car(s) would be reduced to a minimum.

- Those operators which have not adopted a comprehensive pre-installation inspection program would be provided with a guidebook for installing one together with typical installation and operating costs of such a capability.

- The product of this research could serve as the justification for:

  - Capital budget funds to install a comprehensive pre-installation testing capability or to expand and complete an existing partial capability, and

  - Operating budget funds to operate this new or expanded capability.

SECONDARY IMPLICATIONS

- The quality assurance function of each affected car inspection/maintenance facility (CI/MF) would necessarily have to be reinforced and its authority re-confirmed. In this way, both in-house and vendor repair & renewal of car-carried equipment would be performed in such a manner that those repaired and rebuilt equipment would consistently meet the operator's technical specifications (the first time through the appropriate pre-installation procedures.)

- Each operator must maintain the technical specifications for all major items of car-carried equipment current and complete. Those technical specifications are the criteria against which all equipment are measured during pre-installation inspection.

- The configuration of each product that is a major item of car-carried equipment must be maintained current and complete because the technical specifications define the discrete evolutionary modifications of each given product design on cars of different carbuys in the revenue fleet.

Candidates A3, B1, B2, & D3 are interrelated. This must be taken into account when designing and performing research on any of the four.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

Prior to placing each new revenue car into scheduled service(and prior to making the final payment to the car-builder), Acceptance Tests are conducted to demonstrate that the car system fully meets the requirements as set forth in the purchaser's technical specifications. During construction and assembly of those cars the purchaser had witnessed pre-installation testing of a statistical sample of each major component, and carefully examined the pre-installation test records of another statistical sample for each item of car-carried equipment.

Even if a purchaser were to elect not to witness car-carried equipment pre-installation tests or to review carbuilder records of such specification compliance testing, the carbuilder would, of necessity, conduct those tests in order to:

- ensure OEM adherence to the technical specifications and to good work practices
- minimize delays encountered during Acceptance Testing of completed cars, and the associated effect upon cashflow.

And yet, in many instances within the rapid transit industry, car-carried equipment that is later installed as a replacement element on revenue cars is not subjected to similar pre-installation testing to demonstrate that equipment had been manufactured, repaired, and rebuilt to an operating condition that fully conforms with the operator's technical specifications.

In still other instances, adequate testing equipment is either not at hand or not properly utilized for determining whether car-carried equipment functions properly prior to installation on a revenue car. To install non-compliant or marginally-compliant equipment on a revenue car is to ignore the inevitable debilitating effects of such an act on scheduled revenue service and upon car inspection & maintenance.

Failures during revenue service:

- inconvenience riders on the affected train and waiting for and aboard following trains,

- requires the diversion of personnel resources to diagnose the problem and implement a remedy,
- often causes a train to be removed from scheduled service,
- often requires the assistance of another train to assist in movement of the crippled or dead train to the appropriate car inspection/maintenance facility (CI/MF).

Car inspection & maintenance schedules are interrupted; and its resources are inefficiently applied to removal and replacement of the failed unit.

THE RECOMMENDED RESEARCH

The Project Form	Developmental research/systems study
Products	A concise report setting forth the economic implications of pre-installation inspection of all major car-carried equipment.

APPROACH

- Examine the procedures followed by each domestic rapid transit operator to ensure that car system elements comply with applicable technical specification prior to installation on revenue cars.
- Isolate the most cost-effective procedures.
- Estimate the economic implications of adapting the most cost-effective procedures by a "typical" transit authority.
- Document findings in a concise report.

RESOURCES REQUIREMENTS

Calendar Time ____9____ months

Professional Time ____24____ labor months

Computer Processing ____yes__x__ no

Research Candidate B3

Category Practices, Procedures & Standards

Title DISCIPLINED DIAGNOSTIC APPROACHES

THE PURPOSE OF THIS RESEARCH

To perform an economic analysis of exemplary transportation industry approaches to isolating and diagnosing the initial cause of vehicle system failure.

POTENTIAL BENEFITS

Timeframe Research products would produce tangible benefits within 2 to 3 years.

Detail

Rapid transit operators would:

- be apprised of tried and proven diagnostic approaches,
- be provided with the capital and operating costs of each exemplary approach,
- be made aware of competing diagnostic routines and diagnostic equipment and of the operational and economic implications of each option.

SECONDARY IMPLICATIONS

Those parties that had acted to influence the acquisition of diagnostic equipment that was subsequently found to be unreliable, overly complicated, or too expensive to keep in calibration would not appreciate this research candidate assuming project-form.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

Before the resources required to correct the failure of a complex electro-mechanical system can be determined, the actual initiating cause of that failure must have been isolated. Fault diagnoses in industrial and defense applications invariably involves a protocol, or disciplined procedure. That procedure guides trained personnel through a sequence of actions that experience had shown to be the most efficient way of identifying the initiating cause of the failure.

With the advent of nuclear weapons, high performance aircraft and computer-assisted/controlled industrial systems, trusting fault isolation to humans, permitting the failed system to be "down" (inoperable for any appreciable length of time), could no longer be tolerated. Inaccessibility of elements of a failed system--whether because of danger to a human diagnostician or because of the costs, time, and possibility of causing further or more extensive damage during disassembly--stimulated the development and dependency upon diagnostic devices.

A distinctive characteristic of sophisticated diagnostic devices are the facts that they, in turn, require an additional investment be made for calibration devices, and that they frequently require re-calibration.

The principal users of sophisticated diagnostic equipment share a common resource that is in very short supply within the rapid transit community .....money.

THE RECOMMENDED RESEARCH

Project Form Developmental research/systems study

Products

A concise report:

- describing exemplary diagnostic approaches,
- presenting the benefits, costs and institutional implications associated with installing and operating each exemplary diagnostic capability, and
- identifying diagnostic approaches which had been tried during the past two decades and which had been found to be grossly cost ineffective or unsafe.

APPROACH

- Examine the range of procedures and equipment utilized within the transportation industry to diagnose and isolate the actual, initiating causes of equipment failures.
- Isolate tried and proven, exemplary approaches to fault diagnosis.
- Develop the benefits, costs and institutional implications associated with implementing each exemplary approach.
- Identify and discuss those diagnostic approaches which had been tried in transportation applications since 1960 and which had been discarded because of attendant economic or safety implications.
- Recommend a range of cost-effective diagnostic approaches which are limited to procedures and equipment which have been successfully employed in transportation maintenance operations.

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RESOURCES REQUIREMENTS

Calendar Time ______12______ months

Professional Time ______36______ labor months

Computer Processing ____yes__x__ no

Research Candidate B4

Category Practices, Procedures & Standards

Title METHODS, PROCEDURES AND PERFORMANCE STANDARDS

THE PURPOSE OF THIS RESEARCH

To develop a closed-loop system for promulgating, and periodically updating car inspection/maintenance facility (CI/MF) work methods, operational procedures and performance standards that would be uniform for all CI/MF of a rapid transit operation.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits within 2 to 3 years.

Detail

- Uniform work methods and oerating procedures in all car inspection/ maintenance facilities (CI/MF) of each rapid transit operator would make it possible for:
  - training curricula and lesson plans to be developed and implemented for all CI/MF personnel assignments;
  - all CI/MF employees, regardless of specific location, to be evaluated against the same performance standards; (This would create an authority-wide pool of foremen candidates.)
  - productivity standards to be established, applied, and periodically updated.
- Uniform performance standards for all CI/MF personnel assignments would enable the authority to measure personnel performance against objective criteria recognized by the trade unions representing the CI/MF workers.

SECONDARY IMPLICATIONS

- The development, introduction and notice of intention to periodically update uniform work methods, operational procedures and work standards could elicit a formalistic challenge from the labor unions that represent the CI/MF workers.
- Performance standards are analagous to navigational aids. As a sailor sets his course "by the stars", a CI/MF General Superintendent and his subordinate supervisors determine resources requirements, schedule tasks, and assign work on the basis of performance standards. They take into account the nature of the personnel resources:

- experienced/inexperienced,
- fully trained/partially trained/untrained, and
- dedicated/indifferent.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

While every original equipment manufacturer (OEM) publishes methods and procedures for use and maintenance of its products, most transit operators fail to maintain those documents current and complete.

The benefits of performance standards (e.g., average time to perform a given assignment based on objective observations and measurements) are in many cases diminished because of:

- inadequate supervision,
- inadequate recording of actual time worked and materials used to perform discrete maintenance actions, and
- insufficient resources to permit periodic comparison of published standards with actual performance records.

On some of the older rapid transit operations work methods, operating procedures and performance standards are CI/MF - specific rather than being uniform authority-wide. Such a condition precludes management of the total car maintenance function in an even-handed, consistent and cost effective manner.

The absence of published methods, procedures and standards, or the unenforced existence of these directives, act to inhibit cost effective rapid transit car maintenance operations. Promulgated directives and guidelines; formal recognition of those directives and guidelines by organized labor as contractual terms and conditions; and consistently requiring that those terms and conditions to be observed and honored -- all of these are essential elements of an effective car maintenance operation.

Few rapid transit operators can boast of a permanent Methods & Standards Group.

THE RECOMMENDED RESEARCH

Project Form — Developmental research/systems study

Products

A report that details the implementation plan for installation of a closed-loop system that would utilize work order records data as the basis for promulgating, and periodically updating, uniform car inspection/maintenance facility (CI/MF) work methods, operational procedures, and performance standards.

APPROACH

1. Examine the range of practices among domestic rapid transit operators regarding:

   - promulgation,
   - enforcement/observance, and
   - updating

of written work methods, operational procedures and performance standards.

2. Relate an example of:

   - a rigorously administered system of work methods, operational procedures, and work standards, and
   - an example of an indifferently administered system

to car availability and annualized CI/MF operating costs on a per car basis.

3. Discuss the economic, institutional and operational implications of the two examples from Research Objective No. 2.

4. Develop a closed-loop system that would utilize work order records data as the basis for promulgating authority-wide (and periodically updating) uniform car inspection/maintenance facility (CI/MF) work methods, operational procedures, and performance standards.

5. Develop an action plan that any rapid transit operator could follow to install the closed loop system detailed in Research Objective No. 3.

RESOURCES REQUIREMENTS

Calendar Time ___12___ months

Professional Time ___42___ labor months

Computer Processing ____yes__x__ no

Research Candidate **B5**

Category **Practices, Procedures & Standards**

Title **FAILURE MANAGEMENT PROGRAM**

THE PURPOSE OF THIS RESEARCH

To define the essential form and substance of a failure management program

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits within 4 to 5 years

Detail

- Irregular and unsafe revenue service incidents would be more likely to be met with an appropriate, coordinated and disciplined response on those Transit Authorities with a failure management program. The program would codify and detail incident-site responsibilities, authority ladder, and inter-departmental cooperation requirements.

- Training programs would present failure management to all employees at all levels as an expression of Authority-policy.

- The existence of a failure management capability backed by an Authority policy statement would translate into:

  - periodic hazards/undesired incidents analysis

  - post-incident analysis of each significant event by key line and staff personnel in all affected departments/functions.

SECONDARY IMPLICATIONS

Without a strong General Manager:

- a failure management capability could be perfunctorily implemented, and,

- post-incident inter-departmental review-and-analysis sessions could take the form of adversary, accusatory conferences.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

The failure management concept recognizes that undesired incidents are inevitable in any man/machine system. Recognition of that reality, however, is different from fatalistic acceptance. Rather, failure management is a merging of two rational planning, analysis and control functional areas of responsibility involving revenue service interruptions that:

- are either safety-unrelated (or)

- present a real or potential hazard to humans and/could result in significant damage to equipment and/or fixed facilities

The railroad industry has traditionally approached these two functional areas by depending on:

- the combined (but usually uncoordinated) experience-judgment of senior on-site personnel,

- codified "operating rules" (a sacrosanct set of procedures intended to cover likely contingencies, and management's bulwark against post-incident litigation).

Since the older rapid transit operations evolved as mainline railroading derivatives, and because rapid transit provides the safest mode of transportation, the rapid transit industry never got around to recognizing a failure management capability as an essential functional entity within the organizational structure of each operator.

Fatal rapid transit accidents involving revenue trains in recent years, however, point up the urgency of the industy formalizing failure management capabilities. It is ironic that two of those incidents occurred on two new rapid transit authorities that had been designed, constructed, and operated within the context of a systems safety analysis, and with organizational systems safety functional entities in-place.

THE RECOMMENDED RESEARCH

Project Form — Developmental research/systems study

Products — A Systems Safety/Hazards Analysis Guidance Document that any rapid transit operator could adapt simply by adding its site-specific detail and adjusting the scope to reflect the adaptee's requirements. The document would:

- set forth the essential substance of a comprehensive failure management program,

- specify and outline the essential implementing documents,

- detail the basic organization of the failure management functional entity (FMFE),

- provide a model charter for the FMFE, and

- present the essential substance; i.e., the complete, basic failure management operations program, in a generalized manner that would be applicable industrywide.

APPROACH

1. Visit all North American rapid transit operators to (a) view their systems safety/failure management (SS/FM) capabilities, (b) review all pertinent SS/MF guidance and directives, and (c) discuss SS/FM readiness with each:

- General Manager,
- Director of Operations, and
- Systems Safety/Failure Management Director.

2. Evaluate the information and knowledge acquired while accomplishing Objective One.

3. Draft a Systems Safety/Hazards Analysis Guidance Document to conform with the description in, Section e.(2) Products, of this Project Profile.

4. Submit the draft guidance document for review by all North American Rapid Transit Operators.

5. Incorporate those industry reviewer recommendations that would constructively improve the draft guidance document from the industry's collective perspective and in consonance with appropriate federal guidance.

6. Publish the Failure Management Guidance document.

RESOURCES REQUIREMENTS

Calendar Time ____10____ months

Professional Time ____30____ labor months

Computer Processing ____yes __x__ no

Research Candidate B6

Category Practices, Procedures and standards

Title DEVELOPMENT OF AN INDUSTRY-WIDE MAINTENANCE EXPERTISE INFORMATION DISSEMINATION SYSTEM

THE PURPOSE OF THIS RESEARCH

To develop a mechanism for industry-wide interchange of exemplary maintenance practices at any rapid transit operation.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits within 2 to 3 years.

Detail

A means would be provided for concerned parties at any transit authority to become aware of tried and proven, exemplary car maintenance approaches at any other domestic authority.

SECONDARY IMPLICATIONS

- Since published descriptions of exemplary practices would not be satisfactory blueprints for implementation/adaptation, interested readers would be required to more fully explore promising disclosures by follow-up telephone discussions with, and/or site-visits to the rapid transit operation where the exemplary maintenance practice of interest was in-place.
- Shop superintendents could be harried by upper management and by their transit authority budget & planning specialists urging peremptory adoption of attractive practices at other transit authorities.
- Exemplary practices might be tried without prior:
  - sufficient understanding of the resources requirements and institutional implications,
  - adequate implementation planning.
- Some managers may hesitate to emulate exemplary practices for fear that their superiors might regard such emulation as an indication of lack of competence will be an obstacle to implementation.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

There exist a myriad of rapid transit industry committees and subcommittees that:

- meet regularly or occasionally,
- benefit from the research, planning and continuity work performed by permanent staffs,
- contribute to the industry's body of corporate knowledge in all aspects of rapid transit operations, and to the federal government's awareness of the industry's needs, constraints and expectations.

Agencies of the federal government and the industry's promotional national organization periodically disseminate informational and statistical (not a redundancy) publications dealing with many aspects of public transportation.

Many transit industry officials and representatives and federal officials and employees devote significant portions of their workyear: preparing for, traveling to, participating in, returning from and recording the substance of conferences, seminars, and briefings.

And yet, the car inspection/maintenance facility (CI/MF) General Superintendents -- the individuals:

- at the point where policy must be translated into action
- who must see that "the line is met" each day of the year regardless of the shortfall between adequate and available (budgeted) resources
- who could benefit from the opportunity to visit the car inspection maintenance facilities (CI/MF) of other rapid transit operators, view the physical plant, equipment and operations, and exchange ideas and approaches with their counterparts or, lacking that opportunity, to have available a "catalog" of current "best practices" at other CI/MF's throughout the industry --

These key management personnel:

- lack a forum,
- rarely participate in business travel,
- lack a vehicle for interchanging tried-and-proven maintenance innovations among their fellow CI/MF general superintendents throughout the industry.

This research candidate addresses that need.

THE RECOMMENDED RESEARCH

Project Form — Developmental research/systems study

Products — A concise report consisting of two discrete parts:

- Part One (the exchange mechanism) A comprehensive, detailed and complete action plan for implementing an industry-wide maintenance expertise exchange system (MEES).
- Part Two (the exchange vehicle) The first edition of a periodical that would be the vehicle for broadcasting industry-wide those exemplary maintenance approaches that are innovative, cost effective and tried-and-proven.

APPROACH

1. Describe the existing (a) formal, and (b) informal "systems" for industry-wide dissemination of information detailing exemplary rapid transit car maintenance practices & procedures and equipment & facilities utilization.
2. For each of the most promising "systems" identified in Objective One:
   a. Determine the relative: merits, costs and utility;
   b. Estimate the additional resources which would be required to extend or enhance the two most promising existing formal "systems" to become industry-wide maintenance expertise exchange systems (MEES);
   c. Select the most promising, viable MEES.
3. Prepare a comprehensive, detailed and complete action plan for implementing the most promising MEES.
4. Publish the first edition of the Maintenance Expertise Exchange System (MEES) periodical. The initial publication will consist of one exemplary maintenance approach for each North American rapid transit operation.

RESOURCES REQUIREMENTS

Calendar Time __6__ months

Professional Time __24__ labor months

Computer Processing ____ yes __x__ no

Research Candidate B7

Category Practices, Procedures & Standards

Title MANAGEMENT AND COORDINATION OF SERVICEABILITY AND RELIABILITY DEMONSTRATIONS OF ALTERNATIVE PRODUCTS ON REVENUE CARS

THE PURPOSE OF THIS RESEARCH

To develop a uniform management and coordination procedure for revenue service demonstrations of alternative products (retrofitted onto revenue cars) to determine whether the alternative product had been adequately engineered for the cooperating operator's application.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits within the first operational year.

Detail

- Revenue service demonstrations could be performed more cost effectively
- Revenue service demonstrations would produce a more credible basis for post-demonstration data analysis of how well the tested alternative or improved products had been engineered for the specific application.
- Rapid transit operators would more readily consider vendor requests for revenue service demonstration of their products if a management and coordination capability/procedure existed.
- The number of competitive sources would be expanded.
- Competitive pricing of alternative products should result in price reductions.

SECONDARY IMPLICATIONS

Adoption of the management and coordination procedure without a commitment by the General Manager to ensure inter-departmental cooperation in its implementation, could sustain the present informal procedure under a new guise.

THE NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

During the Rapid Railcar Technology Standardization Program revenue car utilization data were analyzed to identify and evaluate those design factors which act to influence car availability for scheduled service. The findings were a restatement of the collective observations of North American rapid transit operators:

> New rapid railcars which incorporate only products which had performed satisfactorily in similar transit applications are shopped for unscheduled maintenance less than are new cars which introduce new products into the purchaser's environment.

Recognizing that a new product would very likely fail to perform satisfactorily in its initial application as part of a rapid railcar system, the operators more than a half century ago instituted the practice of specifying or permitting a limited number of cars within an equipment procurement contract to incorporate new products. A variation of that practice is operator cooperation with suppliers in making revenue cars available for retrofitting: with new technological applications, with advanced designs of equipment on the cars to be retrofitted, or with alternative products from another source. Suppliers are thereby afforded the opportunity to introduce and demonstrate new and improved products as elements of proven car system designs within the intended application and environment.

The two practices go hand in hand: By limiting new car system designs to service-evaluated and test-evaluated products, the operators should be able to more confidently schedule the introduction of new rapid transit cars into revenue service and the retirement of the cars being replaced. New car procurement contracts should thereby become profitable ventures for the carbuilders and suppliers.

