R-344U

U.S. Transit Properties Bus Maintenance Reporting Systems

TASK A REPORT

Prepared by:
Dynamics Research Corporation
Systems Division
60 Concord Street
Wilmington, Massachusetts 01887

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U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Massachusetts 02142

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PREFACE

For nearly a decade the bus transit industry has been concerned with the decreasing reliability, availability, and quality of new buses. It is possible to alleviate this trend with the support of an industry-wide maintenance information data bank which collects and supplies information to the industry for problem solutions. The development of a data bank to service these needs requires an evaluation of the maintenance data reporting systems currently in use throughout the bus transit industry.

This report describes Task A of the contract to "Develop the Groundwork and Prepare the Backup Information Necessary for the Establishment of a Bus TRIP Data Bank", (hereafter referred to as Bus TRIP). The purpose of Task A, the initial stage of the Bus TRIP program, was to appraise and evaluate the incident and maintenance reporting systems used by bus transit systems in the U.S.A. The results, conclusions, and recommendations of this task will be used to define and develop the Bus TRIP data bank. This task was

conducted by the Dynamics Research Corporation (DRC) under Contract Number DTRS-57-80-C-00007 from the U.S. Department of Transportation, Transportation Systems Center (TSC). The Bus TRIP contract was awarded in December, 1979.

EXECUTIVE SUMMARY

Purpose

Decreasing reliability and availability of new buses has been a significant concern of the bus transit industry. To counteract this trend required the development of a data bank which can provide data to the industry so that equipment performance can be evaluated and problems corrected. To achieve this goal, the government awarded a contract to DRC to initiate the development of such a data bank.

Bus TRIP is a government sponsored contract to collect, analyze, and disseminate reliability information on transit bus equipment. The purpose of this Bus TRIP contract is to develop the groundwork and prepare the backup information necessary for the establishment of a Bus TRIP data bank. The objective of Task A, the initial activity of the Bus TRIP contract, is to appraise and evaluate the incident and maintenance reporting systems used by bus transit systems in the U.S.A. The basis for the evaluation was the information collected from a sample of bus properties considered as potential participants for a small-scale experimental data bank.

Information collected from these properties was summarized to present the various data characteristics found during the visits. Five data categories were defined for presenting the data: reference data; bus equipment breakdown; maintenance practices; data collection system; and reports.

Conclusions

The evaluation of candidate bus properties provided a significant insight into the maintenance reporting systems employed by the bus transit industry. The results of this study showed that there is a strong requirement for a common, standard data bank such as Bus TRIP. The decision making process at all levels within the bus transit industry could benefit significantly by the added information afforded by this data bank. This need is essential to the bus transit industry because the industry currently collects an abundance of data, complex in nature, from a variety of data sources, subjective and tailored to each property's needs. It was also made evident that this type of unstructured data cannot provide objective vehicle equipment measurements when comparing data from different sources.

The properties recognize that this disparity in the data exists and they have expressed an interest in modernizing and improving their data base. Most properties are planning to automate their data systems and there is a trend towards accommodating and using reliability data. This trend is encouraging since it makes it easier to collect more meaningful maintenance data and should enhance Bus TRIP data bank operation and use.

Recommendations

The conclusions have provided a significant amount of evidence which show that there is a need for a Bus TRIP data bank. This need makes it necessary to recommend that the development of the Bus TRIP data bank is an essential factor in the continued progress of the bus transit industry. To best proceed with this development, it is suggested that initially a limited number of components be monitored and processed through the data bank to gain experience in providing such a data service. Following the evaluation of this initial step, the bank can then be expanded to provide greater coverage.

Consistent with the development of the bank, Bus TRIP should be organized to provide a variety of data reports to satisfy the needs of the bus transit industry. In addition, the data bank should be capable of accepting special data requests to produce special reports as the need arises. Significant to the development of the data bank should be its ability to accommodate, process and publish reliability type data indicators which will serve to measure equipment performance.