Research, development and engineering costs represent sizeable investments for the suppliers. Budget allocation decisions must be biased toward those products which offer the greatest potential for increasing either market share or market size. A very desireable market is one:

- which is large enough to permit amortization of development costs through sales of a competitively priced product;
- wherein modification (applications engineering) of a product design to satisfy the expectations of potential purchasers either is not required or is minimal.
- in which purchasers are open to more economically-efficient product designs.

Operator recognition of the advantages of considering for purchase all products proved in revenue service or which had successfully completed a revenue service evaluation demonstration would establish such a market.

THE RECOMMENDED RESEARCH

The Project Form   Developmental research/systems study

Products   A generalized, detailed management and coordination procedure (MCP) that could be readily implemented by a rapid transit operator to:

- Plan and schedule the project;
- Obtain policy level -
  - commitment to the plan,
  - assignment of appropriate authority,
  - allocation of required resources;
- Obtain vendor commitment and agreement to project terms and conditions;
- Activate the revenue service demonstration;
- Oversee, monitor, and coordinate the activities of all participants, involved revenue cars, and pertinent car-carried equipment;
- Ensure the consistent recording of all performance and maintenance data upon which suitability or unsuitability of the product undergoing revenue service testing;
- Analyze and perform an objective evaluation of project data; and make a determination as to the product's serviceability and reliability in the intended application;
- Document the post-analysis determinations, and make appropriate recommendations to the appropriate policy-level transit official;
- Initiate and oversee restoration of the retrofit cars to their pre-demonstration state. Release both the restored and control cars to unrestricted service.

APPROACH

1. Examine successful transit authority-specific past and present practices with regard to evaluation of alternative car-carried products in revenue service applications.

2. Identify and discuss:

   a. the -

      - planning,
      - management,
      - control, and
      - coordination

      aspects of each project; and

   b. the -

      - scheduling,
      - monitoring, and
      - security

      aspects of the retrofitted cars and the "control" cars; and

   c. the -

      - removal of the "old" integral carborne equipment,
      - installation of the "new" retrofitted carborne equipment,
      - confirming the systems integrity of each car system

      following retrofitting and prior to operation of each retrofitted car in scheduled service.

   d. recording all required demonstration project data on a real time basis and in a disciplined manner

   e. evaluating recorded data

   f. comparing recorded data for the retrofitted cars with that for the "control" cars

   g. restoring the retrofitted cars to pre-demonstration status

   h. releasing the demonstration cars, both the restored and the "control" cars, to the Transportation Department.

3. Develop a uniform management and coordination procedure which any transit authority could adapt to conduct revenue service demonstration of the serviceability and reliability of alternative products retrofitted on revenue rapid transit cars.

RESOURCES REQUIREMENTS

Calendar Time ____6____ months

Professional Time ____18____ labor months

Computer Processing ____yes__x__ no

Research Candidate C1

Category Human Resources

Title EMPLOYEE QUALIFICATION ASSURANCE

THE PURPOSE OF THIS RESEARCH

Develop a comprehensive, baseline training program for Car Maintenance operations personnel that could be readily adapted to the distinctive requirements and resources of any transit authority.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits within 2 to 3 years.

Detail

The existence of a comprehensive and permanent employee qualification assurance (training) program, which is annually fully-funded as a matter of transit authority policy, would offer, as a minimum, the following benefits:

- Career progression opportunities for all employees;
- Competent, uniformly trained employees in every assignment;
- A working environment which would -
  - attract the more ambitious and career minded to seek initial employment,
  - act to promote mutual respect among employees,
  - condition workers to look upon transit authority employment as a career,
  - be safer, more orderly and more productive than that environment in which employee qualification training is uncertain, inconsistent or unavailable;
- Improve the management/labor relationship.

SECONDARY IMPLICATIONS

A transit authority must adopt as a matter of prevailing policy the commitment to annually provide full funding support for an employee qualification program, before installing such a program. Periodic withdrawal of budget funding support or fluctuation of the funding support-level produces a chain of negative effects which live-on in the institutional memory of the employees on the whole, and demoralize the more responsible and ambitious workers as individuals.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

Usually the first budget line item to be reduced or "temporarily unfunded" during public transit financing crises, is employee training. Yet, the increased technological complexity of new car systems requires personnel who are qualified, or can be trained, to properly maintain them.

An adequate number of professional, technical and craft personnel must have been trained and become qualified to maintain new car system designs prior to the new cars commencing scheduled revenue service. Provisions for this requirement are becoming common features of new car procurement contracts.

While the transit community as a whole recognizes that training programs should be provided for those employees who demonstrate the potential for understanding the material presented and assimilating the training offered, few authorities translate this perception into a commitment.

Where adequate, formal training programs exist or have been organic elements of virtually all transit authorities, those training programs have usually evolved on an ad hoc basis. As a result:

- few could be termed comprehensive,
- few were complete, in that they were structured as -
  - career progression vehicles which would assure continuing education for technical, supervisory/management, and staff personnel throughout lifetime employment,
  - a closed-loop process which (1) measures training program effectiveness in terms of training products, (employee subsequent performance) and (2) modifies training curricula as a function of maintenance requirements which change as new technology applications become part of the revenue fleet.

The reservoir of technically-trained new hire candidates has largely disappeared with (1) the end of the military draft, and (2) society's present disdain for manual labor. As a consequence each transit authority must reevaluate the importance of an in-house formal training capability and its influence on car maintenance effectiveness. An effective car maintenance operation translates into:

- a high fleet availability index,
- fewer scheduled service interruptions,
- fewer overtime hours to perform an operation correctly the second time,

- dependable train schedules,
- contented committed public transit users.

THE RECOMMENDED RESEARCH

Project Form Developmental research in the form of a systems study.

Products

A comprehensive training program complete with:

- career progression curricula for each career field,
- lesson plan outlines,
- physical requirements details for classroom, lecture hall, and hands-on practical training facilities.

APPROACH

Develop a baseline training program which:

- could be used industrywide as the framework for each transit authority's training program, and
- would provide a career progression ladder for shop labor, craft and supervisory personnel, and for management-level employees.

Determine the range of cost for, identify, and discuss the institutional considerations associated with installation of the baseline program on:

- a newer transit authority, and
- an older transit authority.

Describe and discuss the significant features of three exemplary training programs which may be ongoing or which may have been discontinued because of budget allocation decisions.

RESOURCES REQUIREMENTS

Calendar Time 12 months

Professional Time 30 labor months

Computer Processing ____yes x no

Research Candidate C2

Category Human Resources

Title INCENTIVES FOR AND RECOGNITION OF EXCEPTIONAL PERFORMANCE

THE PURPOSE OF THIS RESEARCH

To examine the public transit industry practices regarding (1) recognition of exceptional performance by employees and (2) planned, current, and discontinued incentive programs to improve employee productivity.

POTENTIAL BENEFITS

Timeframe Research products would produce tangible benefits within 4 to 5 years.

Detail

- The more diligent, more responsible members of the workforce would be motivated to outperform their contemporaries
- Those workers who had been performing below their capabilities would be provided with an inducement to improve their productivity.
- Those workers who could benefit from additional training and education would see the interdependent relationship between (1) the effort required on their part to extend their work-related competence, and the (2) tangible benefits offered by the employer to workers capable of performing more demanding assignments.
- A greater number of ambitious individuals would be likely to consider and seek public transit employment.
- More of those employees who had demonstrated individual competence, diligence, and responsibility would elect to continue as public transit workers.

SECONDARY IMPLICATIONS

The record of organized labor is ambivalent with regard to the issues of incentives and recognition of exceptional performance.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

The number, mix and quality of personnel in car inspection/maintenance facilities (CI/MF) in many instances is inadequate. In some situations, fewer qualified people man those facilities than actual experience and sound business practices would indicate to be required. In recent years in a large number of instances, supervisors and managers have come to have their dedication tested as they became subject to pay compression.

It has become increasingly common for members of the shop labor forces to decline promotions to supervisory positions because:

- the new assignment--with its greater responsibility, longer hours (often without compensation) and the attendant informal requirement that paperwork be taken home to be done on the employee's own time--pays less than his or her present assignment, and

- while advancement within the supervisory/management ranks appears to be assured for diligent employees, increased levels of responsibility often are unaccompanied by commensurate increases in compensation and benefits.

These past two decades have imposed frustrating working conditions for the average worker who:

- wants to do a good day's work

- derives satisfaction from a job well done,

- (while comfortable to be referred to as average) feels and likes to demonstrate that he or she can perform a task just a bit better than his or her co-worker.

With the impending withdrawal of the "security blanket" in the form of federal operating subsidies, both the rapid transit operators and organized labor recognize that worker productivity must be markedly improved -- and once improved, sustained at a mutually agreed to performance level.

There are essentially two ways in which productivity can be increased:

- One is by providing more efficient tools and man/machine processes and environments.

- The second is by motivating workers.

This research candidate addresses the second approach.

For a performance incentive to be successful, seven points must be considered:

1. Standardization of each job to determine the best way of doing it before establishing the rate;

2. Adoption of a simple system so each worker would be able to compute his/her own pay;

3. Assurance that the output standards on which incentive earning are based have been determined by competent and acceptable time-study methods or past records;

4. A method of guaranteeing that the earnings differential for above-standard work is proportional to the increased output;

5. Establishment of a clear system of daily inspecting, measuring and recording completed work so that workers can be kept apprised of their performance;

6. Periodic verification that standards are being maintained. Note: The causes are not necessarily an individual worker's fault. The problem may be a result of poor training, faulty equipment, or lack of parts or materials.

7. Development of procedures to allow workers to express themselves, if not satisfied with any part of the system. Dissatisfaction is best handled in the early stage, thereby avoiding bottled-up grievances. To alleviate workers' fears that rates would be cut, workers should be assured that the rates will not be changed except following the introduction of new tools, equipment or processes -- and then only after negotiations had been completed, and contractual agreements arrived at and agreed to by all parties.

THE RECOMMENDED RESEARCH

Project Form — Developmental research/systems study

Products

A concise report that examines:

- Public industry practices that recognize exceptional performance by employees and others directed toward improving employee productivity, and

- Examines the economic and institutional implications of the phenomenon, and presents a benefit/cost analysis of transit industry adoption of a policy against the practice of pay compression.

APPROACH

1. During visits to all North American rapid transit operators, discuss with Directors of Administration and Operations, with General Superintendents, and with appropriate local representatives of the labor organizations that represent CI/MF workers--planned, current and discontinued policies, programs and practices to:

   a. recognize exceptional performance on the part of -

- CI/MF employees, and
- all other employees of that transit authority;

b. motivate employees to improve individual productivity by offering tangible benefits as incentives.

2. Evaluate the policies, programs, and practices which had been related during the Objective One research effort.

3. Applying effectiveness criteria, rank order those incentive recognition policies, programs and practices considered "successful" by Operator and organized labor representatives during Objective One discussions.

4. Develop the economic and institutional implications of the most successful incentive recognition policies programs and practices disclosed during the Objective One research effort.

5. Publish a concise report that presents the findings of this research in an even-handed manner, acceptable to both the transit operators, to the workers, and to organized labor.

RESOURCES REQUIREMENTS

Calendar Time ____6____ months

Professional Time ____15____ labor months

Computer Processing ____yes __x__ no

Research Candidate C3

Category Human Resources

Title THE INFLUENCE OF FORMAL TRAINING ON FLEET UTILIZATION

THE PURPOSE OF THIS RESEARCH

To examine the influence of formally-trained Car Inspection/Maintenance Facility (CI/MF) personnel on car maintenance effectiveness measured in terms of revenue car availability.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits within 4 to 5 years.

Detail

- An industry awareness of the benefit/cost implications of formally-trained car maintenance shop supervisory and management employees.
- Research results should induce transit authorities to install or upgrade existing formal training programs for car maintenance shop supervisory and management personnel.
- The products of such formal training would more effectively employ allocated resources than was the case without such training.

SECONDARY IMPLICATIONS

- Additional budget monies would have to be appropriated to install an effective training program or to subsidize external training at those Authorities that accept the findings of this research.
- Would mandate a policy commitment to the existence, operation and assured annual funding of an effective training program.

THE NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITIES

All rapid transit operators recognize that car maintenance employees must be properly trained and capable of acquiring at least a minimal skill proficiency within their work assignments. Budget resources permitting, in-house formal and on-the-job training programs are provided (to the extent that budget resources permit) to those who demonstrate the potential for:

- understanding the material presented, and
- assimilating the training offered.

Prior to the Second World War, anyone aspiring to work as a craftsman had to participate in an apprentice program. The content and duration of each program, program entry opportunities, and compensation levels were established by each appropriate trade union. During periods of unemployment or under-employment, fewer applicants were permitted to commence apprentice training.

Because of the seemingly endless source of applicants who had received craft training in the uniformed services, the demise of apprentice programs by which a person could advance during a prescribed period of on-the-job training from novice to journeyman status in sub-professional career fields was scarcely noticed within the rapid transit car industry. However, abandonment of compulsory military service during the past decade, coupled with improved pay and benefits for members of the Armed Forces has largely diminished rapid transit car maintenance departments' principal source of trained workers.

During the same period, those Autorities that had established a formal training infrastructure found themselves forced by budget shortfalls to either reduce the level of training or to eliminate training capability entirely. As a consequence revenue car availability declined, and incidents of road failures during scheduled service increased.

During periods of budget resources shortfalls, training is inevitably the first functional area to have:

- ongoing programs reduced,
- planned programs delayed, or
- the entire in-house training function dissolved.

If the employer, the transit authority, cannot assure each willing and trainable employee the continuous availability of the necessary training and education to qualify for advancement, organized labor insists, the incorporation into labor contracts of what has come to be a universal tenet, i.e., employee advancement on the basis of seniority plus demonstrated qualification, becomes a meaningless objective.

Since two rapid transit operators have acted since 1980 to dissolve the training capability (in one instance) and to sustain the training function at a sharply reduced level (in the other instance), consideration of innovative approaches to providing and assuring effective, continuing training for public transit employees is a timely research issue. Providing career progression training in-house has shown itself to be:

- an uncertain resource,
- unappreciated by the budget decision-makers, and
- a source of management/labor misunderstanding.

THE RECOMMENDED RESEARCH

Project Form — Developmental research/systems study

Products

A concise report presenting the results of:

- a benefit/cost analysis of transit authority-provided formal training of all Car Maintenance Department (CMD) employees within a comprehensive program and as a policy commitment, and
- an examination of the requisite resources and the process to establish and sustain a cooperative public program for the primary purpose of providing continuing education and vocational training for transit authority employees.

APPROACH

1. Following discussions with appropriate officials of each North American rapid transit oeration:
   - Select three formal training programs that are currently or had been conducted/supported by any three Authorities, and
   - Compare the essential nature of each; e.g., organizational structure, resources, affected employees, logistics, capital and operating budgets, benefits and derivative associated inefficiencies in terms of Car Maintenance Department effectiveness.
2. Perform a benefit/cost analysis of each of those three training programs.
3. Relate composite (capital costs amortized over 5-years plus the aggregate operating budgets for 5 consecutive years) costs of each formal training program normalized on a per-car (in the active revenue fleet) basis.
4. Present the substance of the research analysis as Part One of the final report.
5. Examine existing cooperative public transit operator/State and local government programs to provide job-related, continuing education for all employees of the public transit operator.
6. Examine existing programs wherein State and/or local governments provide job-related educational opportunities for employees of:
   - publicly funded services, and
   - local industries.

7. (For each viable program identified in Objectives One and Two), examine and compare the:

   - capital and operating costs,
   - economic implications, and the
   - institutional implications.

8. Either recommend one of the programs identified in Objectives One and Two as the model-for-adoption by domestic transit authorities, or develop a composite, coherent program that incorporates the better features of two or more viable approaches.

9. Document the substance of the research analysis as Part One of a final report. An action plan for implementing the recommended approach would be Part Two of the final report.

RESOURCES REQUIREMENTS

Calendar Time ____8____ months

Professional Time ____30____ labor months

Computer Processing __x__ yes ____ no

Research Candidate C4

Category Human Resources

Title THE INTERACTIVE ROLES OF CAR MAINTENANCE ENGINEERS AND SHOP OPERATIONS

THE NATURE OF THIS RESEARCH

To develop the framework within which Car Maintenance Department (CMD) engineering staffs could most effectively be utilized and be immediately accessible to Car Inspection/Maintenance Facility (CI/MF) General Superintendents on a daily basis.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits during the first operational year.

Detail

1. An improved knowledge on the part of each transit authority's CMD engineers of the design, interfacing, operational & maintenance:

   - features,
   - behavioral characteristics,
   - limitations/deficiencies

   of each car system/car-type within the active revenue fleet.

2. A synergistic capability merging the distinctive backgrounds of professional engineering and shop labor personnel would act to improve:

   - car maintenance productivity,
   - car availability ratios,
   - the process of identifying carborne equipment/interface deficiencies in the incipient stage, and
   - the time required to develop product improvements which can be retrofitted to carborne equipment which performs unacceptably in its application.

SECONDARY IMPLICATIONS

- Some CMD engineers could be placed under the direct supervision of Car Inspection/Maintenance Facility (CI/MF) General Superintendents.

- CMD engineers could be required to spend a given part of each work day on the CI/MF floor, in the yards, on sidings under and on board cars operating in scheduled service.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

All rapid transit operators have an integral car maintenance engineering capability. This capability might take the form of a permanent staff organized as a support function. It could be a group large enough to meet the Authority's normal requirements; or the car maintenance engineering function might be performed by two or three individuals in that assignment, or by line managers in positions which include car maintenance engineering as an additional duty.

The charter of a car maintenance engineering section, group, or staff generally encompasses the following responsibilities:

1. Evaluate car system technology on an active revenue fleet basis to promote transit authority-wide standardization and to optimize car utilization;

2. Develop & design modifications to total car system design and to car system elements to improve overall dependability;

3. Develop technical specifications for rebuilt cars and for car system design modifications to incorporate, by retrofit, car-carried equipment that is technologically different;

4. Ensure contractor and vendor compliance with technical specifications for equipment and material;

5. Develop diagnostic (troubleshooting) procedures and fault isolation protocols;

6. Plan and carry out special projects;

7. Oversee each of the above programs for the transit authority;

8. Perform engineering consulting services for car maintenance managers, planners, and line supervisors.

This research candidate addresses the eighth-listed responsibility in that basic charter.

It would appear that, for a rapid transit operators engineering resource to be most effectively employed, the charter under which that resource operates should be expanded to require:

- that a proportionate amount of each engineer's time be regularly spent in Car Inspection/Maintenance Facilities;

- that each engineer develop and maintain current -

  - a detailed knowledge of the engineering design, construction and maintainability aspects of at least one car system design within the active revenue fleet,

  - a comprehensive familiarity with each of the major components that are integral to each of the car system designs in his/her area of responsibility and;

- that the comprehensive familiarity be developed firsthand by periodically working as a member of a CI/MF team inspecting & servicing that/those car(s) and by participating in the removal/replacement and in-house repair/renewal of major car-carried equipment.

The synergy of the distinctive capabilities of CI/MF technicians and members of the car maintenance engineering staff should markedly improve and sustain a near optimal fleet availability ratio.

THE RECOMMENDED RESEARCH

Project Form — Developmental research/systems study

Products

A report which any domestic transit authority could use as a model for modifying its internal policies, practices & procedures to provide for:

- more effective utilization of Car Maintenance Department (CMD) engineering personnel

- immediate accessibility of CMD engineers to car inspection/maintenance facility (CI/MF) General Superintendents on a daily basis.

APPROACH

1. Examine the role of car maintenance department (CMD) engineering personnel at three domestic transit authorities. Define that role from the separate perspectives of:

   - car inspection/maintenance facilities (CI/MF) general superintendents,

   - the CMD Engineering Staff Head,

- selected Members of the CMD Engineering Staff, and
- the Chief Mechanical Officer/Director of Rail Operations.

2. Recommend procedures, operating practices, and an organizational structural relationship which would act to optimize the responsiveness of Car Maintenance Department (CMD) engineers to Car Inspection/ Maintenance Facilities' (CI/MF) requirements for engineering assistance.