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LIST OF ABBREVIATIONS

ADB	Advanced Design Bus
AMG	American Motors General
APTA	American Public Transit Association
ARMS	Account Reporting Management System
BREL	Bus Reliability Equipment List
CTA	Chicago Transit Authority (Chicago, IL)
CORS	Coach Operations Reporting System
COTA	Central Ohio Transit Authority (Columbus, OH)
DOT	Department of Transportation
DRC	Dynamics Research Corporation
FLX	Grumman Flxible Corporation
GMC	General Motors Corporation
GPL	Generic Parts List
MARTA	Metropolitan Atlanta Rapid Transit Authority (Atlanta, GA)
METRO/H	Houston Metropolitan Transit Authority (Houston, TX)
METRO/S	Municipality of Metropolitan Seattle (Seattle, WA)
MSA	Management Science of America
MTA	Mass Transit Administration (Baltimore, MD)
MTTR	Mean Time To Repair
N/A	Not Available
NLC	New-Look Conventional
OEM	Original Equipment Manufacturer
PM	Preventive Maintenance
RIPTA	Rhode Island Public Transit Authority (Providence, RI)
RRV	Rapid Rail Vehicle
SCRTD	Southern California Rapid Transit District (Los Angeles, CA)
SEMTA	Southeastern Michigan Transportation Authority (Detroit, MI)
SIMS	Service Information Management System
TRIP	Transit Reliability Information Program
TSC	Transportation Systems Center
UMTA	Urban Mass Transportation Administration
VIA	San Antonio Metropolitan Transit (San Antonio, TX)
VMS	Vehicle Maintenance System

SECTION 1 - INTRODUCTION

Decreasing reliability and availability of new buses has been a significant concern of the bus transit industry. To help reverse this trend requires the development of a data bank to provide data to the industry so that equipment performance can be properly assessed. These assessments would help management in making decisions concerning the maintenance, operation and purchasing of equipment. To support this objective, Bus TRIP, a government initiated contract was awarded for the purpose of preparing the background information for developing a data bank for bus transit vehicles.

The purpose of Task A, the initial portion of the Bus TRIP contract, was to appraise and evaluate the incident and maintenance reporting systems used by bus transit properties in the U.S.A. Task A focused on the current capacities of these properties to collect, process and evaluate data and to assess their performance and trends in this field. This was accomplished by reviewing a sample of properties from which the problems and progress experienced by data collection systems could be determined.

To describe the activities and results of the Task A portion of the contract, this report has been partitioned into the following major sections:

Background - The historical development of the Bus-TRIP program and intent.

Approach - The rationale used for the evaluation.

Property Descriptions - Property selection, descriptions and a summary of their data characteristics.

Government Industry - A description of the material and functions of government and industry in supporting a data bank program.

Conclusion - A presentation of the results of the evaluation.

Recommendations - Proposed actions which would benefit the industry.

1.1 - BACKGROUND

Transit Reliability Information Program (TRIP) is a government initiated program to assist the transit industry in satisfying its needs for rapid rail transit vehicle reliability information. TRIP will provide this assistance through the implementation and operation of a national

reliability data bank. The data collected will be disseminated to the transit operating industry, equipment suppliers, and federal agencies to assist in recognizing reliability problems, improving maintenance, operations, and thereby reducing maintenance costs. In September 1978, DRC was awarded a contract to implement TRIP for Rapid Rail Vehicles (RRV). This contract (RRV TRIP) has two major phases:

Phase I

- Define, document, and present the RRV TRIP data bank requirements and configuration.
- Establish and operate the TRIP experimental data bank.

Phase II

- Assist and support the establishment of a full scale TRIP data bank.

At present, Phase I of RRV TRIP is in operation with an experimental data bank receiving data from five properties, covering the brake, doors, and propulsion systems on 1300 RRVs.

Bus TRIP, a parallel extension of RRV TRIP, designed to accomodate bus transit vehicles was awarded to DRC in December 1979. The purpose of this contract (Bus TRIP) was to prepare the backup information necessary for establishing a bus reliability data bank. Bus TRIP was designed to use the present TRIP structure and experience in collecting and processing RRV information. Bus TRIP will be developed similar to RRV TRIP and will utilize the same data bank configuration and general equipment breakdown where possible. The output generated from the bus reliability data bank will be disseminated to the bus transit industry, in the same way that RRV TRIP information is distributed to the rail transit industry. To carry out the program, the Bus TRIP contract was divided into five tasks, described as follows:

Task A Appraise and evaluate incident and maintenance reporting systems used by bus transit systems in the USA.