3. Present the research findings and recommendations in a concise, but comprehensive, final report.

RESOURCES REQUIREMENTS

Calendar Time ___6___ months

Professional Time ___15___ labor months

Computer Processing ____yes __x__ no

Research Candidate D1

Category Physical Resources

Title MATERIALS STORES MANAGEMENT

THE PURPOSE OF THIS RESEARCH

To examine and evaluate the relative cost and effectiveness of the range of rapid transit industry materials stores management approaches.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible results within 2 to 3 years.

Detail — More effective materials stores management would act to:

- reduce the number of instances of cars either unavailable for revenue or cannibalized because of parts unavailability;
- reduce understocking of items -
  - with very long reorder lead times,
  - for which a normal usage rate has been established by experience or can be forecast based on program planning;
- reduce overstocking of some items -
  - which require minimal re-order lead time,
  - to take advantage of a price break which cannot be offset by the cost of holding those items in inventory.
- provide that source selection not be made solely on a low-bid basis and without regard for product compliance with end-use service requirements and technical specifications;
- improve inventory dynamics recordskeeping;
- improve purchasing/materials stores responsiveness to Car Inspection Maintenance Facility CI/MD requirements.

SECONDARY IMPLICATIONS

Since the roles, prerogatives and influence of organizational entities tend to be regarded as sacrosanct in established bureaucratic organizations, it would not be reasonable to anticipate initial, enthusiastic acceptance and adaptation of the products of this research project by the older rapid transit operators.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

The cost of materials and spare parts for maintenance and overhaul of rapid transit cars accounts for a sizeable portion of car maintenance department budgets. Those transit authorities, which do not at present have in-place computerized materials management systems, are acting to develop and install such a capability.

A typical transit authority has in-place the traditional materials storage and dispensation organizational elements. The procurement and inventory management at the bulk storeroom, or wholesale, level of materials, replacement parts, tools and fasteners is usually performed by the Purchasing Department. The local, or retail, stockrooms at each Car Inspection Maintenance Facility (CI/MF) may be operated and staffed by either CMD or Purchasing employees.

Some Purchasing Departments have the resources to require each vendor to submit production samples of the item being purchased for specification compliance testing prior to commencing delivery of items (for which purchase orders/procurement contracts have been executed). Most Purchasing Departments lack this capability.

In many instances:

- Records of stock-in and stock-out activity are not made part of the overall materials inventory on a timely and regular basis,

- Stock usage/draw-down data are not analyzed according to a periodic schedule and by knowledgeable personnel to permit detection of changes in consumption rates (trends) and to relate future stockage levels to anticipated consumption rates,

- Stock replenishment trigger-levels are not subjected to periodic (at least semi-annual) updating and revision to ensure a correspondence between anticipated maintenance requirements and parts availability.

The distinctive materials/parts requirements to maintain an aging revenue fleet in safe, dependable condition are rarely anticipated and programmed. Too often those needs are addressed after the availability/road failure experience has exceeded the public's tolerance level.

THE RECOMMENDED RESEARCH

<u>Project Form</u> Developmental research/systems study

Products A generalized optimal design for a materials stores management capability which any domestic rapid transit operator could readily adapt to its specific requirements and constraints.

APPROACH

1. Examine and summarize the range of rapid transit operator-specific:

   - policies,
   - charters,
   - practices,
   - organizational distribution of responsibility and authority, communications requirements between collateral organizational entities which constructively affect and implement the materials stores function.

2. Configure alternative materials stores management:

   - policy,
   - organizational structure,
   - operating objectives,
   - accountability/performance measurement criteria.

3. Develop the economic and institutional implications of each alternative.

4. Develop an implementation/action plan for each alternative. Include:

   - resources requirements,
   - phased scheduling,
   - policy level management oversight instructions.

5. Develop an inter-departmental oversight and coordination unit for materials stores management as a permanent organizational entity accountable to the chief operating officer. This unit would ensure:

   - that best business practices would be observed in purchasing, inventory management, security and wholesale-retail service to the car maintenance shops; and
   - that materials stores stockage levels are responsive to the needs of the car maintenance shops.

RESOURCES REQUIREMENTS

Calendar Time ____10____ months

Professional Time ____32____ labor months

Computer Processing ____yes __x__ no

Research Candidate D2

Category Physical Resources

Title RELATIVE EFFECTIVENESS OF TRANSIT INDUSTRY CAR INSPECTION/ MAINTENANCE FACILITIES' (CI/MF) FUNCTIONAL WORKFLOWS

THE PURPOSE OF THIS RESEARCH

To catalog best rapid transit industry functional workflows and associated resources applications at car inspection/maintenance facilities (CI/MF).

POTENTIAL BENEFITS

Timeframe Research products would produce tangible benefits within 4 to 5 years.

Detail

The catalog would assist civil, architectural and structural engineers in optimizing the design of new Car Inspection/Maintenance Facilities (CI/MF) and in the modernization and expansion of existing CI/MF.

SECONDARY IMPLICATIONS

The decision to apply or to disregard the information contained within such a catalog could be made by a transit authority official responsible for physical plant construction and maintenance and without prior consultation with CI/MF key management and operating personnel.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

The design of Car Inspection/Maintenance Facilities (CI/MF) evolved from a recognition that routine and complex maintenance actions can most economically and effectively be performed at two distinctly designed and separate facilities.

Routine Maintenance is defined as:

- periodic inspections and servicing of the car as a complete, engineered system,
- that on-car maintenance that is usually limited to parts replacement,
- diagnosis of in-service failures, and
- routine cleaning of car interiors and exteriors.

Complex Maintenance is defined as that repair work which normally requires the immediate availability of:

- skilled craftsmen,
- industrial machinery, equipment and tooling,
- very heavy lift and transport capability, and
- turntables.

Car Inspection Shops normally perform routine maintenance. Heavy Repair Shops are designed, equipped, and manned to perform complex maintenance. Car Inspection Shop employees possess a thorough understanding of their assigned work and a general knowledge of the total equipment. Car Inspection Shops are equipped, manned and logistically supported to perform the following work:

- routine inspections and servicing of car system elements requiring lubrication, cleaning, consumables/disposables replenishment and sub-element adjustment;
- scheduled inspection and maintenance actions as a function of time or revenue mileage;
- diagnosis and isolation of the initial, actual cause of road failures of revenue trains, determination of the appropriate remedial action, and estimation of resources requirements.

While inspection and servicing schedules are initially defined by the carbuilder and his subcontractors, these schedules are invariably refined by the owning operator at the end of the warranty period with the objective of optimizing equipment utilization within the constraints of available resources.

Those repairs that require longer than one working day to complete are usually assigned to heavy repair facilities. Because of the complex nature of the work, the skilled craftsmen who comprise the workforce are supported by the Engineering Section.

Each Heavy Repair Shop is a hybrid of two functional areas; i.e., Vehicle and Manufacturing.

Within the Vehicle Area. maintenance is performed at the car system (total car) level. The Manufacturing Area is actually a complete industrial facility made up of individual shops, or crafts-areas; thereby, providing the rapid transit operator with the capability of rebuilding all major components on its revenue cars.

Representative shop activities include:

- Rotating apparatus overhaul;

- Truck rebuilding -
    - •• wheel and axle assemblies,
    - •• journal bearing overhaul,
    - •• drive unit overhaul
    - •• primary and secondary suspension
- Brake overhaul;
- Electrical control overhaul;
- Electronics systems servicing;
- Carbody -
    - •• painting &
    - •• structural repair and restoration;
- Wheel trueing;
- Pneumatics.

Following completion of the appropriate maintenance action or overhaul, the cars are moved to a final inspection and cleaning area where testing and inspections verify that cars meet all established criteria and can be returned to revenue service.

Generally, except for the newest transit authorities, car inspection and maintenance facilities were built between 30 and 80 years ago. Except for maintenance facilities built during the past twenty years, shop space and layout are designed for the movement, placement, lifting, maintenance and disassembly of single cars -- not of dependent-pairs. Those earlier design single cars were less complex in car system design, and more "forgiving" of rough handling and maintenance procedure oversights on the part of shop personnel. Some salient characteristics of the older facilities point up the design inadequacies:

- The trackage of many older Inspection and Heavy Maintenance Shops is not laid out to permit one-way, unswitched movement of cars or trains. A car/train cannot always enter a shop at one end, be inspected and serviced on the track on which it entered, and depart the shop on that same track, but from the opposite end of the shop.

- Where transfer tables are used, they are sized for single unit cars. Therefore, dependent-pairs must be separated when in-shop movement between tracks is required.

- Lift, trackage and turntable availability and layout greatly extend the labor hours and shop space allocations for de-trucking and re-trucking of cars.
- Most older wheel trueing equipment is labor intensive. In some installations the location of this equipment does not provide for efficient use of trackage and shop space.
- Air conditioning maintenance resources; i.e., qualified personnel, diagnostic & test equipment, tools, and facilities, are generally inadequate.
- Electronics system servicing requires a clean area which is not available without shop modernization.

THE RECOMMENDED RESEARCH

Project Form Developmental research/systems study

Products

A book that compiles and comprehensively describes and details the best rapid transit industry functional workflows and associated resources applications at Car Inspection/Maintenance Facilities (CI/MF).

APPROACH

1. During visits to all North American rapid transit operations, view all normal operations at each Car Inspection/Maintenance Facility (CI/MF). Summarize and detail within a uniform format the observed exemplary functional workflows and/or applications of the associated requisite resources (e.g., personnel, tools, portable and fixed equipment, floorspace utilization). In those instances where one exemplary functional workflow/resources application is not clearly superior to all others, list up to three candidates.

2. Develop the capital and annual operating costs for each exemplary candidate.

3. Graphically depict all exemplary candidates observing a uniform presentation criteria.

4. Submit the draft "catalog" for critical review by the:

   - General Managers,
   - Car Maintenance Department Managers,
   - CI/MF General Superintendents of all the domestic rapid transit operators.

5. Reflect, in the final version, those industry reviewer recommendations which would materially improve the draft version's utility.

RESOURCES REQUIREMENTS

Calendar Time ___8___ months

Professional Time ___30___ labor months

Computer Processing ____yes _x__ no

Research Candidate D3

Category Physical Resources

Title DEVELOPMENT OF A PROCEDURE TO KEEP ALL RAPID TRANSIT OPERATORS INFORMED OF MULTIPLE SOURCES FOR MATERIALS STORES ITEMS BELOW THE SEPL LEVEL

THE PURPOSE OF THIS RESEARCH

To develop a procedure whereby rapid transit operators could individually develop, and collectively share information regarding multiple sources for materials stores items below the SEPL Level.

POTENTIAL BENEFITS

Timeframe Research products would product tangible benefits within the first operational year.

Detail

- Reduced inventory levels
- Fewer stock item outages
- Reduced investment in materials stores inventories
- An enhanced ability of using transit authorities to
  - borrow from one another
  - benefit from joint procurements
- Expanded price competition
- Industry movement toward greater uniformity of equipment/ product usage.

SECONDARY IMPLICATIONS

Because the typical sub-SEPL item is relatively cost insignificant, this project and its end products will lack the allure of competing research funding candidates.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

The current situation within the rapid transit industry reflects the lack of standardization of form, fit and function parameters and is characterized by each rapid transit car procurement specifying subsystem major components that are sufficiently dissimilar to preclude interchangeability among competitor products. In fact, in many instances components manufactured by the same supplier are not interchangeable for different rapid transit car system applications. The result has been to:

- inhibit competition among suppliers,
- prevent the industry from reaping the benefits of production economy of scale,
- increase applications engineering costs,
- limit the sources for replacement parts,
- increase life cycle (ownership) costs to the operators, and
- reduce car availability.

The evaluated products concept, on the other hand, offers industrywide visibility to those product designs which:

- satisfy the operating and maintenance requirements of more than one operating authority,
- are interchangeable with competing products, and
- can be retrofitted to revenue cars and thereby improve operational, maintenance and energy efficiency, and stimulate source competition.

Research, development, and engineering costs represent sizeable investments for the suppliers. Budget allocation decisions must be biased toward those products which offer the greatest potential for increasing either market share or market size. A very desirable market is one:

- which is large enough to permit amortization of development costs through sales of a competitively priced product,
- wherein modification (applications engineering) of a product design to satisfy the expectations of potential purchasers either is not required or is minimal, and
- in which purchasers are open to more economically efficient product designs.

Operator recognition of the advantages of considering for purchase all products proved in revenue service would establish such a market.

If the transit industry's elusive quest for equipment which is more reliable, maintainable, and interchangeable is to be advanced, industrywide visibility of product usage and performance information must be established. The Service-Evaluated Products List (SEPL) fulfills that objective.

While the Service-Evaluated Products List (SEPL) provides the transit community with usage and performance data for those products which satisfy the specifications for one of the principal subsystem components of rapid transit cars operating in scheduled revenue service in North America, the operators and carbuilders also want to know what sub-SEPL products are elements of other transit operators' revenue cars and what are the sources for those interchangeable sub-SEPL items which are common to revenue cars operated by different transit authorities.

THE RECOMMENDED RESEARCH

Project Form Developmental research/systems study

Products

A catalog listing:

- those products at the sub-SEPL level that are most widely used by rapid transit operators, and
- all vendors of each product together with each vendors stock identification designation for each product.

(Note: The last three pages of this Project Profile is a listing of car equipment parts that PATCO purchases from sources other than the original equipment manufacturer (OEM).)

APPROACH

1. Determine which car-carried products (on revenue cars that will continue in scheduled service at least through 1982) at the sub-SEPL level only are interchangeable among at least two rapid transit operators' revenue cars.

2. Reduce the total listing of such products to a manageable number of different products.

3. Determine for each short-listed product:

   - the identity, address, purchasing representatives' identities and telephone numbers for each source,
   - each sources' stock identity designation,
   - the current price as a function of order quantity, and
   - the lead time to fill each order.

4. Cross reference the complete products listing with:

   - using rapid transit operators, and

- OEM and vendor sources.

5. Validate all information contained in the draft catalog with each:

   - rapid transit operator, and

   - listed OEM and vendor.

6. Publish the first edition of the Sub-SEPL Catalog.

RESOURCES REQUIREMENTS

Calendar Time ___6___ months

Professional Time ___12___ labor months

Computer Processing ____yes _x__ no

Example of Second Source Material Tabulation (Sheet 1 of 3)

PORT AUTHORITY TRANSIT CORP. OF PA. AND N. J.
Lindenwold, N. J. 08021

PATCO PART NO.	DESCRIPTION
4CG0115J	Screw, cap, tappet, made by PATCO Shop from 3/8"-16 x 3/4" socket head screw (replaces Wabco Pc No. 528817)
4CG0312	Unit, Rubber Draft Gear, Manufactured Rubber Products (Wabco 572958)
4CG0303	Bolt, tension, made by PATCO from 3/4"-10 x 3" Allen socket head cap screw (Wabco 572963, OEM)
4CG0304	Spacer, made by PATCO from 1-1/8" hex stock, 3/4-10, threaded (replaced Wabco Pc 573773, OEM)
4CL01	Hose, Airbrake, 59" with fittings, Stratoflex 275001-12-12-16 (Aeroquip 153110-12-16, OEM)
4CL02	Hose, Uncoupling line, 3/8" x 63", Aeroquip A265122-6-663 (replaces Budd piece, OEM)
4CL03	Hose, Adapter, Aeroquip 2045-6-6
4CN series	Jumper cables by Budd Co. OEM, made by PATCO with Pyle-National connectors (same as used by Budd), various pins, sockets, etc. obtained from Pyle-National to repair jumpers used between married pairs.
4DA02	Windshield, heated, shatterproof, Sierracin 504700-03 obtained thru Graham-White Sales, (replaced Libby-Owens-Ford safety glass which did shatter) to Budd Dwg. E66-11078
4DA04, 4DD, etc.	LOF window glass is being replaced by polycarbonate, Rohm & Haas Tuffak CM-2 obtained cut to size by C. W. Thomas & Co.
4DC, etc.	Glazing, rubber, various, obtained from Inland Rubber Co. (Budd Co., OEM)
4DF, etc.	Glazing strip, obtained from Power Parts Co. (Budd Co., OEM)
4EA07	Handhold, fabricated stainless steel tubing replaces aluminum casting made to a Budd Co. Dwg.
4HM14	Cab signal acknowledge buzzer was replaced by an electronic siren beeper assembled by PATCO from parts obtained from CyberSonic Corp., namely Cybersonic BT-111A (12 volt) in series with a 100 ohm resistor, 12 watt, Ohmite 3778, to allow operation on 37.5 volts DC. Reliability was greatly enhanced.

Example of Second Source Material Tabulation (sheet 2 of 3)

PATCO PART NO.	DESCRIPTION
4NA0102	Coupling, Safety Elec. S-4709, motor to air conditioning compressor, was obtained from actual manufacturer, Rexnord Corp., their No. SP D8Z-B163. Parts to repair this coupling are available individually from Rexnord's distributor.
4NA0101Q	Strainer, Safety Elec. T-15531, obtained from manufacturer, Henry Valve Co. 896B 5/8 S, and parts thereof to repair strainer also from Henry.
4NA0105C	Brush, carbon, Safety Elec. T-11539-1 to Safety Elec. Motor T-8181, obtained a brush with better life from Helwig Carbon Products, Style 20K1
4NA0209A	Duct, flexible, Budd Co. D88-70154, made locally by Gradico Industries, a local job shop, by simply copying a Budd duct.
4NA0301A	Blower, exhaust, 37.5 volt DC, Safety Elec. T-13033, parts obtained from Bodine Elec. (the manufacturer)
4NA0600 series	Strip heaters supplied by Vapor Corp. have been obtained from actual manufacturer, Chromolox, as were insulators, standoffs, hardware.
4QB series	Trainphone and Public Address System originally Wabco Union Switch and Signal UN452082-0901 replaced throughout the fleet with Motorola Portable Radios MX350
4RA	G.E. Motor/Generator GMG177A1 has been replaced with a solid state converter Westinghouse WH209D.
4RK	Exide nickel-iron batteries supplied by Budd have been replaced over a 12 year period with McGraw-Edison nickel-cadmium Style ED120 in single cars and ED160 in pairs.
4VA0204	Lamp ballast OEM Translite AD-1673-2 now obtained from Electro Winding Co. EWC 1875.
4WA0103	Spring,hand brake, OEM Ellcon-National, now obtained from Murphy & Reed (Note: actually most springs required for various parts have been obtained from Murphy & Reed.)
43G1902	Valve, Load Weighing Magnet, OEM Budd, now Skinner Electric.
44A0103A	Pad, shock, OEM Budd, now Manufactured Rubber Products.
44A0401A	Bellows, Air Spring, OEM Budd, now Firestrone

Example of Second Source Material Tabulation (sheet 3 of 3)

PATCO PART NO.	DESCRIPTION
45C08	Dryer, Air, OEM Wabco, now Salem 950-054.
44D02	Sensor, Magnetic, for Speed Sensors, OEM General Electric, now remanufactured by PATCO using sensors obtained from Airpax.
44A0101	Ring, Journal, Rubber, OEM Budd D99-57885, now obtained to same spec from Minisink, joint with LIRR.
43A1201A	Contact, blue switch, for cam controller, GE41A259862P1 probably now from Ulrich Copper.
44A0105	Bearing, side, Budd (Gatke) now from Dayco 30479-A. Joint with Reading Co. 1972, now Conrail.
44B02	Wheel, new, OEM Budd-Standard Steel, variously from Edgewater Steel or Canadian Steel Wheel Div. of Hawker-Siddley Canada Ltd.
44B01A	Axle, machined, tubular, OEM Budd-Standard Steel, now machined by PATCO from Timken Steel Div. blank tubes to Budd Co. Spec D99-57633.
44B0300B	Bearing, journal, 6x11, OEM SKF, now from Timken HM129848-90192
44B0302B	Housing, journal bearing, OEM SKF, modified in-house by PATCO to Timken drawing K-399062.
44C0102A	Cloth, filter, snow, Irish linen, Maybeck 65H, 36x36 threads/sq. in., now provided by OEM, added by PATCO annually during January and February.
44C0115	Brush, carbon, for Traction Motor GE 1255A3, OEM GE T-583 (they cracked) now use Airco Speer E-60 Multiflex

Various gaskets and shims are made locally by N. J. Gasket Co. for use in traction motors and gear units (GE GA56B1)

44D0124A	Brush, ground, gear unit, OEM GE, now Helwig Carbon Products, Graphite Grade 688, 1-1/4 x 1-1/4 x 2-1/4, Style Q5, Bevel 0 deg.
44F0104	Bolt, suspension, gear unit, vertical, OEM GE, now from United Knitting Machine Co. to G.E. Dwg. 41A235984G2. (Various pads for this assembly are also provided by United Knitting)

Research Candidate D4

Category Physical Resources

Title ECONOMIC IMPLICATIONS OF A PIPELINE APPROACH TO PROVIDING LOGISTICAL SUPPORT VS THE TRADITIONAL MATERIALS STORES APPROACH

THE PURPOSE OF THIS RESEARCH

To identify, quantify and evaluate the economic implications of (1) a "pipeline" approach to providing logistical support vs (2) the traditional materials stores, "large capital investment in spares inventory" approach.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits within 2 to 3 years.