Task B Establish a bus reliability equipment list.

Task C Define and scope the reliability data bank required by Bus TRIP.

Task D Define, recommend, and produce guidelines for the implementation and operation of Bus TRIP.

Task E Participate in and contribute to a Bus TRIP project review and prepare the Bus TRIP final report.

In addition to an appraisal of bus transit systems, government agencies and bus manufacturers were contacted to obtain information on bus standards and specifications. Ultimately, Bus TRIP data bank outputs will be used as inputs to such specifications and standards.

1.2 - APPROACH

The development of a Bus TRIP data bank required an assessment of the reliability data that can be supplied by bus properties. This requirement necessitated an evaluation of the maintenance reporting systems in use throughout the bus transit industry. To collect such information from all the bus properties in the United States would be an impossible task given the available resources. Therefore, the approach was to select a sample which would represent a cross section of the properties throughout the country. Having established this baseline, the intent was to determine the criteria for selecting the sample.

A number of factors were considered in determining the criteria for selecting properties as candidates for participation in the Bus TRIP program. First, fleet composition of properties was a primary consideration. Since future bus fleets will consist primarily of Advanced Design Buses (ADBs), New-Look Conventional (NLC) Buses, and Articulated Buses, maintenance data collected on these later models would be valuable. Thus, properties operating ADBs, NLCs, and Articulated Buses were selected as candidates. Second, it was desirable to choose properties that had maintenance data collection systems which could provide a sufficient quantity and quality of data to contribute to a Bus TRIP data bank. Third, it was important that the bus property candidates represented operations which would indicate a variety of operating conditions, such as climate, location, terrain, and fleet size. Climate determined the stress on bus equipment due to cold, hot, humid, and dry environments. A variety of geographic locations provided a country-wide representation of properties. Terrain was considered because various elevations and grades reflected different bus equipment stresses. Property size was considered because it represented large, medium, and small property data collection and maintenance operations.

Overall, the above factors insured that a comprehensive criteria was employed in selecting the candidates, and that a balanced fleet representation of ADB's, NCL's and Articulated buses from the candidate properties was obtained.

In addition to the data gathered from the properties, information from government agencies and bus manufacturers was sought. The information from government agencies will serve to provide Bus TRIP with transit bus reliability specifications for new bus designs. The information from bus manufacturers will provide equipment descriptions, manuals, and reliability requirements. The government/ manufacturer data will also contribute in the development of Task B, the establishment of the bus reliability equipment list (BREL).

SECTION 2 - PROPERTY DESCRIPTIONS

Each property is unique in the maintenance data collection system it employs, how it operates, its equipment identification and description. For this reason, it was necessary to interview each property that was selected as a candidate. The object here was to collect, evaluate and summarize the major points of their maintenance data reporting systems. By doing this we could provide a composite summary of the progress, voids and data trends being experienced by the properties.

Consistent with the above approach and to illustrate the results, this section has been divided into three major subsections as follows:

Selection Development - The selection method used to determine the final list of candidates to be visited and interviewed.

Descriptions - A general description characterizing each property visited.

Data Summary - A summary of the properties fleet and maintenance reporting systems divided into five distinct data information categories.

2.1 - Selection Development

This subsection describes the steps that evolved in determining the final list of candidates. As described in the approach, a criteria was established for selecting a sample of properties as Bus TRIP candidates. Applying this criteria, a preliminary list of 20 candidates was made from which ten final candidates would be selected. The preliminary list of twenty candidates are as follows:

Table 2.1-1.

Preliminary Candidate List

Atlanta, GA	Miami, FL
Los Angeles, CA	Milwaukee, WI
Baltimore, MD	Omaha, NB
Chicago, IL	Philadelphia, PA
Columbus, OH	Pittsburgh, PA
Dallas, TX	Providence, RI
Denver, CO	St. Louis, MO
Detroit, MI	San Antonio, TX
Houston, TX	Seattle, WA
Kansas City, MO	Washington, DC

The above properties represented the east and west coasts, the north, midwest, and southern regions of the country. They also indicated various property sizes, climates, and terrain. After review by APTA and TSC officials, the list was reduced to ten prime candidates. These candidates represented a good balance of ADB's, NCL's and Articulated buses in their fleets. Applying the selection criteria to them we may describe them as follows:

Table 2.1-2.
Selection Criteria

Property	Size	Location	Climate	Terrain
Atlanta, GA	Medium East	South- Hot, humid Summer	Mild Winter Small Hills	
Baltimore, MD	Large	East Hot, humid Summer	Fair Winter Hills	Small
Chicago, IL	Large Central	North Cold, windy Winter	Fair Summer	Level
Columbus, OH	Small Central	North Cold Winter	Hot Summer	Level
Detroit, MI	Small Central	North Fair Summer	Cold Winter Level	
Houston, TX	Medium Central	South Hot, humid Summer	Mild Winter Level	
Los Angeles, CA	Large west	South- Winter Dry hot Summer	Very mild and hilly areas	Level
Providence, RI	Small east	North- Mild Summer	Cold Winter Hills	Small

Property	Size	Location	Climate	Terrain
San Antonio, TX	Small Central	South Dry, hot Summer	Mild Winter plains	Flat
Seattle, WA	Medium	North-west	Cool Summer Wet, cold Winter	Hilly

After the above selections and before visiting them, a checklist was developed to define both the information and data that would be sought and collected. The data was grouped into five specific categories as follows:

- Reference data - property fleet composition by models, manufacturers and age.
- Bus equipment breakdown - system structure, codes, replacement frequency.
- Maintenance practices schedules, inventories and procedures.
- Data collection system - methods, capacity, forms
- Reports - operational, maintenance

Some of the information gathered (regarding data input, storage, computer automation, and output requirements) will be used for the definition and development of the data bank

in Task C. With the final selections made, scheduled visits were planned and executed.

2.2 - Descriptions

This subsection describes the various properties that were visited and characterizes their maintenance data collection operations. It can be stated that there exists complex, voluminous and varied data sources throughout the industry. Each property has a unique data collection system tailored to its needs. All of the properties, with one exception, collected data manually. CTA is totally automated and uses no forms or records. Several properties have partially automated systems which require some degree of manual interface. It was found that most properties are converting to automation, regardless of size.

The properties visited ranged in size from small operations with a few hundred buses to large operations with several thousand buses. In large properties operating several divisions, the collection and emphasis on information processed may vary with each division. Road call data and repair data may vary with the individual who records the data. Some individuals are definitive in identifying component failures while others are more general

in their identification. Sound engineering judgement is necessary to accommodate such data and insure proper evaluation for meaningful results. It can also be stated that there is a continuing interest amongst the properties to collect reliability data.

2.2.1 - ATLANTA, GA (MARTA)

MARTA is a medium size property employing a fleet of 841 buses, 134 of which are Advanced Design Buses (ADB). It has an extensive manual maintenance data collection system consisting of 12 forms pertaining to repairs, test, inspection, cleaning, and consumables. A preventive maintenance schedule provides for a daily, weekly, and 7000 mile check of each bus and includes provisions for major component inspections, dynamometer tests, and tune-ups every 25,000 miles.

The fleet includes ten different bus models, the majority of which are manufactured by GMC. These buses were introduced in service from 1963 to 1978 when ADBs were delivered. One standard maintained throughout the fleet is the high level of cleanliness, where coaches are cleaned on a daily basis.

MARTA does not use equipment breakdown codes and does not perform detailed component data collection. Although it has a good maintenance record, it has experienced significant problems with Grumman FLX 870 ADBs, especially

with the air conditioners. MARTA does not issue periodic reports on maintenance and operations although it does summarize data from which overall performance can be monitored. Appendix A.1 provides a detailed description of MARTA's data.