Detail

Significantly reduced inventory:

- size,
- value,
- stockage of obsolete items, and
- out of stock incidents

SECONDARY IMPLICATIONS

Personnel responsible for materials stores purchasing and operations might perceive this initiative as negative criticism of their efforts and the operations that they control or influence.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

The typical transit authority has in-place the traditional materials storage and dispensation organizational elements. The procurement and inventory management at the bulk storeroom or wholesale level of materials, replacement parts, tools and fasteners is usually performed by the Purchasing Department. The retail or local stockrooms at each Car Inspection/Maintenance Facility (CI/MF) may be operated and staffed by either CMD or Purchasing Department employees.

The domestic rail transportation operators, over the past two decades, have adopted the singular practice of maintaining large parts inventories to be used in the maintenance of their rolling stock. Two unrelated factors caused this cost-ineffective practice to evolve: First, it became necessary to stockpile (i.e., maintain excessive inventory beyond the level that normal conditions would dictate) as a hedge against the likelihood of source interruptions resulting from increasingly common "wildcat" work stoppages.

The second cause was the "zero inventory" philosophy which came to be generally adopted throughout the railway supply industry.

The Operators found that they were no longer able to purchase materiel off the shelf because the sources of those materiel had instituted the policy of scheduling production of their proprietary items of manufacture only following the placement of firm orders.

In contrast, domestic aircraft manufacturers and European and Japanese manufacturers decades ago adopted an alternative, "pipeline" approach to providing and ensuring timely logistical support of production lines.

Adoption of the pipeline approach by the rapid transit operators would require them to first develop, install and utilize:

- a Car Maintenance Department (CMD) materials requirements/usage records data management and analysis system,
- the capability to forecast all CMD materials requirements on an annualized basis, and to base each forecast on an analysis of CMD materials requirements/usage records data for past years, and
- the practice of contracting once each year for the procurement of all materials required by the CMD for one full year.

The cost savings inherent in the pipeline approach are implied in its name. Materials "flow" into the Car Inspection/Maintenance Facilities (CI/MF) as they are needed, thereby sharply reducing the space, security, and rehandling requirements. The pipeline approach:

- keeps on-hand inventory size and value to the minimal responsible level,
- involves all vendor sources in mutually beneficial contractual commitments over the long term, and
- is predicated on a comprehensive procurement process which requires:
    - effective communication between the production planning, manufacturing, purchasing and materials stores areas of responsibility,
    - detailed planning of all materiel delivery/use schedules,
    - multiple, qualified sources of each materiel item to be purchased,
    - a management information system capable of monitoring materials stores activity.

THE RECOMMENDED RESEARCH

Project Form — Developmental research/systems study

Products — A comprehensive report that examines the economic implications of a typical domestic rapid transit operator adopting the pipeline approach to providing logistical support for its active revenue fleet compared with economic implications of the in-place materials stores approach.

APPROACH

1. Describe the domestic rapid transit industry's typical materials stores purchasing, inventory control and replenishment practices.

2. Describe exemplary operational pipeline approaches to replacement parts-support of complex transportation vehicles.

3. Define and quantify the:

   - annualized costs of each approach

   - utilization/availability ratios of the vehicles supported by each approach

4. Estimate the resources required for a typical rapid transit operator to change from its present, in-place materials stores concept to the pipeline concept.

5. Identify, discuss and evaluate economic and institutional implications of such a change.

RESOURCES REQUIREMENTS

Calendar Time ___8___ months

Professional Time ___20___ labor months

Computer Processing ____yes __x__ no

Research Candidate E1

Category Car System Design

Title CAR MAINTENANCE DEPARTMENT INFLUENCE ON NEW CAR DESIGN

THE PURPOSE OF THIS RESEARCH

To examine the economic implications of rapid transit industry practices regarding Car Maintenance Department (CMD) participation in the development of new car designs.

POTENTIAL BENEFITS

Timeframe Research products would produce tangible benefits during the first operational year.

Detail New car system designs would:

- incorporate only proven technology,
- be evolutionary design improvements of car systems in the active revenue fleet,
- incorporate items of car-carried equipment, structural and outfitting features and elements that are successfully incorporated into car systems of the active revenue fleet -- to the degree practicable and cost effective,
- require accessibility for ease of inspection, servicing and maintenance of all car-carried major components, and
- require that all car-carried major components be replaceable without prior removal or displacement of other elements of the car system.

As a direct consequence, such car systems should:

- operate more dependably,
- demonstrate an optimal fleet availability index,
- cost less to maintain than other car system designs.

SECONDARY IMPLICATIONS

Organizational structures and operator practices, in a number of instances, preclude car maintenance department participation in:

- establishing the initial car system design criteria for a new car procurement
- developing the technical specifications for procurement of new cars,

- reviewing carbuilder engineering design detail and manufacturing drawings

- monitoring the assembly during manufacture and post-manufacture qualification and acceptance testing of the new cars.

It would seem unlikely that the heads of the organizational entities with rapid transit operations that presently exclude Car Maintenance Department participation in the design and procurement of new cars would willingly abandon or share such authority, influence and control over the sizeable capital funds involved.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

A too prevalent practice is the development of technical specifications for new revenue cars without the participation of car maintenance personnel--despite the fact that surveys of public transit users have consistently disclosed that service schedule adherence is the overriding criterion in their choosing to use public transit. Service schedule adherence translates into rapid transit car dependability. Dependability, in turn, is the measure of a transit operator's commitment to car maintenance.

During the past 20 years, U.S. transit authorities have purchased nearly 7,000 transit cars. Examples of poor reliability proliferate--whether it be brakes, trucks, motors, doors, air conditioning, propulsion control, or some other subsystem or component. Carbuilders have incurred unbudgeted program costs in the tens of millions for retrofit of defective items, while the operators cite excessive maintenance expenses for cars presumed to represent the best designs available.

A number of causes contribute to the general dissatisfaction with rail transit cars. Lack of proper specification definition design changes by the purchaser during production, inexperienced manufacturing plant workers, and poor quality control, all share the focus. Three factors are especially significant:

- A lack of design standardization which has led to inclusion of different car systems integration requirements on each new car order;

- Political and economic pressures that emphasize quick delivery of cars, thereby not allowing the depth of pre-revenue service testing required to ensure long-term reliability; and

- The role of the Car Maintenance Department in the design and during procurement of new revenue cars, at some Authorities, is minimal or nil.

If a transit authority's image and its ridership (and, therefore the size of its operating deficit) depends more upon the authority's commitment to car maintenance than upon any other single factor, it is a contradiction then that a transit authority would not include the Car Maintenance Department as a key contributor and decision element in the design and procurement of new revenue cars.

THE RECOMMENDED RESEARCH

Project Form   Developmental research/systems study.

Products

A report which discusses in depth the economic implications of the influence of Car Maintenance Departments upon new revenue car system designs at all North American rapid transit operators

APPROACH

1. For each North American rapid transit operator:

   - Ascertain whether the technical specifications design (hardware) or performance-oriented?

   - Determine the role assigned to/permitted the Car Maintenance Department in the design and procurement of new revenue cars;

   - Determine the influence that the Car Maintenance Department played during the design and procurement phases for the newest revenue cars (where all cars of that procurement had been accepted and placed into scheduled revenue service). Had the CMD made recommendations that were not incorporated into the procurement specifications? Were those disregarded recommendations later proven to have been worthwhile?

   - Examine the records of those procurements giving particular attention to - production delays, qualification and acceptance testing schedules, car dependability compared to cars of other carbuys in the active revenue fleet, car availability index compared to the indices for each other carbuy in the fleet.

2. Perform a cost analysis to relate the impact of additional costs associated with three degrees of Car Maintenance Department influence on new car procurements; i.e.,

   - Significant influence comparable to that of any other decision influence,

   - Less-than-significant influence (participation discontinuous), or

   - Essentially no influence.

3. Present the substance of these operational and cost analyses in a concise report.

RESOURCES REQUIREMENTS

Calendar Time ____4____ months

Professional Time ____10____ labor months

Computer Processing ____yes __x__ no

Research Candidate E2

Category Car System Design

Title IMPROVED AIR COMFORT SUBSYSTEM

THE PURPOSE OF THIS RESEARCH

To examine the state of air comfort systems designs in modern domestic rail transit vehicles and to develop cost-effective software and hardware solutions to any identified problems. This will involve and require integration of environmental (HVAC) subsystem: performance, carsystem interfaces, and maintenance support requirements.

POTENTIAL BENEFITS

Timeframe Research products would produce tangible benefits within 4 to 5 years (following completion of Phase III) as a result of retrofitting revenue cars and incorporation in the design of new cars to be procured in the future.

Detail

Air comfort subsystem generic standards that, if observed by all competitive vendor sources, would result in:

- new car system designs properly integrating the HVAC subsystem;
- carbuilders giving proper consideration (1) to structural and engineered systems integration of the HVAC subsystem, and (2) to providing for cost effective ease of inspection, servicing and replacement by the owning operators;
- fewer cars being shopped for HVAC problems/failures and less time in shop to perform fault diagnosis, inspections, servicing and repairs; and
- improved fleet availability during warm, hot and humid periods.

POTENTIAL IMPLICATIONS

- Should this research take the form of federal subsidization, (and therefore promotion) of the development of innovative, commercially-untried air conditioning concepts instead of a systems engineering program to integrate air comfort subsystem: performance, maintenance and rapid transit carsystem interface requirements, the transit industry suppliers of air comfort equipment would act to quash the program.
- Unless the developmental research rigorously provides for a generic air comfort system design, the involved manufacturer would become the sole source for the products of this program.

- Since the major problems experienced with air comfort systems in rapid transit applications derive from the applications engineering aspects in adapting that equipment to overall car system designs, the contractor for this program must possess a strong, firsthand HVAC/rapid transit applications engineering experience.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

With the exception of San Francisco's MUNI, all recent U.S. rail transit cars incorporate air conditioning as the third element of the heating, ventilation and air conditioning (HVAC) air comfort subsystem.

Concerns have been voiced regarding (1) the accessibility and maintainability of air conditioning equipment, and (2) whether that equipment had been adequately engineered for the rapid rail environments. The problem in the specific case of air comfort subsystems is the result of an interdependent combination of factors; e.g.,

- Carbody structural design practices, allocate space for placement of air comfort equipment which, in most instances -
    - is inadequate for efficient equipment packaging,
    - locates the equipment in such a way as to make ease of access for servicing and removal;
- Installation of an air comfort subsystem, in many instances, fails to adequately provide against vibratory failure of connecting elements;
- Maintenance personnel are, in many instances, under-qualified and improperly equipped to perform proper servicing of air comfort equipment;
- Inadequate exchanges of the nature and frequency of specific problems experienced with, and actions taken to -
    - ameliorate or correct those problems, and
    - minimize air comfort subsystem effects upon revenue fleet availability and scheduled service adherence

Excessive time to remove and replace equipment from the car for maintenance purposes has been cited. Once air conditioning equipment fails, the car is taken out of service and repaired in a maintenance shop due to the inaccessibility and size of the equipment.

Variations in environmental conditions, power source and loading demands further complicate understanding of the problem.

In normal transit practice, an inoperable air comfort system results in the car being taken out of service. This imposes severe performance requirements on the air comfort system. Statistically, air comfort subsystems vie with door operators and controls as the leading cause of (together with deferred maintenance) trains being unable to commence, or having to be removed from revenue service for unscheduled maintenance.

A compilation of product performance data covering all rapid transit car major components was completed as UMTA Report "The Service Evaluated Products List (SEPL) For Rapid Transit Car Subsystem Components". The information contained in the SEPL has the potential of serving as a foundation for identifying maintenance, service, and hardware oriented problem areas on air comfort systems.

THE RECOMMENDED RESEARCH

Project Form	A three-phase effort:
Phase I	Technical Assessment and Systems Analysis
Phase II	Detailed Production Design, Fabrication, Test and Evaluation
Phase III	Preproduction Demonstration

Products

Phase I Examine current air comfort systems for design deficiencies, maintenance and operational service problems. Develop life cycle costs; assess alternatives and rank the relative merits of each alternative. Explore a conceptual air comfort system for development. For this concept, perform a system analysis to identify hardware specifications, evaluate component alternatives, and establish system benefits/costs and deployment potential.

Phase II is in two parts:

Part A - Establish the detailed design. Fabricate, and test in the factory. If the factory testing verifies that the project objectives can be met, integrate the equipment into two representative transit vehicles, and test at the Transportation Test Center (TTC).

Part B - Following completion of the TTC tests, move the vehicles to the host property and operate in revenue service.

PHASE III

Use the equipment specification and documentation developed in Phase II to procure a limited production run of equipment. The equipment shall differ from the prototype equipment of Phase II in that it shall represent a final production design derived from the development program. This equipment shall be evaluated by the transit operators for an extended period to acquire detailed maintenance, operating costs and reliability data.

APPROACH

1. Quantify and evaluate the extent of problems with current air comfort systems in U.S. rail transit applications.

2. Minimize the effect of air comfort system malfunctions on vehicle availabilities.

3. Provide improvements in air comfort system reliability and maintainability.

4. Demonstrate concepts which promote the use of standardized equipment.

5. Provide the technical specifications and documentation which will enable a transit property to procure or use a system developed under this program with a minimum of redesign or specialization.

RESOURCES REQUIREMENTS

(Refer to "STARS" program budget)

Research Candidate E3

Category Car System Design

Title WINTERIZATION OF RAPID RAILCAR PNEUMATIC SUBSYSTEMS

THE PURPOSE OF THIS RESEARCH

To develop a set of generalized maintenance procedures that have industry-wide application and that, if followed, would act to minimize equipment failures during freezing conditions.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits during the first operational year

Detail

- Elimination of condensate moisture freezing in pneumatic subsystem equipment would remove the single, biggest cold weather problem experienced by rapid transit operators.
- As a result,
  - trains could be made up and placed into scheduled service more predictably and with less effort required -- and reduced overtime
  - early morning rapid transit users would experience fewer late train arrivals
  - rush hour schedules would be more consistently met with full on time service during freezing weather.

SECONDARY IMPLICATIONS

There appear to be no undesired implications. The industry has come to appreciate the importance of capital investments for air dryers as a cost effective alternative to excessive labor costs and equipment service outages during freezing weather.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

All North American rapid transit cars, with the exception of the Chicago Transit Authority (CTA) fleet, are equipped with pneumatic brakes. Pneumatic braking over the past century has come to be relied on throughout the world for safe, effective control in railroading (mainline, industrial) autobus, and motor truck applications.

There is one inherent aspect of pneumatics that plagues rapid transit operations: freezing of entrapped condensate moisture.

The temperature of the air (in the pneumatic subsystem) is quite hot when it is discharged from the high pressure cylinder of the compressor -- from 300 to 400 degrees F. (150 to 200 degrees celsius). Air is cooled in the after-cooling pipe and the main reservoirs. Moisture drops out as the air cools and is collected in the main reservoirs. Drain valves, most often automatic types, drain off the collected moisture from the reservoirs. Equipping of cars with air dryers is also an effective way of removing liquid water from the piping and valves that make up the subsystem.

Neither of these equipment designs; i.e., automatic drains or dryers, consistently correct the source of the problem. Automatic drains can freeze in the open position, thereby, preventing car movement. If air dryer dessicants are not replaced or dried at appropriate intervals, their value is negated.

THE RECOMMENDED RESEARCH

Project Form   Developmental research/systems study

Products   A catalog of proven exemplary maintenance practices in preparation for and during freezing weather.

RESOURCES REQUIREMENTS

Calendar Time ____4____ months

Professional Time ____10____ labor months

Computer Processing ____yes __x__ no

Research Candidate E4

Category Car System Design

Title MULTIPLEX TRAINLINING OF SUBSYSTEM STATUS INFORMATION

THE PURPOSE OF THIS RESEARCH

To examine the feasibility and determine the economic implications of trainlining the operational status of critical car-carried equipment by means of a multiplexing network.

POTENTIAL BENEFITS

Timeframe: Research products would produce tangible benefits within 4 to 5 years

Detail

- The conductor, train operator and/or central control (via telemetry circuits) could be informed on a realtime basis of the operating status of those elements of the train that are considered critical.
- By employing suitable recording devices, it would be possible to inform car maintenance personnel of (1) incipient failures, (2) the causes of intermittent faults, and (3) the initiating causes of unsatisfactory train performance.

SECONDARY IMPLICATIONS

- Should the research results be especially promising, rapid transit operators might feel compelled to seek sources of funding to retrofit all of the newest cars in their revenue fleets.
- Should the project be ill-conceived or poorly executed and (as a result) the research objectives not be achieved, assessment of the potential of multiplexing in public transit applications might be forestalled for at least a decade.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

Multiplexing is the simultaneous transmission of different messages/intelligence/data over a single wire. This communications phenomenon was brought to the stage of commercial practicality by the requirement to integrate the extremely complex avionics subsystems of the wide-body U.S. strategic mobility airlift transport, the CX. The procurement of this conceptual, very long range ultra-large capacity aircraft, spawned the Boeing 747, the Douglas DC-10, the Lockheed 1011 commercial airliners -- and the C5A Lodestar.

Multiplexing enables the flight crew to monitor on a realtime basis the status and performance of all vital functions of an aircraft. It would be impossible to satisfy such a requirement if a dedicated wire were necessary for every distinctive "execute" and "status" signal. The weight of the wiring would prevent the aircraft from being able to carry a "payload" -- the very reason for its existence.

The most frustrating aspect of a car maintainer's day is to have to record, "No Trouble Found", following careful examination of a car shopped because of unsatisfactory performance during scheduled service. Availability of a multiplexing network on that car may have either (1) provided the traincrew with an indication of the problem source or (2) recorded in digital form that same information. Such a focal capability would have the effect of:

- reducing unnecessary shopping incidents,
- performing or assisting in fault diagnosis, or
- providing the traincrew with valid justification for requesting removal of a train from scheduled service.

THE RECOMMENDED RESEARCH

Project Form — A technology adaptation systems study

Products — A detailed implementation plan for the adaptation of a multiplexing system to domestic rapid transit cars.

APPROACH

1. To determine the most suitable form for adapting multiplexing to rapid transit revenue fleets.
2. To develop the resources requirements to retrofit revenue cars to incorporate a multiplexing dimension.
3. To exercise the multiplexing capability in either simulated or scheduled revenue service operations.

RESOURCES REQUIREMENTS

Calendar Time ___8___ months

Professional Time ___36___ labor months

Computer Processing _x_ yes ____ no

Research Candidate E5

Category Car System Design

Title SOLID STATE/AC PROPULSION TECHNOLOGY DEPLOYMENT

THE PURPOSE OF THIS RESEARCH

Within the context of a revenue service demonstration to evaluate and refine one or more proprietary engineered designs of solid state/ac propulsion systems.

POTENTIAL BENEFITS

Timeframe Research demonstration products would produce tangible results within 4 to 5 years.

Detail

- The use of simple ac induction motors eliminates the onerous and costly inspection and maintenance requirements that are inherent with DC motors. No commutators, brushes, or power contact devices are required; thereby, significantly reducing the cost of periodic maintenance.

- A PWM propulsion system is lighter than either the CAM or chopper alternative.

- More power can be regenerated with the PWM propulsion system than is possible with dc shunt motor systems.

- PWM-equipped cars can be made to operate compatibly in mixed consists with non-PWM cars.

- ac squirrel cage induction motors perform reliably year-round with minimal maintenance. They are unaffected by snow and rain.

- Passenger comfort is enhanced. The ride during the acceleration phase is quiet, smooth and jerk-free.

- A PWM propulsion system was demonstrated in Cleveland to be completely compatible with the wayside communications and signal system. Its filtering properties acted to reduce the levels of externally-originated radio frequency emissions along the right of way as PWM-equipped trains passed by.

SECONDARY IMPLICATIONS

- The inverter causes the capital costs of the PWM propulsion system to be greater than the initial costs of the CAM or chopper alternatives.

- A solid state/ac propulsion system is more complex than either a CAM or chopper system.

- Because of equipment complexity, the training required for transit maintenance personnel would be greater than for CAM or chopper systems.

- Test equipment would have to be more sophisticated and more expensive.

- The sensitivity of torque output and load sharing to wheel size could pose a problem for car maintenance operations.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

Rapid transit propulsion systems and propulsion systems control concepts/ power conditioning technology has advanced more in recent years than during any comparable period since the introduction of electric urban transit during the nineteenth century. Power conditioning options range from the generally used CAM controller, to the chopper and solid state/ac Inverter alternatives, which are used with dc trackside power.

The CAM Switched Resistor (C.S.R.) is well established for transit propulsion systems, having evolved to its present state of development over a period of more than 40 years. Cam-controller equipment engineered designs have been thoroughly proven, debugged, and refined over many years of service on many transit systems. A CAM system has the lowest initial cost and is the lightest in weight. It needs no separate motor-driven blowers for equipment cooling, thus eliminating one source of audible sound. The simplicity of the circuits makes trouble-shooting relatively easy; so the few maintenance skills required can be achieved with minimum training. Reliability is excellent, although CAM controllers depend on good maintenance because switch contacts and motor brushes must periodically be replaced to compensate for mechanically-induced wear.

Disadvantages include:

- The ride is not as smooth as that which can be achieved with the other systems;

  Step current changes tend to make wheel slips and spins more revalent;

  eration resistor losses cause power consumption to be some- igher;

  namic braking is practical;

  ting resistor heat under the car during braking es to heat-induced equipment failures and high tunnel es; and

  ller equipment is not as adaptable to automatic control ernative systems.

Thyristor converter systems provide a smoother ride than CAM-controller equipment. Because of the ease with which motor or braking torque can be achieved, these solid state systems are adaptable to automatic speed control and complete automatic train control. The ability to regenerate energy to the dc supply greatly reduces heat output and offers the potential for power cost savings. Periodic maintenance costs are materially less because thyristor systems have fewer mechanical contacts and proper control of the converter virtually eliminates arcing of these contacts. On the other hand, the thyristor systems have a higher initial cost. The filter components and the motor reactor make the control packages for chopper systems approximately 20 percent heavier than CAM-controller equipment.

From a maintenance viewpoint thyristor systems, and more specifically their control logic, are quite complex. Their use requres more extensive technical training of maintenance personnel, more sophisticated instrumentation, and the availability of sophisticated test devices.

The principal shortcomings of CAM and chopper systems are (1) the dc motor maintenance requirements and (2) susceptibility to failure caused by the freezing of moisture ingested with cooling air.

The third and the most promising alternative is the PWM propulsion system which employs ac induction motors. AC motors are not subject to freezing in rapid transit applications, and there are no brushes to wear. Because there are no active domestic suppliers of inverter systems control propulsion equipment, UMTA has selected this technology as "STARS" program

4. Restore the demonstration cars to their pre-demonstration configuration.

RESOURCES REQUIREMENTS

(Refer to "STARS" program budget)

Research Candidate E6

Category Physical Resources

Title MAINTAIN THE SERVICE-EVALUATED PRODUCTS LIST (SEPL) UP-TO-DATE AND COMPLETE

THE PURPOSE OF THIS RESEARCH

To establish the mechanism for ensuring that the Service-Evaluated Products List (SEPL) is maintained up-to-date and complete and to publish the first revision thereto.

POTENTIAL BENEFITS

Timeframe Research products would continue to produce tangible benefits by sustaining the availability of current, verified and complete SEPL data.

Detail

An annually updated SEPL would benefit the entire transit community.

The operators benefit by being able to:

- compare performance data for similar products,
- share preventive maintenance and repair experience,
- identify potential alternate sources for products on their cars (thereby promoting greater design interchangeability among the best performing products), and
- consider retrofitting competitor products to their revenue fleets to improve operational efficiency and car availability and to reduce the cost of maintenance and replacement parts.

Carbuilders and suppliers would benefit because the SEPL provides:

- concerned Corporate Officers with unedited user evaluations of their own, and their competitors' products,
- Engineering Managers with persuasive justification for adequate product improvement and warranty support budgets,
- Marketing Managers with objective, quantifiable data as the basis for establishing priorities, and
- Manufacturing Managers with the leverage to sustain a quality assurance program which would ensure that the products reflect corporate standards.

SECONDARY IMPLICATIONS

If the SEPL is not maintained current and complete, it will fall into disuse, thereby depriving the transit community of the benefits of expended federal research funds.

THE NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

During Phase One of the Rapid Railcar Technology Standardization Program, utilization data was analyzed to identify and evaluate those design factors which act to influence car availability for scheduled revenue service. The findings were a restatement of the collective observations of North American rapid transit operators:

> New rapid railcars which incorporate only products which had performed satisfactorily in similar transit applications are shopped for unscheduled maintenance less than are new cars which introduce new products into the purchaser's environment.

The evaluated products concept offers industrywide visibility to those product designs which:

- satisfy the operating and maintenance requirements of more than one operating authority,
- are interchangeable with competing products, and
- can be retrofitted to revenue cars and thereby improve operational, maintenance and energy efficiency, and stimulate source competition.

Research development, and engineering costs represent sizeable investments for the suppliers. Budget allocation decisions must be biased toward those products which offer the greatest potential for increasing either market share or market size. A very desirable market is one:

- which is large enough to permit amortization of development costs through sales of a competitively priced product,
- wherein modification (applications engineering) of a product design to satisfy the expectations of potential purchasers either is not required or is minimal, and
- in which purchasers are open to more economically efficient product designs.

Operator recognition of the advantages of considering for purchase all products proved in revenue service or which have successfully completed the test evaluation process would establish such a market.

The Service Concept

How a product performs in scheduled revenue service, as determined from the maintenance records of each user, is testimony to how well that product has been engineered for the rail transit environment and for the site-specific application. Such testimony must, of course, be evaluated in the context of the reporting user's environment, maintenance capability, practices and resources. By supplementing the user's evaluation with the supplier's clarifying comments on that evaluation, the reader is offered an evenhanded account of each product's design adequacy.

An industrywide awareness of the range of revenue service-evaluated products which are permanent parts of the newest rapid transit car designs operating in North America should benefit the entire transit community and stimulate technology standardization at the subsystem component level.

If the transit industry's elusive quest for equipment which is more reliable, maintainable, and interchangeable is to be advanced, industrywide visibility of product usage and performance information must be established. The Service-Evaluated Products List (SEPL) fulfills that objective.

THE RECOMMENDED RESEARCH

Project Form

- An UMTA policy statement committing the federal government to maintaining the SEPL;
- Assignment of responsibility for maintaining the SEPL and publishing revisions thereto; and
- Allocation of resources to publish updated SEPL editions

Products

- An UMTA policy statement regarding the mechanism selected to ensure periodic, regular updating of the SEPL, and publication of the second edition of the SEPL.
- Periodic publication of updated SEPL editions.

APPROACH

1. Obtain the Administrator's concurrence in promulgating periodic, regular revision and publication of the SEPL.
2. Implement that policy pronouncement by funding the SEPL updating project.

3. The SEPL - updating project group shall replicate the processes which created the first edition of the SEPL.

4. Publish the second edition of the SEPL.

RESOURCES REQUIREMENTS

Calendar Time ______6______ months

Professional Time ______10______ labor months

Computer Processing ____ yes __x__ no

Research Candidate E7

Category Physical Resources

Title REDUCTION OF MATERIALS STORES INVENTORY INVESTMENT BY PROMOTING GREATER UNIFORMITY OF CAR-CARRIED EQUIPMENT, ELEMENTS, PARTS AND FASTENERS

THE PURPOSE OF THIS RESEARCH

To provide an analytical and evaluation procedure which any transit authority could follow to identify those car system elements (of all cars within the active revenue fleet) that appear to be amenable to form, fit & functional standardization for:

- all future new car procurements, and
- possible retrofitting throughout the revenue fleet.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits within 4 to 5 years.

Detail

- Reduced investment in materials stores/shop stockrooms (wholesale/retail) inventories.
- Capital & operating cost savings resulting from reduced requirements for:
  - facilities floor space & outfitting,
  - warehouse, stockroom & logistical personnel,
  - purchasing & incoming inspection functions, and
  - security.
- Fewer instance of stock-item outages.

SECONDARY IMPLICATIONS

A blind commitment to uniformity could inhibit rational, objective consideration of alternative products which might improve operational effectiveness.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

The active revenue fleet roster of a typical older rapid transit operator consists of a mix of car system designs purchased under different procurements contracts at varying points in time over a period of 30 years. In most instances, each car system design was manufactured to the purchaser's technical specifications by different carbuilders and incorporates different mixes of proprietary equipment. The typical active revenue fleet, therefore, embodies a mix of technological applications and technological obsolescence.

A direct consequence of this reality is an economically inefficient logistics support requirement. Because many products which are similar in design and performance are nevertheless not interchangeable, an excessively varied inventory of replacement parts, materials and fasteners must be constantly maintained by the operators. Of course, those different product and fastener designs require different tools and adaptors.

A recently published Department of Transportation analysis of the domestic motor car industry cited as two factors favoring the Japanese:

- Where Toyota plants keep a parts inventory ranging from two hours to two days supply, U.S. manufacturers regard 10 days as a minimum and have $8 billion tied up in the parts pipeline;
- Nearly a third of new U.S. auto factory space is devoted to inventory and parts storage, which is practically non-existent in Japan.

THE RECOMMENDED RESEARCH

Project Form — Developmental research/systems study

Products

Generalized guidelines, which any domestic transit authority could readily adapt to suit its site-specific requirements, for internal standardization of car-carried equipment, elements, parts and fasteners throughout an operator's active revenue fleet.

APPROACH

1. Examine and summarize the internal practices of all North American rapid transit operators that are directed toward promoting uniformity of car system elements on a revenue fleet basis.
2. Isolate the exemplary practices, and relate the economic and institutional implications of each.
3. With the most cost effective exemplary practices as the basis, develop a coherent set of generalized guidelines, which any domestic transit authority could readily adapt to suit its site-specific requirements, for internal standardization of car-carried equipment, elements, parts and fasteners throughout an operator's active revenue fleet.

RESOURCES REQUIREMENTS

Calendar Time ____12____ months

Professional Time ____36____ labor months

Computer Processing ____ yes __X__ no

Research Candidate F1

Category Policy

Title ESTABLISHMENT OF THE ESSENTIAL SUBSTANCE OF A TRANSIT AUTHORITY'S CAR MAINTENANCE PHILOSOPHY

THE PURPOSE OF THIS RESEARCH

To codify the basic essential substance and content of a car maintenance philosophy for every transit authority.

POTENTIAL BENEFITS

Timeframe Research products would produce tangible benefits within 2 to 3 years.

Detail

A commitment to the philosophy of consistently and properly performing all required preventive and corrective maintenance of the revenue fleet would:

- eliminate the need for periodic general overhauls of the entire car system,
- reduce road failures to the achievable minimum,
- reduce ownership (life cycle) costs,
- provide for efficient utilization of available resources,
- act to stabilize the Car Inspection/Maintenance Facilities' (CI/MF) workforce,
- act to reduce the resources required to perform unscheduled, corrective maintenance -- the principal reason for employee overtime, and
- improve revenue fleet dependability and thereby act to sustain the patronage of satisfied riders.

Concurrent development of a family of uniform rapid transit fleet utilization and revenue service performance standards and measurement criteria would provide:

- State gubernatorial offices, departments of transportation, and legislatures with a basis for -
  - allocating State subsidies,
  - trickling down federal subsidies;

- Transit authority boards of directors and local and regional governing bodies with a basis for measuring revenue service performance against that of other transit authorities and against the previous year's performance; and

- Transit authority chief executive officers with a basis for measuring the performance of key line and staff personnel.

SECONDARY IMPLICATIONS

All transit authority policy level decision-makers with public visibility and/or corporate accountability would have to individually and collectively observe the elementary tenet of a responsible car maintenance philosophy:

> Annually allocate sufficient resources to properly maintain the revenue fleet on a realtime basis.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

Because a transit authority is a public body, budget making is a political process. Policy level board members owe their tenure to the electorate -- to voters whose overriding concern is personal economics. Taxes reduce personal discretionary income. Since elected and appointed officials serve fixed terms of service, budget considerations tend to be lopsightedly oriented toward near term objectives.

Rapid transit car maintenance does not lend itself to absolute performance measurement criteria. However, the nature of car maintenance and the relationship between the resources required to perform that work and fleet utilization/revenue service performance standards can be established quantitatively and objectively -- given common measurement criteria. Performance measurement criteria must be readily quantified from the records data products of each rapid transit operator. Each of those records data must be derived in the same manner and for a common reporting period.

Policy is the action form of a philosophy. The absence, or diffused substance of a car maintenance philosophy accounts, to a large degree, for the transmutation of incipient debilitating practices into institutionalized expressions of policy. Three significant, universal examples are:

- deferred maintenance,

- cannibalization, and

- worker availability.

Deferred Maintenance

The present industrywide crisis of too few ready-for-service rapid transit cars to meet the incipient general acceptance of (and in a number of instances, preference for) public transportation is the inevitable product of deferred maintenance.

During the past two decades, Americans became familiar with the term, deferred maintenance, as railroad followed railroad into bankruptcy. The concept of deferred maintenance was sold to management by financial advisers who proposed this near term solution as the post-World War II economy depressed rail carrier profitability. Keynesian economics persuasively supported this course of action. Unfortunately rail transport revenues continued to decline and deferred maintenance became an institutionalized business practice both in mainline railroading and in commuter and rapid transit operations. The prosperous times necessary to balance the Keynesian equation failed to arrive.

As privately-owned rapid transit firms approached insolvency because of the ability of the average American family to own and operate private autos, local governments recognized that the metropolitan areas served by public transit could not grow, retain their vitality, or perhaps even survive without rapid transit service. The 1960's saw public transit supplant privately-owned rail transit operations in the United States. Deferred maintenance, as entrenched policy, was inherited by the public transit authorities with the transfer to public ownership.

Cannibalization

In those instances where parts are unavailable from materials stores, the car is normally placed onto a storage track and classified as, "Inactive Status Awaiting Parts". However, if the car (or dependent-pair) must be made fit for revenue service so that the line can be met, the out-of-stock part(s) will in all probability be removed from another car in the "Awaiting Parts Status" pool. This practice is referred to as "cannibalization".

Worker Availability

Worker availability has emerged as a major problem. It generally takes two forms; i.e., controllable and uncontrollable. Controllable absenteeism refers to those instances when a worker's absence is not contractually provided for as an approved leave provision.

One form of uncontrollable absence is that contractual provision or institutionalized practice which permits workers to schedule vacation periods without regard to worker team cohesion or the availability of a minimal leavl of qualified experienced shop labor, inspection, and supervisory personnel in every area of specialization. For example, seasonal fluctuations, which had been characterized by workload demand peaks starting late each Fall and ending mid-Spring, have largely disappeared because of air conditioning of the newer cars. However, workers with seniority and school age children continue to choose to take their vacations during the hottest months -- and those workers for the most part are the more experienced, more dependable and better motivated.

It has also become a widespread, common practice to hold the manning level of the Car Maintenance Department below that authorized and for which funding had been allocated. Understaffing results in:

- unbudgeted overtime,
- stretch-outs of programmed maintenance intervals, and
- more frequent road failures.

THE RECOMMENDED RESEARCH

Project Form   Developmental research/systems study

Products

A concise, codified statement of the basic, essential substance and content of rapid transit car maintenance philosophy which would be universally applicable to all domestic transit authorities.

APPROACH

1. Compare budgets of the combined support departments with budgets of each of the transportation and the Car Maintenance Departments.

2. Establish minimal performance service standards.

3. Develop measurable performance indicators.

4. Define essential organizational elements.

5. Codify the discrete and interrelated responsibilities of each organizational element.

6. Perform a separate benefits/cost analysis for the Transportation, Car Maintenance, and combined support departments. Evaluate the findings.

7. Circulate among all domestic transit authority boards of directors for review and comment.

8. Reflect transit authority boards of directors' recommendations in the final, published form as the essential substance of a rapid transit car maintenance department philosophy.

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RESOURCES REQUIREMENTS

Calendar Time ____8____ months

Professional Time ____18____ labor months

Computer Processing ____ yes __x__ no

Research Candidate F2

Category Policy

Title EXAMINATION OF BUDGETARY RESOURCES ALLOCATION PRACTICES WITHIN THE TRANSIT INDUSTRY

THE PURPOSE OF THIS RESEARCH

To describe typical transit industry practices; i.e., the processes, mechanisms, rationales, constituencies and influences, that annually determine how a public transit authority's budgetary resources are to be allocated.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits within 4 to 5 years

Detail

- Elected officials and transit authority policy level officials would be provided with a quantitative basis for allocating a proportionate share of available resources to car maintenance.
- The statistical relationship between the apportionment of budget resources to car maintenance in the period since 1960 and (1) revenue service dependability, (2) revenue car availability and (3) ridership would be established.
- A minimum proportionate share of budgetary resources might be statistically inferred from examination of the interrelationship (over the past two decades) between the share of available resources allocated for car maintenance and (1) revenue service dependability, (2) revenue car availability, and (3) ridership.

SECONDARY IMPLICATIONS

- The influence and positioning within each transit authority of the public transit image portrayal and enhancement element -- marketing, public relations, industrial design, computer management information system (MIS) statistical and graphical reports generation functions--would come under scrutiny.
- Involvement in the annual budgeting process would thereafter require a commitment of significant time on the part of all participants. Each participant would find it necessary to prepare him/herself to evaluate each allocation strategy in terms of its statistical merits.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

Subsequent to the transition of electric urban rail transportation from private to public ownership during the post World War II years, the resources allocated for preventive maintenance of revenue fleets declined below that level at which the useful economic life of the cars would equal or exceed their design life. A curious contradiction has been the contemporaneous, year-by-year, increases in budget commitments for the support elements of a typical public transit authority's infrastructure:

- planning staffs,
- computerized management information systems' (MIS) staffs, hardware & software,
- public information/relations/communications staffs,
- image enhancement services, and (of course)
- an administrative services capability to coordinate and sustain this burgeoning infrastructure.

While:

- route sign markers and bus stop collection sites became visually more attractive,
- bus and rapid railcar exteriors bloomed with distinctive color patterns and unique logograms, and
- the local media earned advertising revenues from cashflow-poor transit authorities to alert the public to the availability of a "new" public transport system "ready to serve them better",

the car maintenance share of a typical rapid transit operational budget experienced both an absolute percentage decline (in constant-dollars) as the rate of inflation flared in the late sixties.

A transit authority's image and its ridership (and, therefore the size of its operating deficit) depends more upon the authority's commitment to maintenance than upon any other single factor. It is a contradiction then that transit authorities annually increase the size of their marketing budgets during the 1970's while at the same time reducing the already inadequate funding support for car fleet maintenance.

Following passage of the Urban Mass Transportation Act in 1964 federal funding became available for capital needs--but not for maintenance. Ten years later additional federal funding became available to subsidize operating costs.