2.2.2 - BALTIMORE, MD (MTA)

MTA is a large property with 1038 buses operating in five divisions. Although it is a large organization, it maintains a detailed and extensive manual data collection system. The fleet consists of 11 different models, the majority manufactured by GMC. Service years for the buses range from 1957 to 1978, the latest representing the ADBs in service.

MTA categorizes road calls by mechanical and miscellaneous codes and employs 22 system breakdown codes. All data collected is well documented and detailed. A maintenance flow diagram describing the data collection procedure is available to show how the system works. Maintenance of the fleet is accomplished by 221 nonspecialized mechanics who perform general duties. MTA uses an extensive preventive maintenance schedule with periodic foremen inspections and checks following each repair. A daily and monthly inventory of fuel and oil deliveries is maintained. A coach record listing all completed repairs is maintained for each bus.

Baltimore plans to update its manual data collection system to an automated operation which will collect a larger volume of data. Maintenance and operational reports are issued on a monthly and annual basis. These reports range from summaries of road calls to consumables. Appendix A.2 provides a summary description of MTA's data.

2.2.3 - CHICAGO, ILL (CTA)

CTA is a large property operating a fleet of 2420 buses consisting of eight different models. The fleet operates from 10 garages which perform unscheduled and scheduled maintenance. Functionally, each garage can be equated to an operating division. A central shop supports the garages and is responsible for performing heavy maintenance such as unit rebuilding.

CTA employs a modern and fully automated real-time, on-line data collection system. This system uses an IBM 370 to provide an abundance of data. It records a wide range of maintenance activities and provides for quick and simple data recall. The initial phase of data transmission occurs when a road call is transmitted by radio to a control center. The control center then verifies the data and it is sent to the computer for processing. This scheme does not require the use of forms, cards, or paper work in the process of recording data. Regular and/or periodic reports are not issued or necessary because the system provides on-line capabilities such as total recall grouping, and display of information for immediate review as the occasion

demands. With 2-1/2 years of data already sorted and updated regularly, this information provides a suitable base for forecasting maintenance loads. Typically, each vehicle's mileage is monitored every day and fed into the computer.

Maintenance of the fleet is supported by 900 mechanics with 400 operating from the central shop. Thirteen different crafts are represented by the maintenance crews and all repairs are performed in-house. A training program acquaints personnel with changing equipment and sophistication. As a result, personnel attend refresher courses every three to five years to become familiar with advances in bus maintenance. Apprentice programs for new mechanics cover a four year training period.

Scheduled maintenance is performed on a 6000-mile interval with brakes examined every 2000 miles. The most significant problems in repairs have been primarily with transmissions and with air conditioners. When accepting vendor products, a broad test program is initiated to insure high standards of performance.

Despite the use of the most advanced data system in the industry, CTA intends to add features to the program capability such as inventory, stock tracking, and historical trends and analysis. Appendix A.3 provides a detailed description of CTA's data.

2.2.4 - COLUMBUS, OH (COTA)

COTA is a small property in central Ohio operating a fleet of 273 buses consisting of six GMC models. Plans for expansion and modernization are underway to include the addition of several hundred buses for a total of 444. A new facility for operating and maintaining the expanded fleet will be occupied in the near future.

COTA uses a manual data collection system with a variety of forms to record its data. Data is recorded initially on a road call form by a bus operator. This form is sent to the maintenance area and a mechanic is assigned to work on the problem. The fleet is maintained by mechanics who function in specialty areas of repair, such as electronics and body mechanics. The overall level of competence of the maintenance crew is reasonably high. Current plans call for a training program that will further improve the proficiency of the mechanics.

For controlling repairs, the bus equipment is divided into a number of major equipment categories, each of which identify major components with corresponding numerical codes. A repair rationale for the recorded problem supplements this identification. Additional work order

information is used to denote the specific problem, the time consumed during repair, and the corrective procedures used. General repair interest appears to center around brakes and shock adjusters. However, outstanding repair problem were not noted.