THE RECOMMENDED RESEARCH

Project Form — Developmental research/systems study

Products

- An objective portrayal of the evolution of budgetary resources allocation practices among rapid transit operators from pre-UMTA days (1960) to 1980.
- The basis for an appreciation and understanding of the interdependency between discrete annual funding levels and a multi-year pattern of successive-year funding levels, and between the quality (dependability) of scheduled service and revenue car availability.

APPROACH

1. Develop a generalized description of rapid transit operator budgetary resources allocation practices:
    - in 1979
    - in 1970
    - in 1960
2. Discuss the realm of influences and constituencies that annually compete on a typical public transit authority for the allocation of available resources.
3. Determine from firsthand interviews with domestic transit authority:
    - General Managers,
    - Board Chairmen,
    - Senior Budget Officers, and
    - Chief Mechanical Officers

of four rapid transit operators, the implications over the 1960 to 1979 twenty year period of budgetary resources allocation practices upon:

- the local tax base,
- the infrastructure of each transit authority,
- patronage, and
- local citizen image of each transit authority.

4. Recommend a minimum proportionate share of available budgetary resources that should be allocated to car maintenance with the objective of assuring a given level (quality) of service.

5. Examine with a four rapid transit operator sample, the statistical relationship between the percent of the annual operating budget that had been allocated for rapid transit car maintenance:

   - in each of the years 1960, 1970 and 1980,
   - within the two decades, 1960-1969 and 1970-1979,
   - the quality (dependability) of scheduled service, and
   - revenue car availability.

RESOURCES REQUIREMENTS

Calendar Time ___12___ months

Professional Time ___30___ labor months

Computer Processing _x_ yes ___ no

Research Candidate F3

Category Policy

Title EXAMINATION OF THE ECONOMIC IMPLICATIONS OF A PROGRESSIVE MAINTENANCE PROGRAM VS THE MAJOR OVERHAUL APPROACH TO CAR MAINTENANCE

THE PURPOSE OF THIS RESEARCH

To perform an ownership (life cycle) cost analysis of alternative approaches to rapid transit car maintenance; i.e., progressive maintenance vs. complete car overhaul.

POTENTIAL BENEFITS

Timeframe — Research products would produce tangible benefits within 4 to 5 years.

Detail

- Development of the life cycle cost implications of these two typical car maintenance approaches would disclose the economic and service benefits inherent in the progressive maintenance approach.
- Knowledge of the long term benefits and aggregated operating and maintenance costs of supporting the revenue fleet under either option would equip involved policy-level elected and transit authority officials to obtain the support of their constituencies for consistently adequate annual car maintenance budgets.
- Departure from the whole car overhaul approach would:
  - eliminate periodic shortages of revenue cars during the overhaul period,
  - permit the selective, cost effective replacement of car-carried major components on the basis of product failure data,
  - recognize that Car Inspection/Maintenance Facilities (CI/MF) are not sized for efficient in-house overhaul of each complete car of each procurement contract.

SECONDARY IMPLICATIONS

Those rapid transit operators with older revenue fleets:

- that have not been maintained within a rigorous preventive maintenance program, (and/or)

- for which adequate maintenance and performance records have not been maintained and effectively utilized for the complete car system and for each car-carried major component

would probably have to overhaul those revenue cars on a whole-car basis.

NATURE OF THE REQUIREMENT/IMPROVEMENT OPPORTUNITY

There are two approaches to rapid transit car renewal maintenance:

- One is, "Progressive Maintenance"
- The other is, "Overhaul".

Progressive maintenance is characterized by selective removal and replacement (R&R) of each car-carried major component within a unique timeframe established on the basis of empirical performance data. Each timeframe is operator-specific. For example, Operator A may choose to replace major component x (MC-x) after MC-x has been on the car for a given period of time or on a car that had accumulated a given revenue mileage. Operator B may require that, in addition to meeting Operator A's R&R criteria,"y"percent of MC-x must first have failed. Only that major component which is entering that stage beyond which the rate of failures in revenue service would be unacceptable, is removed for renewal conditioning. Removal and replacement operations normally do not require overnight shopping of a car (usually in the form of a married pair).

Major Overhaul, also called complete car overhaul, is the traditional rapid transit industry practice. It owes its origin to mainline railroad practices that were imposed by the Interstate Commerce Commission to assure a minimum level of safety. Rapid transit cars, however, are complex, engineered systems. Revenue car utilization is four to six times that of the average railroad car. From eight to twenty railroad freight cars could be purchased for the price of one rapid transit car.

The practice of shopping each car of each procurement contract from one to three times during its design life for extensive rehabilitation of virtually the entire car system:

- places an almost unmanageable burden on CI/MF space and shop personnel,
- taxes the purchasing/materials stores logistical support elements of the operator,
- denies the transportation department a significant number of units from the active revenue fleet, and

- results in the removal and replacement of car-carried major components that are in varying stages of performance--ranging from optimal at one extreme to a condition during which incipient problems are evidenced.

Unsubstantiated by empirical data (shop records), this practice inefficiently consumes available resources and requires over-investment in active revenue fleet size to ensure a minimum level of service during each overhaul stint.

THE RECOMMENDED RESEARCH

Project Form — Developmental research/systems study

Products — A concise report presenting:

- a comparative life cycle cost analysis of these alternative maintenance approaches, and
- the economic implications inherent in each option.

APPROACH

1. With the cooperation of four rapid transit operators--two of which practice progressive maintenance with the other pair committed to the major overhaul approach--develop from each operator's records:

   - the annualized unit costs of inspecting and maintaining all of the cars purchased under a given procurement contract -
     - in years during which no carbuy-wide major component remove-and-replace (R&R) programs were conducted,
     - in years during which such R & R programs occurred, and
     - in years during which major overhauls were conducted.
   - Extrapolate from the above data the life cycle maintenance costs for each carbuy on a unit cost basis.

2. Develop and examine the economic implications of each option.

   Discuss from the separate perspectives of the:

   - public transit users,
   - involved elected officials,
   - transit authority policy-level officials,

- Chief Mechanical Officers, and
- Car Inspection/Maintenance Facilities' (CI/MF) General Superintendents.

3. Present the results of this comparative life cycle cost/economic analysis in a concise report understandable to readers not possessing engineering, accounting, or statistical backgrounds.

RESOURCES REQUIREMENTS

Calendar Time ____8____ months

Professional Time ____30____ labor months

Computer Processing __x__ yes ____ no

APPENDIX B

AN OPTIMIZED CAR MAINTENANCE SCENARIO

DESIGN LIFE PROGRAMMED MAINTENANCE

The transit community generally considers 30 years to be the design life of a rapid transit car. Translating a design life car maintenance program from a plan to a cost-effective operation requires four essential elements; i.e.,

- *good revenue service mileage recordkeeping,*
- *complete servicing, failures & modifications histories for all car-carried equipment,*
- *up-to-date knowledge of the actual car configurations of each and every car in the active revenue fleet, and*
- *adequate resources.*

The first element became an inherent part of the maintenance function long before program planning was given the aura of a formalized, scientific process in the 1960's. The second element provides the only sound basis for programmed maintenance. The third element assures effective employment of CI/MF resources, and determines materials stores composition and inventory levels. The fourth element is a policy issue.

Because the consequences of years of deferred maintenance have become visible and intolerable to the general public, the criticality of this element is now recognized by the budgeting decision-makers.

This Optimized Car Maintenance Scenario presumes the uninterrupted availability of adequate resources and a policy commitment to dependable scheduled service. The scenario is conceptual only in the sense that it does not fully describe the car maintenance practices of any one North American rapid transit operator. A synthesis of best industry practices, the Optimized Scenario provides individual operators with a model against which each might compare the relative effectiveness of discrete aspects of its own car maintenance operations.

Exhibits B-1 through B-8 have been generalized to represent industry best practices:

Exhibit B-1, A Generalized Maintenance Support Profile Of A Typical Rapid Transit Fleet, traces the revenue service inspection and maintenance cycle.

Each day:

- cars on the Available for Scheduled Service roster are placed into scheduled service.

- Cars are periodically shopped for programmed preventive maintenance at established intervals. (See Exhibit 3).

- When failures are experienced during revenue service, the affected cars are shopped for fault diagnosis and remedial maintenance.

- Following completion of each scheduled and unscheduled maintenance action, cars are either -

  - returned to the Available For Scheduled Service roster, or

  - should needed parts be unavailable, the car is placed into an Inactive Status Awaiting Parts.

Exhibit B-2A, Design Life Car Maintenance Program (Graphic), summarizes the maintenance support of a typical rapid transit car over its 30-year design-life.

Exhibit B-2B, Design Life Car Maintenance Program (Key Events), defines the maintenance support actions over a 30-year design-life, commencing with delivery of the new cars (block 1a) and concluding with retirement of the cars following 30 years of revenue service (block 15).

Exhibit B-3, The Types of Car Maintenance, identifies each maintenance action as either Unscheduled or Scheduled and summarizes the nature of each action. Programmed maintenance actions become more extensive at each of four levels. The intervals between shoppings for scheduled inspections and maintenance were established to compensate for age and usage wear and to provide for periodic replacement of major components as each approaches the end of its dependable life, thereby acting to minimize revenue service failures.

Exhibit B-4, A 30-Year Design-Life Performance Profile Of Maintenance Support Actions, completes the generalized maintenance scenario by adding such program planning essential information as:

- where each maintenance action is normally performed

- who the responsible party is (parties are)

- budgeted hours/contract values

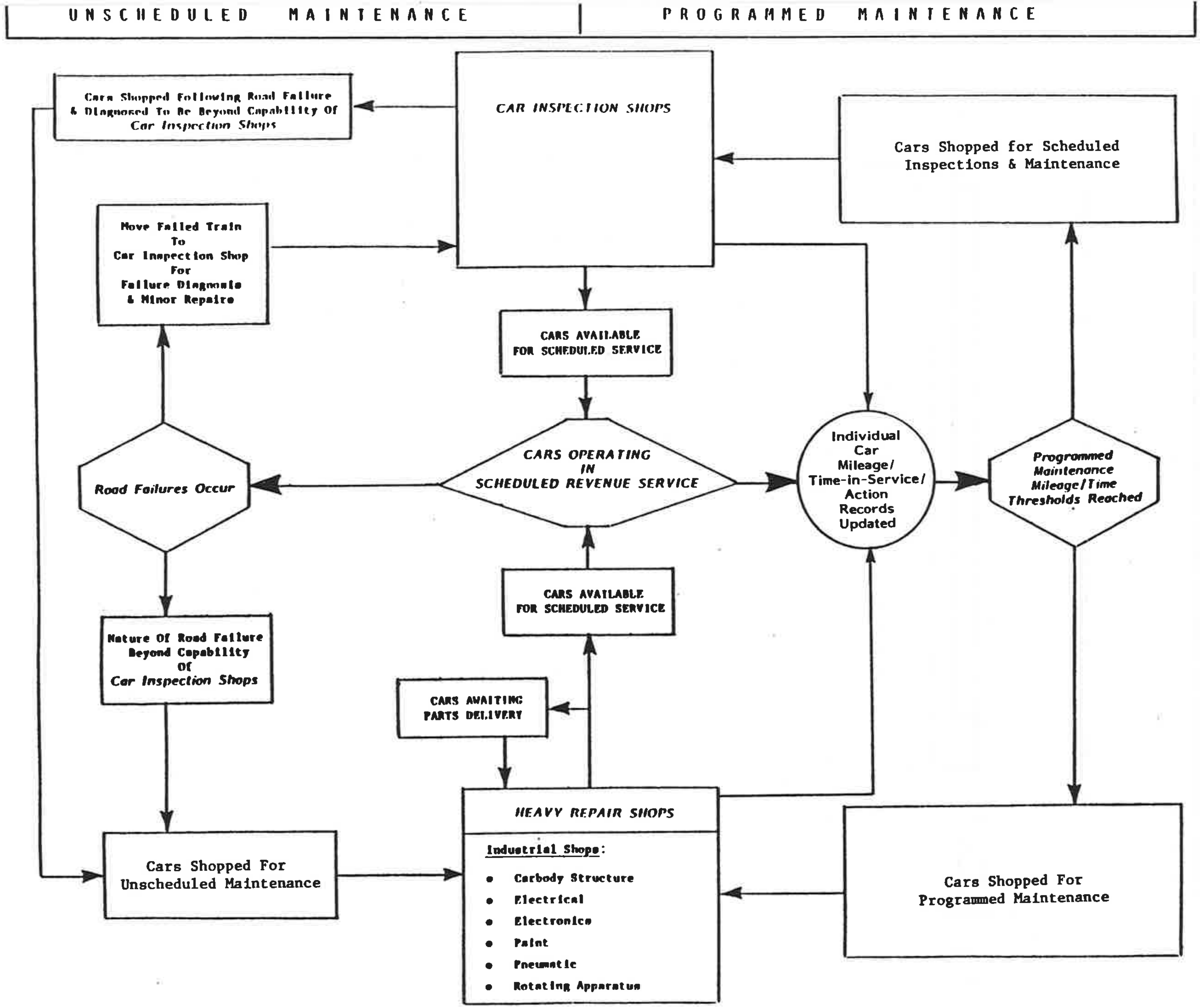
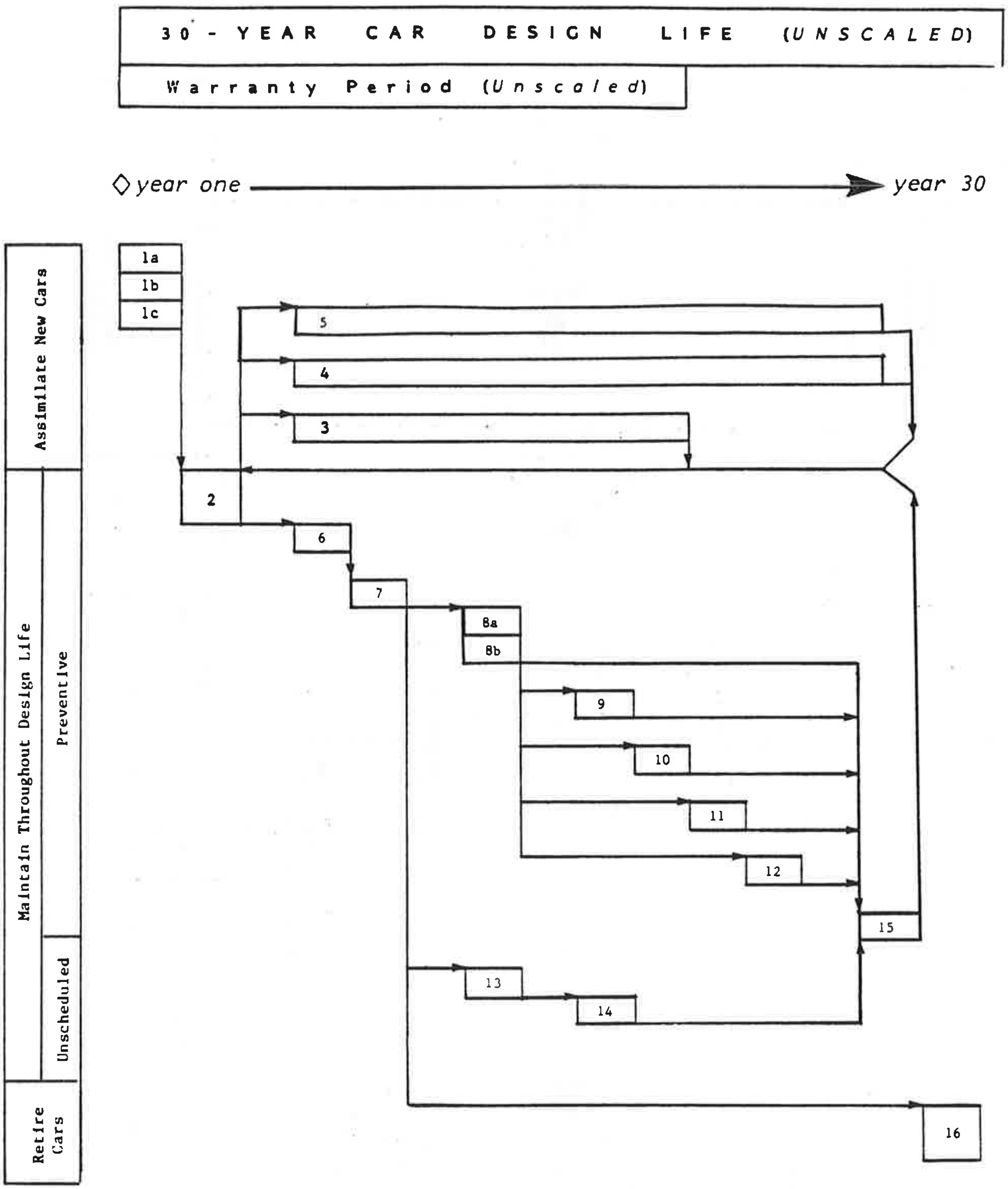


EXHIBIT B-1. A GENERALIZED CAR MAINTENANCE SUPPORT PROFILE OF A TYPICAL RAPID TRANSIT FLEET



Note: Each of the 16 numbered *key events* is described in *Exhibit B-2B*

EXHIBIT B-2A. DESIGN-LIFE CAR MAINTENANCE PROGRAM *(GRAPHIC)*

DESCRIPTION OF EACH NUMBERED BOX IN EXHIBIT 2A

1. a. Receive new cars
   b. Conduct Acceptance Testing and complete the training of maintenance personnel
   c. Perform transition engineering as a prerequisite to the new cars commencing normal scheduled revenue service

2. Add cars to ACTIVE REVENUE FLEET ROSTER

3. Provide warranty support (Carbuilder & Sub-contractors):
   - Perform total car system refinement/fine tuning as shall be necessary to assure compliance with the purchaser's technical specifications
   - Perform according to a schedule which will minimize the downtime of the new cars, such inspections, servicing and product design/performance modifications of car system elements under warranty as shall be necessary to assure compliance with the purchaser's technical specifications
   - Replace with redesigned, improved products those car system elements that fail to achieve contractually-specified performance requirements

4. Without removing cars from scheduled revenue service, perform routine inspections, servicing of car system elements requiring lubrication, cleaning, consumables/disposables replenishment and sub-element adjustment, and exterior cleaning (weather permitting) of cars either daily or at frequent intervals

5. Redesign and retrofit to meet operational needs and maintenance support requirements

6. Schedule cars for revenue service

7. Operate cars in revenue service

8. a. Cars reach TIME or MILEAGE programmed maintenance thresholds
   b. Car system elements reach dependable service life replacement thresholds

9. Perform routine, first-level scheduled inspection and maintenance actions as a function of time or revenue mileage

10. Perform second-level scheduled inspection and maintenance actions at intervals which are multiples of first-level maintenance actions

11. Perform replacement/rebuilding of major car-carried subsystems

12. Perform general overhaul of the total car system

13. Road failures occur while train is being placed into or during scheduled revenue service

14. Perform *unscheduled* maintenance

    Isolate and diagnose the initial, actual cause of the failure on the revenue train: determine the appropriate remedial action, estimate resources and requirements; and perform necessary repairs

15. Perform interior cleaning of cars in active revenue fleet

16. Retire cars at end of their design (useful economic) life

EXHIBIT B-2B. DESIGN LIFE CAR MAINTENANCE PROGRAM *(KEY EVENTS)*

UNSCHEDULED MAINTENANCE is performed following road failures experienced while trains are being placed into or during revenue service.

- Isolate and diagnose the initial, actual cause of the failure on the revenue train, determine the appropriate remedial action, and estimate resources requirements
- Perform necessary repairs

SCHEDULED MAINTENANCE is performed according to either a design-life maintenance program plan, or as a function of annual budget allocations.

First-Level	Perform routine periodic inspection and servicing of each subsystem to ensure the cars are capable of safe and dependable scheduled revenue operations.
Second-Level	Perform inspection and maintenance actions at intervals which are multiples of first-level maintenance
Subsystems Replacement	Perform rebuilding/replacement of car-carried subsystems. Performed at time or mileage intervals established either on the basis of funding availability or upon failure data records analysis
Car System Overhaul	General overhaul of the total car system. Performed at 15 to 17 years to restore car to like-new condition. (If subsystems are replaced fleetwide as their performance falls below operator-specific indicators, car system overhauls would not be necessary.)

EXHIBIT B-3. THE TYPES OF CAR MAINTENANCE

Typical Transit Authority Car Maintenance Department Support Functions / Maintenance Actions Performed: • By • Where • at What Cost	Responsible Party				Where Performed				Budgeted Hours/ Contract Value				
	Carbuilder	Supplier	Rebuilding Contractor	Transit Authority	on Outside Track	Inspection Shops	Heavy Repair Shops	Contracted Out	Hourly Workers	Line Supervision	Administrative Support	% Contracted Out ($)	
1 Place new carbuy into service:													
a Receive New Cars	C			P	EO	EO							1 a
b Conduct Acceptance Testing	C	S		P	EO	EO							1 b
c Perform Transition Engineering	C	S		P	EO	EO							1 c
2 Provide Warranty Period Support at the carsystem-level *(systems integration)*	X				EO	EO	EO						2
3 Provide Warranty Period Support at the subsystem-level		X			EO	EO	EO						3
4 Clean car interior				X	ML	FF	FF						4
5 Clean car exterior				X	ML	ML			operator-specific data				5
6 Perform routine servicing & replenishment of consumables/disposables				X	PS	ML	FF						6
7 Perform *Unscheduled Maintenance*				X		ML	PS						7
8 Perform *Scheduled Maintenance:*													
a Periodic inspections and maintenance				X		ML	PS						8a
b Subsystems replacement			C	P		FF	OS						8b
c Car system overhaul			C	P		FF	OS						8c

KEY

RESPONSIBILITY:
X Sole
P Primary (if shared)
C Contract-defined
S Subcontract-defined

WHERE PERFORMED:
EO At any of the cited locations
FF Location determined by other maintenance processes
ML Most likely location
OS Determined by operator-specific policy
PS Programmed second location

EXHIBIT B-4. A 30-YEAR DESIGN LIFE PERFORMANCE PROFILE OF MAINTENANCE SUPPORT ACTIONS

A FUNCTIONAL PROFILE OF CAR MAINTENANCE OPERATIONS

THE ROLE OF THE CAR MAINTENANCE DEPARTMENT

The role of the Car Maintenance Department (CMD) is to ensure that the public is provided with rapid transit cars that are safe, clean and dependable and, each day, to make available a full schedule of cars.

The active revenue fleet is sized to:

- permit each car to be shopped for preventive inspections and maintenance according to schedules which are transit authority-specific, and
- provide for a *worst case* number of cars to be shopped for unscheduled maintenance because of in-service failures.

A typical rapid transit car averages between 36,000 and 50,000 miles in revenue service each year.

The Car Maintenance Department is responsible for the maintenance, inspection, cleaning, repair and overhaul of all rolling stock. These responsibilities are carried out in four functional areas:

- Fleet Maintenance
- Intra-Departmental Effectiveness
- Resources Management
- Engineering

Exhibit B-5 summarizes the discrete activities within each functional area.

FLEET MAINTENANCE

- Provide rolling stock to the Transportation Department
- Inspect and maintain all rolling stock; and replace parts, as required,
- Maintain the interior and exterior appearance of all revenue cars.

INTRA-DEPARTMENTAL EFFECTIVENESS

- Develop methods and standards to promote: safety, efficient employment of available resources, procedural consistency, uniform performance standards, and fleet-wide parts interchangeability to the extent practicable.
- Inspect all completed work to ensure conformance with quality assurance standards.
- Monitor the quality and effectiveness of all maintenance, modification and overhaul/rebuilding actions of the revenue fleet and of support rolling stock.
- Periodically review, evaluate and update all inspection and repair procedures to assure their adequacy and effectiveness.
- Evaluate the methods of inspecting and repairing new car equipment within the CMD against best transit industry practices and those exemplary practices of related industries that appear to be suitable for adaptation.
- Investigate repetitive failures of car-carried equipment.
- Analyze car maintenance records to:
    - detect trends in car-carried equipment reliability and car system-level performance dependability and
    - identify failure conditions for car-carried equipment.
- Determine replacement cycles for car-carried equipment based on analysis of recorded failure data.
- Investigate and analyze the need for and feasibility of modifying car-carried equipment with the objective of improving maintainability and reliability.

EXHIBIT B-5. THE PRINCIPAL FUNCTIONS OF A TYPICAL CAR MAINTENANCE DEPARTMENT (1 of 2)

RESOURCES MANAGEMENT: A. Department-Level

- Perform future-year maintenance program planning and budgeting.
- Following publication of the upcoming year's budget, adjust that year's program plan as a function of budgeted resources.

B. Employee Qualifications

- Train personnel at all levels of responsibility and in each craft and work assignment. Make available formal training programs designed to ensure initial employee qualifications and progressive career advancement on the basis of enhanced qualifications.
- Conduct on-the-job training to enhance skills,knowledge and competence and to qualify personnel for increased responsibility and for supervisory and management positions.

C. Materials Stores

- Develop and maintain an awareness of multiple sources for all car system elements & replacement parts.
- Perform liaison with the vendors and subsystem suppliers.
- Maintain and update a service-evaluated products list for the various types of car-carried equipment within the revenue fleet.

MAINTENANCE ENGINEERING

- Ensure contractor and vendor compliance with technical specifications for equipment and material.
- Develop diagnostic (troubleshooting) procedures and fault isolation protocols.
- Develop & Design modifications to total car system design and to car system elements to improve overall dependability.

EXHIBIT B-5. THE PRINCIPAL FUNCTIONS OF A TYPICAL CAR MAINTENANCE DEPARTMENT (2 of 2)

A typical *Car Maintenance Department (CMD)* is structured with the car maintenance facilities operations as the nucleus, and with the support functions as satellites of, and solely responsive to, the needs of the *hands-on* maintenance functions. A number of support elements are integral to the CMD, while others are properly provided by the Administration Department (which centralizes those functions common throughout the transit authority). Exhibit B-6 is an organizational overview of a typical CMD organization.

On larger rapid transit systems, overall responsibility for car maintenance operations is distributed between sub-fleet managers. Distribution of responsibility is on the basis of one of the following:

- gecgraphical area of operation,
- established zones of operation,
- specific, discrete routes within the overall route structure,
- type of revenue equipment (i.e., all cars built under a given procurement contract).

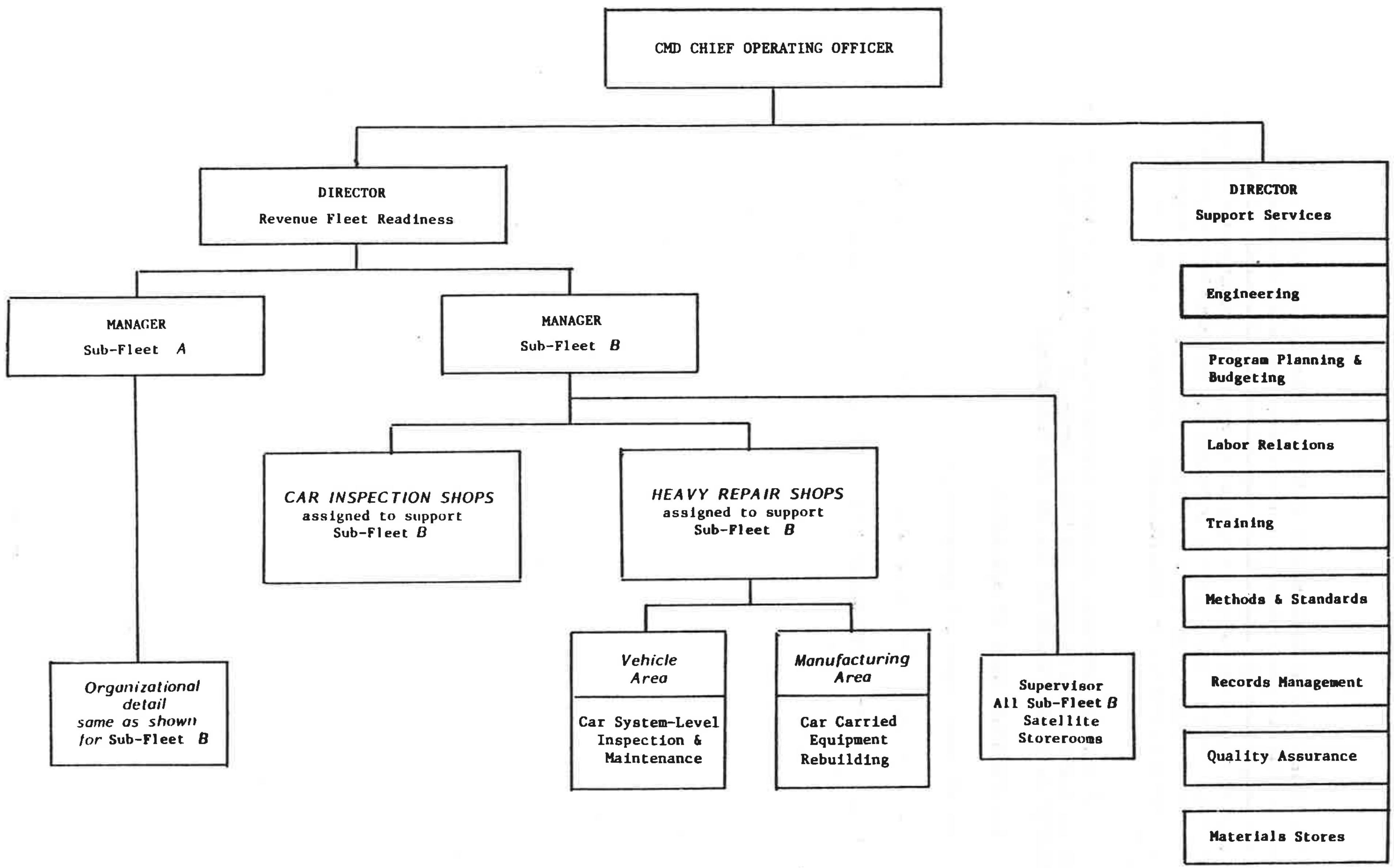


EXHIBIT B-6. FUNCTIONAL STRUCTURE OF A TYPICAL CAR MAINTENANCE DEPARTMENT (CMD)

MAINTENANCE FACILITIES OPERATIONS

The Physical Plant

The physical plant design evolved from a recognition that routine and complex maintenance actions can most economically and effectively be performed at two distinctly designed and separate facilities.

Routine Maintenance is defined as:

- periodic inspections and servicing of the car as a complete, engineered system
- that on-car maintenance that is usually limited to parts replacement
- diagnosis of in-service failures
- routine cleaning of car interiors and exteriors

Complex Maintenance is defined as that repair work which normally requires the immediate availability of:

- skilled craftsmen,
- industrial machinery, equipment & tooling
- very heavy lift & transport capability
- turn tables

Car Inspection Shops normally perform routine maintenance. Heavy Repair Shops are designed, equipped, and manned to perform complex maintenance.

Car Inspection Shops

Car inspection shop employees possess a thorough understanding of their assigned work and a general knowledge of the total equipment. Car inspection shops are designed, equipped, manned and logistically supported to perform the following work:

- Routine inspections and servicing of car system elements requiring lubrication, cleaning, consumables/disposables replenishment and sub-element adjustment.
- Scheduled inspection and maintenance actions as a function of time or revenue mileage.
- Diagnosis and isolation of the initial, actual cause of road failures of revenue trains; determination of the appropriate remedial action; and estimation of resources requirements.

While inspection and servicing schedules are initially defined by the car-builder and his subcontractors, these schedules are invariably refined by the owning operator at the end of the warranty period with the objective of optimizing equipment utilization within the constraints of available resources.

Heavy Repair Shops

Those repairs that require longer than one working day to complete are usually assigned to heavy repair facilities. (See Exhibit B-7, HEAVY REPAIR SHOP ORGANIZATION & PERSONNEL RESOURCES.)

The day shift is sized to accomplish, according to a normal schedule, all work planned for a given year. A partial second shift is employed to:

- efficiently utilize very expensive machinery
- perform wheel trueing
- complete certain operations that can neither be completed during one shift nor be discontinued until the next work day,
- work on special projects.

The skilled craftsmen who comprise the work force are supported by the Engineering Section.

Each heavy repair shop is a hybrid of two functional areas; i.e.,

- Vehicle, and
- Manufacturing

Within the Vehicle Area, maintenance is performed at the car system (total car) level. The Manufacturing Area is actually a complete industrial facility made up of individual shops, or crafts-areas; thereby, providing the rapid transit operator with the capability of rebuilding all major components on its revenue cars.

Representative shop activities include:

- Rotating apparatus overhaul
- Truck rebuilding:
    - wheel and axle assemblies
    - journal bearing overhaul
    - drive unit overhaul
- Brake overhaul

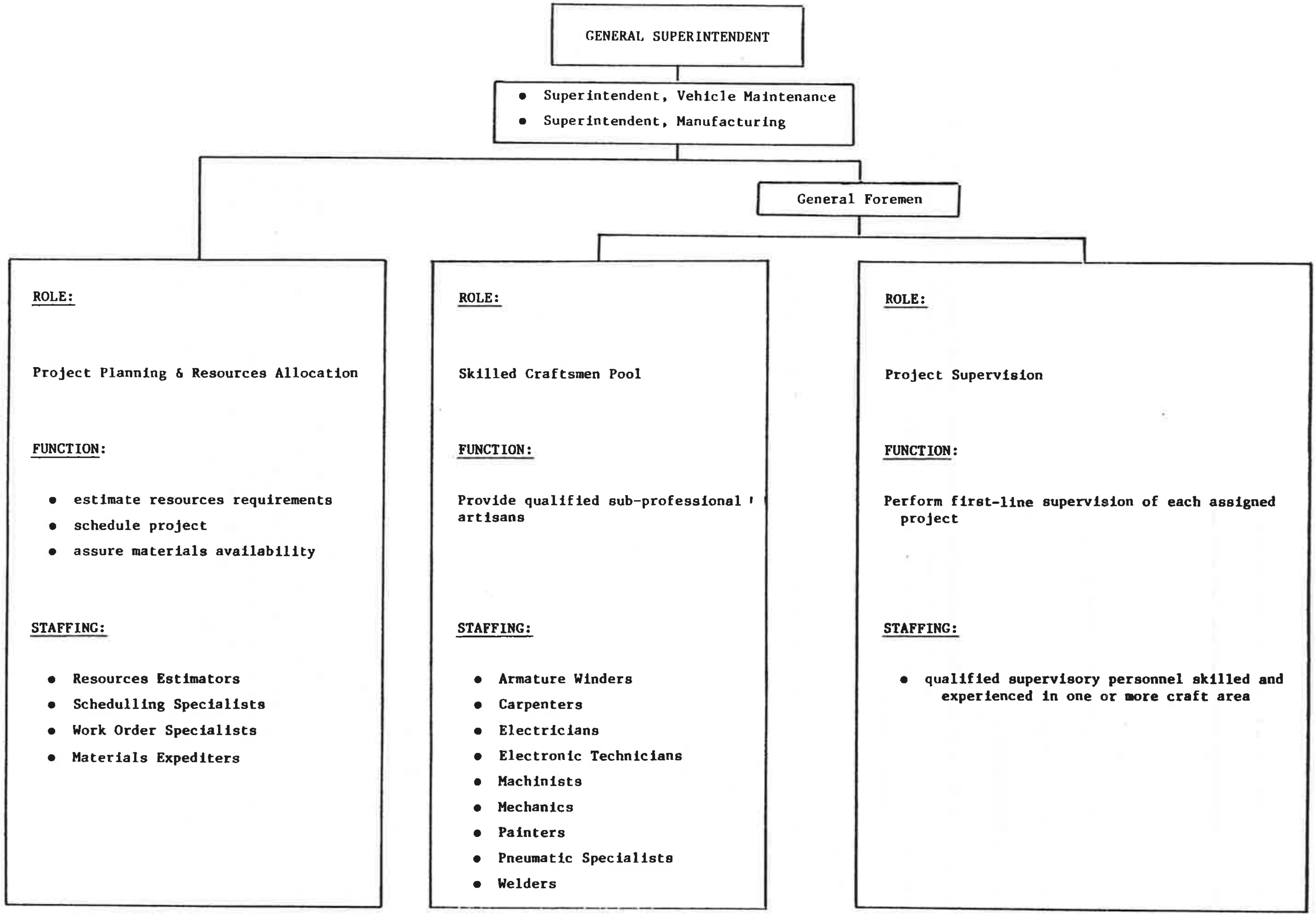


EXHIBIT B-7. HEAVY REPAIR SHOP ORGANIZATION & PERSONNEL RESOURCES

- Electrical control overhaul
- Electronics systems servicing
- Carbody:
    - painting
    - structural repair & restoration
- Wheel trueing
- Pneumatics

Following completion of the appropriate maintenance action or overhaul, the cars are moved to a final inspection and cleaning area where testing and inspections verify that cars meet all established criteria and can be returned to revenue service.

CMD SUPPORT SERVICES

There are eight functional support elements which are organic to a typical CMD:

- Car Maintenance
- Engineering
- Program Planning & Budgeting
- Labor Relations
- Training
- Methods & Standards
- Quality Assurance
- Records Management
- Materials Stores

Several of the support elements within this basic listing are extensions of Administration Department functions. While each of these particular functions is carried out according to the guidance directives of Administration, actual performance accountability is to the CMD Manager, and line supervision is provided by CMD employees. (Exhibit B-8, CMD RESOURCES ALLOCATIONS MATRIX FOR SPECIAL PROJECTS, identifies responsible action and support elements for each of a special project assigned to a Heavy Repair Facility.)

SPECIAL PROJECT FUNCTIONAL STEPS	HEAVY REPAIR SHOP PERSONNEL RESOURCES				CMD SUPPORT SERVICES							
	Superintendent	General Foreman	Foreman	Craftsmen	Engineering	Program Planning & Budgeting	Labor Relations	Training	Methods & Standards	Records Management	Quality Assurance	Materials Stores
1. Determine priorities for work assigned to the Heavy Repair Facility	X											
2. • Define assigned work in the form of coherent projects • Prepare a project plan for each discrete work assignment • Estimate required resources • Determine resources availability, including engineering assistance • Take action to correct any resources deficiencies • Allocate required resources • Schedule work • Issue work order					IS	X			IS			IS
3. • Designate Project Supervisor • Assign appropriate mix of skilled personnel • Ensure availability of all required resources: •• personnel •• tools •• shop equipment •• materials		X	A	A	(A)							IS
4. Accomplish assigned project			X	A	(A)							
5. Conduct testing to demonstrate compliance with technical specifications			X	A	(A)							
6. Inspect completed work to ensure compliance with quality standards											X	
7. a. Record resources actually expended to accomplish work order			X							A		
b. Analyze resources-expended records data									X	A		A
8. Return project team personnel to supervisory/craftsmen pools		X	A	A								
9. Close out work order			P_1			P_2						

Key: X=Sole Responsibility; P_=Shared Responsibility; IS=Information Source; A=Essential Action Element; (A) Action Element, As Needed

EXHIBIT B-8. CMD RESOURCES ALLOCATION MATRIX FOR SPECIAL PROJECTS

Summary charters of each of the eight basic support elements follow:

Car Maintenance Engineering

Develop technical specifications for rebuilt cars and for car system design modifications to incorporate, by retrofit, car-carried equipment that is technologically different. Oversee each of the above programs for the transit authority. Evaluate car system technology on an active revenue fleet basis to promote transit authority-wide standardization and to optimize car utilization. Perform engineering consulting services for fleet maintenance physical facilities managers and for car maintenance managers, planners, and line supervisors. Plan and carry out special projects.

Program Planning & Budgeting

Develop annual, long range, and special program plans. Prepare resources requirement estimates and justifications. Perform life cycle, trade-off and economic analyses. Oversee departmental operating budget. Allocate available (actual budget) resources.