Columbus plans to install an automated data collection system patterned after CTA's (Chicago) concept. Although this concept will be scaled down to meet the needs of a small property, COTA believes the CTA system is ideally suited for it. Development is expected to parallel COTA's expansion with completion in two years. Currently, COTA cannot monitor maintenance problems in a formal way. However, using the raw data, it can respond to problems and perform investigative solutions manually, such as correlating components consumed versus inventory. COTA does not have formal reports for periodic publication. Appendix A.4 provides a detailed description of COTA's data.

2.2.5 - DETROIT, MI (SEMTA)

SEMTA is a small property operating a total fleet of 331 buses, 123 of which are GMC ADBs. It has experienced an availability rate of 94 percent due to its extensive maintenance practices. These practices include a failure analysis program, follow-up procedures on all repairs, and pit inspections for each coach every three weeks. SEMTA employs a preventive maintenance schedule with inspections at 12,000-mile intervals. Mileage, fuel, oil, and coolant usage are recorded daily for each coach. The number of parts used and the material cost per bus is reported at inspections. Parts inventory is handled by a computerized system that automatically reorders parts when its bin reaches a minimum level. SEMTA has three terminal facilities, each containing a parts store.

SEMTA employs 130 maintenance personnel, 25 percent of which are maintenance generalists. All repairs are performed within the property, with the exception of reboring engine blocks. Foremen follow up on all repairs and perform failure analyses. All failures are summarized

in a weekly maintenance report which includes information on the total fleet availability, road calls, miles between road calls, fuel (MPG), oil (MPQ), and coolant usage. A monthly report, and a consolidation of the weekly reports, are also issued. Appendix A.5 provides a detailed description of SEMTAs data.

2.2.6 - HOUSTON, TX (METRO)

Metro is a medium size property with a fleet of 890 buses operating in four divisions. The fleet employs ten different models primarily manufactured by GMC. In the past the property experienced operational difficulty and is now reorganizing its efforts to improve services. Although this description denotes Metro's current status, it should be noted that all aspects of operation, maintenance, and data processing are in a transitional period. The problems encountered at Metro are wide-ranging and cover both equipment and personnel difficulties. For example, METRO has difficulty attracting and retaining mechanics due to the large number of employment opportunities in Houston. In addition, the varied ethnic backgrounds employed at METRO result in communication difficulty.

Maintenance control basically centers around a "Bad Order Bus Report" defining an initial problem which is passed on to maintenance for repair action. All repairs are performed at the property by 271 mechanics who are classified as specialists in specific grade classifications. Preventive maintenance, road calls, and consumables are monitored with codes indicated on the various forms. Although a system structure for equipment is

coded and defined, it is not used. METRO's present use of 115 forms and cards to perform maintenance has complicated matters. In addition, a number of significant maintenance problems have occurred, necessitating equipment engineering design changes to maintain fleet operation.

METRO employs an automated data processing system which includes inventory and spares control. Incorrect data entries have resulted in numerous errors, and much of the inventory data has been found invalid when the stock room is checked. With the use of numerous forms, which contribute information and the data entry problems, the system is taxed to the extreme. As a result, a complete overhaul of the system is planned.

METRO issues a monthly summary of consumables, a daily "Bad Order Bus" summary, and performance indicators. Beyond this level, formal reports are not published. However, the report situation also is slated for improvement.

Although a transitional period is currently in effect, METRO feels sure that it can improve its data system. Appendix A.6 provides a detailed description of METRO's data.

2.2.7 - LOS ANGELES, CA (SCRTD)

SCRTD is a large property with over 2800 buses assigned to 11 divisions with scheduled operations that approximate 110 million miles per year. This massive operation is currently undergoing a reorganization by management in maintenance and operations. SCRTD has an aging fleet and significant financial constraints which will result in the retirement of at least 1200 buses from next year's fleet of 3600 buses. SCRTD has recently added 230 FLX 870s to its fleet. This will improve the fleet in terms of modern equipment, but it will add more maintenance problems.

SCRTD employs a UNIVAC system for monitoring inventory, oil consumption, road calls, and general performance information. Data is collected and summarized by each division, permitting direct focus on problems in a specific area of operation. While a significant amount of information is covered, not all information is reported in a manner to best represent the details and results desired. Although data is collected in terms of major system categories, detailed information on component failures is not available. The current warehousing scheme for spares is an extensive and complex system that will be improved in the future.