Labor Relations

Coordinate all labor relations involving Car Maintenance Department personnel and affecting the ability of the department to perform its function. Review all grievances and disciplinary activities. Investigate and recommend disposition of appeals of disciplinary decisions. Conduct departmental hearings for supervisory, career, and salaried employees. Maintain those files and statistics required for CMD periodic reports.

Training

Develop and implement a comprehensive training program to ensure:

- qualified CMD employees in every assignment and at every level of responsibility,

- eligibility for career progression by all employees who are both motivated and able to benefit from CMD training.

Conduct formal classroom training both at the transit authority's central education sites and at the maintenance facilities. Develop technical and management training curricula within the local vocational education infrastructure with the cooperation and participation of both the local school districts and State-level educational offices.

Methods & Standards

Develop and publish inspection and maintenance manuals which detail the most cost-effective and safe procedures. Develop work performance standards based on analysis of objective data, actual experience, and observations within the CMD. Develop useful-life (i.e., satisfactory performance) statistics for all car-mounted equipment as the basis for:

- materials stores inventory planning, and
- establishing equipment replacement schedules,

thereby acting to minimize cars out-of-service because of parts outages and failures during revenue service.

Quality Assurance

Assure and maintain the quality, reliability and safety of the revenue fleet and the work/service rolling stock of the fleet by verifying that repairs have been accomplished in conformance with established standards.

Records Management

The CMD Records Management function does not include the classical personnel records of CMD employees.

The data recorded includes:

- revenue service mileage of each car
- individual car history records
- road failure cause, required repairs, resources expended, and time out-of-service
- nature of each maintenance action performed in-shop and the resources expended
- materials (parts, components & items of equipment) consumption, and instances of non-availability.

Revenue service mileage (RSM) records are maintained for every rapid transit car on the active fleet roster. Each day the number of miles that each car has operated in scheduled service is recorded. Depending on the data management system adopted by the transit authority, the daily service mileage may be:

- manually added to each car's hard copy performance record, or
- entered into a computerized performance record by use of punch cards or computer terminals, or
- entered automatically into a computerized performance record via a computer program which queries automatic train car identification devices.

Whether manual or ADP, each transit authority's RSM records are designed to isolate and identify all cars which have accumulated sufficient revenue mileage/time since a previous datum event to ensure timely shopping of those cars for scheduled preventive maintenance or for planned overhaul action.

Data are formatted to permit analysis by Methods & Standards as the basis for:

- developing CMD standards
- adjusting materials stores stockage/replenishment levels
- monitoring and adjusting work assignment performance standards
- identifying incipient equipment problems
- establishing/achieving cost effectiveness goals.

Materials Stores

Assure availability of new and replacement car system elements component parts necessary to maintain the fleet in a clean, reliable and safe condition. Stock, operate and provide logistical support to satellite storerooms.

To avoid having cars unavailable for scheduled revenue service because of lack of parts, storeroom stock levels and replenishment trigger-levels are based on planned, scheduled, and anticipated unscheduled maintenance and on any planned or ongoing major overhaul programs. Records of stock-in and stock-out are indexed to permit correlation of actual and planned consumption rates.

APPENDIX C

OPERATOR-SPECIFIC CAR MAINTENANCE RESOURCES DATA

OPERATOR-SPECIFIC CAR MAINTENANCE RESOURCES DATA

This Appendix is in 3 Sections:

SECTION A. DATA REQUEST FORMAT

PART ONE. Car Maintenance Budgeted/Expended Resources

PART TWO. Transit Authority-Specific Policies & Practices

SECTION B. EXPLANATORY NOTES (to clarify line-item data limitations)

SECTION C. COMPUTER PROGRAMMING INSTRUCTIONS

PART ONE. General

PART TWO. Line-Item Specific

Note: See pages 6 and 12 for additional comments.

SECTION A. DATA REQUEST FORMAT *

PART ONE. CAR MAINTENANCE BUDGETED/EXPENDED RESOURCES

0. Year of Record (Note 1)

I. Car Maintenance Department (CMD) capital & operating figures (Notes 2 & 3)

BUDGETED $

ACTUAL $

IIA. Capital & operating figures for all Car Inspection/Maintenance Facilities (CIMF)(Note 4)

BUDGETED $

ACTUAL $

IIB. Capital & operating figures for only certain CIMF (Note 4)

BUDGETED $

ACTUAL

IIIA. No. of salaried positions, all CIMF (Note 4)

AUTHORIZED

ACTUAL

---

*Section A is in two parts

IIIB. No. of salaried positions at ONLY CERTAIN CIMF (Note 4)

AUTHORIZED

ACTUAL

IVA. Foremen are salaried

yes

no

IVB. No. of foremen at all CIMF

AUTHORIZED

ACTUAL

IVC. No. of foremen at only certain CIMF

AUTHORIZED

ACTUAL

VA. No. of shop labor hours at all CIMF (Notes 4 & 5)

BUDGETED	Total	ACTUAL	Total
	S-Time		S-Time
	O-Time		O-Time

VB. No. of shop labor hours at only certain CIMF (Notes 4 & 5)

BUDGETED	Total	ACTUAL	Total
	S-Time		S-Time
	O-Time		O-Time

VC. No. of CIMF equivalent labor hours at all CIMF (notes 4, 5 & 17)

BUDGETED (Total) ACTUAL (Total)

VD. No. of CIMF equivalent labor hours at all CIMF (notes 4, 5 & 17)

BUDGETED (Total) ACTUAL (Total)

VI. Amount for contracting out renewal, repair or rebuilding of car system components

BUDGETED

EXPENDED

VII. Equivalent value of amount contracted-out in terms of labor hours (Note 6)

BUDGETED $

EXPENDED $

VIII No. of labor hours/car for unscheduled (failure) maintenance (Notes 5 & 7)

BUDGETED	Total	ACTUAL	Total
	S-Time		S-Time
	O-Time		O-Time

IX. No. of shop labor hours/car for scheduled (preventive maintenance (Notes 5 & 7)

BUDGETED	Total	ACTUAL	Total
	S-Time		S-Time
	O-Time		O-Time

X. No. of shop labor hours/car to perform periodic inspections (Notes 5 & 7)

BUDGETED	Total	ACTUAL	Total
	S-Time		S-Time
	O-Time		O-Time

XI. No. of shop labor hours/car to perform off-car renewal/repair/rebuilding of car subsystems & major components (Note 5)

BUDGETED	Total	ACTUAL	Total
	S-Time		S-Time
	O-Time		O-Time

XII. Formal classroom training costs (Note 8)

AUTHORIZED

ACTUAL

XIII. Cost of materials stores stockage & replenishment (Note 9)

AUTHORIZED

ACTUAL

XIV. No. of road failures (Note 10)

XV. Ratio of the no. of all shop labor hours to the no. of serviceable cars maintained by those CIMF to which the workers are assigned (Note 5)

XVI. Ratio of (1) all shop labor hours to perform only scheduled car inspections & maintenance to (2) the no. of shop labor hours to perform both scheduled and unscheduled car inspections & maintenance (Note 5)

AUTHORIZED

ACTUAL

XVII. Ratio of (1) all shop labor hours to perform only unscheduled car maintenance to (2) the no. of shop labor hours to perform both scheduled and unscheduled car inspections & maintenance (Note 5)

AUTHORIZED

ACTUAL

XVIII. Ratio of (1) all shop labor hours to perform only unscheduled car maintenance to (2) the no. of shop labor hours to perform only scheduled car inspections & maintenance (Note 5)

AUTHORIZED

ACTUAL

XIX. Ratio of (1) all Car Inspection/Maintenance Facilities (CIMF) personnel (including shop superintendents) to (2) all Car Maintenance Department personnel

AUTHORIZED

ACTUAL

XX. Total no. of unscheduled maintenance actions (Notes 11 & 12)

XXI. Mean distance (revenue miles) between unscheduled maintenance actions (Notes 11 & 12)

XXII. Mean distance (revenue miles) between failures (Notes 11 & 12)

SECTION A. DATA REQUEST FORMAT*

PART TWO. TRANSIT AUTHORITY-SPECIFIC POLICIES & PROCEDURES

XXV
A. Size of Active Revenue Fleet (Cars) (Note 13)
B. Percent under 10 years old
C. Percent 10 to 20 years old
D. Percent older than 20 years

XXVI Average no. of cars available for scheduled revenue service (Note 14)

XXVII Average no. of cars scheduled for revenue service (Note 14)

XXVIII Average annual mileage per car in scheduled revenue service (Note 15)

XXIX Budget includes emergencies as a line item (Note 16)

Yes No

XXX Materials stores are purchased

A. On an as-needed basis from the lowest bidder at the time each purchase order is issued

Yes No

B. On the basis of annual competitive contracts which fix the price of the items contracted for and the delivery times following issuance of each purchase order, but with the no. of separate purchase orders, the size of each purchase order and the issue date of each purchase order at sole discretion of the purchaser.

Yes No

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*Section A is in two parts

XXXI Journeyman-Level applicants can be hired

Yes No

XXXII The reporting operator has an Apprentice program

Yes No

XXXIII Formal classroom training is provided for CIMF employees

Yes No

XXXIV If formal classroom training is provided for CIMF employees, training is

On-site Off-site

XXXV If formal classroom training is provided for CIMF employees, training is during normal working hours

Yes No

XXXVI Minimum formal training hours budgeted for each new CIMF employee during first 12-months employment

hours

XXXVII No. of CIMF employees who were enrolled and participated in formal classroom training provided by the transit authority during the reporting year

XXXVIII CIMF employee time away from normal duty station to attend formal classroom training is budgeted as

Available for duty Unavailable for duty

XXXIX The Authority reimburses employees for the cost of Off-Site formal classroom training on the employee's own time in those instances where successful course completion will directly or materially improve an employee's qualification for that employee's present job assignment or logical advancement

Yes
No
Depends on circumstances

SECTION B. EXPLANATORY NOTES

1. This is the recent, completed budget year for which the particular transit authority is reporting. Actual (i.e., expended) figures may or may not have been audited.

2. Complete budget under the direct control of the Rapid Rail Car Maintenance Department (CMD) Chief Operating Officer. Includes (on a transit authority-specific basis) costs of:

   - New and replacement capital equipment and tools
   - Expendables/consumables
   - Contracted-out work
   - Operations (primarily CMD personnel costs including fringe benefits)

   The cost of training CMD employees with funding allocated to another department may be included in Data Element XII.

3. All mileage and dollar figures are in thousands; therefore, each value must be multiplied by 1000.

4. Not all transit authorities (TA) provided data for all car inspection/maintenance facilities (CIMF). In those instances where a TA only provided data for one or more specific CIMF, those specific facilities are identified in the appropriate accompanying TA profile.

5a. An A suffix to the fill-in values means that the TA has included the labor hours for foremen, mechanics, helpers, work control clerks and car cleaners.

A B suffix means that the TA has not included foremen

A C suffix means that car cleaners have not been included.

A D suffix means that the workforce represented by the reported labor hours is uncertain.

Note that both B and C suffixes can occur.

5b. S-Time means, straight-time

O-Time means, overtime

5c. Labor hours include paid absence time away from duty (e.g., sick leave, vacation, holiday, training).

5d. Total time is the sum of straight-time plus overtime.

5e. Shop labor hours may or may not include paid absence time.

6a. Labor hours are calculated in one of two ways:

(1) An E suffix means that the divisor is the wage scale (including fringes) of a top-level mechanic under terms of the existing contract with the reporting TA.

(2) An F suffix (divisor) is the average wage scale (including fringes) of all hourly non-supervisory shop employees at the reporting TA.

6b. We recognize that the cost of performing in-house the work which is contracted out would be greater than the equivalent value because the unconsidered value of necessary additional capital costs and worker compensation differences has not been factored in.

7. In those instances where data for fewer than all CIMF has been provided, the divisor is the number of serviceable cars which are maintained by that/those CIMF.

8. Amount for formal classroom training of CIMF craft and supervisory employees regardless of whether such training is:

- Conducted in-house by transit authority employees,
- Contractor-conducted, or
- Acquired on the employee's time off-site.

Include costs of: curricula development, textbooks, training aids, and instructor training. Costs need not be CMD budget line items.

9. Items may have been purchased with funds included in another department's budget.

A G suffix indicates that the values do not include associated storeroom/stockroom (wholesale/resale) operating costs.

An H suffix indicates that associated operating costs are included.

A J suffix indicates uncertainty as to whether associated operating costs are included.

10. A road failure is a train delay or service interruption during revenue operations or while attempting to place a train into revenue service. Also referred to as a service call. Each transit authority has its own definition. In each instance, the sources of the values in Data Element XIV were the appropriate TA's, each applying its own definition.

11. A K suffix means: Each unscheduled maintenance action is recorded following completion of each associated shop work order, and the figure provided by the reporting operator is the sum total of all unscheduled maintenance actions during the reporting year.

An L suffix means: The figure provided by the reporting operator was extrapolated from a sample of records data.

An M suffix means: Data source different from K or L.

12. The P, Q, & S suffixes define the time reference for each Part Two Data Element, specifically:

P means: Either at the time a budget request is approved or at the beginning of the budget year

Q means: At the end of the budget year

S means: Annualized average for the reporting year

13. Does not include:

- cannibalized cars
- those cars which have suffered extensive damage/debilitation and were awaiting rebuilding/scrap decision
- cars judged to be beyond economic rehabilitation.

14. On any given local workday. Exclude weekends, holidays and special events.

15. If cars of different new car procurement contracts or cars assigned to dedicated lines or routings accumulate mileage at different rates, the specific averages of each are listed separately followed by numerals in parenthesis to correlate with the appropriate operator-specific notes.

16. This practice would obviate charging Emergency maintenance actions to either Lost Time or to Unscheduled Maintenance.

17. This value is the sum of Cost Elements V and VII and represents the hypothetical CIMF in-house labor resources if no work were contracted-out.

SECTION C. COMPUTER PROGRAMMING INSTRUCTIONS*

PART ONE. GENERAL

GEN-A The computer printout should replicate Section A exactly. Words written out in Section A should not be abbreviated if space permits.

GEN-B A number in the left column of Section C refers to a specific data element from Section A.

GEN-C GEN - letter, in the left column of Section C identifies a general instruction which is applicable to more than one data element.

GEN-D (Unless data element-specific program instructions override) In each instance where a transit authority has failed to provide an unambiguous response, print on each fill-in underline: No TA Data.

GEN-E Colons are unnecessary and will not be used

GEN-F Divide all mileage and dollar figures by 1000

GEN-G Print dollar signs even when no values are available

*Section C is in two parts

SECTION C. COMPUTER PROGRAMMING INSTRUCTIONS*

PART TWO. LINE-ITEM SPECIFIC

LINE-ITEM NUMBER	INSTRUCTIONS
O	Print UNK if specific year of record (YOR) not provided by TA or if YOR uncertain
IIIA & IIIB & VA & VB & VIII & IX & X & XI & XV & XVI & XVII & XVIII	Print to right of each value (leaving one space blank as a separating buffer between value and first suffix letter and between suffixes) and in alphabetic order all of the A through D letter suffixes occurring on the input work sheets (See Note 5)
VI	Print to right of each value (leaving one space blank as a separating buffer) either an E or an F as indicated on input work sheets (See Note 6)
XIII	See Note 9
XX & XXI & XXII	See Note 11
XXV & XXVI & XXVII	See Note 12
XXVII	Where different figures are given by a transit authority because of different carbuys or dedicated routings, identify each figure with a numeral suffix in parenthesis. Start with the numeral, 1, and progress through 2, 3, 4, etc.

* Section C is in two parts

APPENDIX D

NORMALIZATION FORMAT FOR COMPARISON
OF
OPERATOR-SPECIFIC CAR MAINTENANCE RESOURCES DATA

NORMALIZATION FORMAT FOR COMPARISON

OF

OPERATOR-SPECIFIC CAR MAINTENANCE RESOURCES DATA

This Appendix presents the thirteen normalized cost data ratios (NCDR)/performance measurement indicators (PMI) for industry-wide comparison of rapid transit car maintenance effectiveness. Note that these thirteen normalized cost data ratios are the basis for calculating 55 discrete values which are in effect, Car Maintenance Effectiveness Performance Measurement Indicators (PMI).

These normalized cost data ratios, if accepted by the industry as a reference datum against which recent operator-specific performance might be compared, would make it possible for each operator to compare its car maintenance effectiveness with that of other operators in instances of reasonable similarity.

Note: See pages 6 and 12 of text for additional comments.

THE NORMALIZED COST DATA RATIOS/PERFORMANCE MEASUREMENT INDICATORS

N-1 Capital & Operating figures for all/or for only certain Car Inspection/Maintenance Facilities (CIMF)--per car

BUDGETED $______________1 ACTUAL $______________2

N-2 Personnel allocated at or assigned to all or only certain CIMF--per car

a. Foremen and below; i.e., all hourly workers reporting to or under the direction of first line supervisors (foremen)

BUDGETED	Total	__________3	ACTUAL	Total	__________6
	S-Time	__________4		S-Time	__________7
	O-Time	__________5		O-Time	__________8

b. All other CIMF employees, including clerical

BUDGETED	Total	__________9	ACTUAL	Total	__________12
	S-Time	__________10		S-Time	__________13
	O-Time	__________11		O-Time	__________14

c. The total of N-2a. plus N-2b

BUDGETED	Total	__________15	ACTUAL	Total	__________18
	S-Time	__________16		S-Time	__________19
	O-Time	__________17		O-Time	__________20

(Note: S = straight; O = overtime)

N-3 CIMF employee hours--per car (All employees actually located at that/those sites.)

a. Foremen and below; i.e., all hourly workers reporting to or under the direction of first line supervisors (foremen, plus all foremen

BUDGETED	Total	____________ 21	ACTUAL	Total	____________ 24
	S-Time	____________ 22		S-Time	____________ 25
	O-Time	____________ 23		O-Time	____________ 26

b. All other CIMF employees, including clerical

BUDGETED	Total	____________ 27	ACTUAL	Total	____________ 30
	S-Time	____________ 28		S-Time	____________ 31
	O-Time	____________ 29		O-Time	____________ 32

c. The total of N-3a plus N-3b

BUDGETED	Total	____________ 33	ACTUAL	Total	____________ 36
	S-Time	____________ 34		S-Time	____________ 37
	O-Time	____________ 35		O-Time	____________ 38

N-4 Mean-Distance-Between-Repairs (MDBR) unscheduled maintenance actions ____________ 39
(Note: All repairs of any nature excluding "No Trouble Found" incidents

N-5 Number of road failures/car

40

N-6 Availability Index Ratio of the: Average no. of cars daily available for scheduled revenue service to the Size of the active revenue fleet

41

N-7 Ratio of: Total no. of CIMF employee hours/car to the average annual mileage/car in scheduled revenue service

BUDGETED 42 ACTUAL 43

N-8 Ratio of: All CIMF employee hours to perform ONLY SCHEDULED car inspection & maintenance to the No. of shop CIMF employee hours to perform both SCHEDULED AND UNSCHEDULED car inspections & maintenance

BUDGETED 44 ACTUAL 45

N-9 Ratio of: Materials stockage & replenishment costs to the mean distance between unscheduled maintenance actions

BUDGETED 46 ACTUAL 47

N-10 Ratio of: The no. of CIMF equivalent labor hours at all or only certain CIMF to the total no. of unscheduled maintenance actions at those CIMF

BUDGETED 48 ACTUAL 49

N-11 Ratio of: The no. of foremen at all or only certain CIMF to the no. of cars maintained there

BUDGETED 50 ACTUAL 51

N-12 Ratio of: Materials stores stockage & replenishment costs to active fleet size

BUDGETED 52 ACTUAL 53

N-13 Ratio of: Total no. of CIMF equivalent labor hours to the no. of cars maintained by those CIMF

BUDGETED 54 ACTUAL 55

APPENDIX E

REPORT OF NEW TECHNOLOGY

The work performed under this contract did not lead to any new inventions. The work did involve an assessment of current rapid rail maintenance procedures as practiced at several rapid rail transit systems in the United States.

50 copies