The size and complexity of SCRTD suggest the need for an improved data collection system. As a result, one division of SCRTD is currently testing the replacement of their UNIVAC system with an IBM-VMS system based on Chicago's VMS system. Data extracted from the test division would be supplied to the Bus TRIP program.

SCRTD employs an extensive preventative maintenance schedule and provides checklists for inspections. All repairs are performed by SCRTD unless overload circumstances warrant outside work. SCRTD presently is making every effort to improve maintenance and to recruit and retain good mechanics. As part of this effort, SCRTD created a 12-man training department, including six bilingual instructors. Mechanics are employed as generalists and are not classified by specialty.

SCRTD does not publish periodic maintenance or operational reports at the present time; but with the current improvement plans, SCRTD expects to improve the kind and frequency of data it can report. Appendix A.7 provides a detailed description of SCRTD's data.

2.2.8 - PROVIDENCE, RI (RIPTA)

RIPTA is a small bus property operating a fleet of 257 buses of which 77 are ADBs. The maintenance data is recorded carefully and maintenance activities are well controlled and reviewed on a daily basis. RIPTA employs 55 mechanics who perform all repairs in-house and are not specialized by classification. This permits versatility in meeting repair demands for a small operation. RIPTA employs a good preventative maintenance system using a number of forms. These forms not only cover inspections at specific time and mileage intervals, but also record consumables and major component inspections. Since the maintenance department does not log in the actual cause of failure, it cannot monitor component replacement. Equipment breakdown or codes are not used to track failures. Nevertheless, road call symptoms and the resulting repairs are recorded carefully so that a coach's repair history can be traced to highlight the significant problems it has experienced.

The maintenance data is available for review and is summarized monthly. Although formal reports are not issued detailing maintenance problems, the summaries are a means for monitoring maintenance progress. At RIPTA, spares are followed by the purchasing agent who orders new parts based

on the requisition received when a component is used. However, purchasing does not tie in with repairs directly, thus no correlation is made of parts purchased versus repairs/failure symptoms reported. Nevertheless, RIPTA appears to follow and control their operation effectively. Appendix A.8 provides a detailed description of RIPTA's data.

2.2.9 - SAN ANTONIO, TX (VIA)

VIA is a small property operating a fleet of 430 buses with a history of exceptional fleet performance recognized industry-wide. This quality can be attributed to good maintenance and innovative ideas. Several years ago, the property was converted to a private enterprise which services city equipment as time permits. This additional service allows VIA to utilize their work force in the most efficient manner, compensating for slack periods in the maintenance workload.

VIA does not use an automated data processing system and, therefore, does not employ a system breakdown or codes. For a property of its size, this lack of automation and codes has not caused any problems since VIA collects a significant amount of information on a variety of forms. However, VIA does not forecast maintenance trends and only summarizes major equipment repairs, unless a significant problem occurs. Although no formal reports are issued, the volume of data available permits VIA to respond to an inquiry with the appropriate information.

VIA employs 100 mechanics, classified as specialists and generalists, who perform all repairs in-house. Repair monitoring centers around a card which covers the maintenance history of each coach. Trends can be followed by examining each coach's card and determining the frequency of repairs. Tight control is maintained on repairs since the repair time is recorded and the actual repair is checked by a lead mechanic. This system allows VIA to monitor and verify maintenance activities in a precise manner.

The addition of ADBs to the fleet has caused significant maintenance problems. VIA was the first property to receive and operate GMC ADBs. The most prominent problem has been the air conditioning system. This problem prompted VIA to initiate an extensive redesign program. However, VIA has made strong progress maintaining fleet operation despite the difficulties encountered. Appendix A.9 provides a detailed description of VIA's data.

2.2.10 - SEATTLE, WA (METRO)

Metro is a medium size property which operates 914 buses. The fleet is composed of a mixed variety of vehicles from manufacturers such as GMC, Grumman, Flyers, AMG, and M.A.N. Metro owns 109 trolley buses, and also operates the largest number of articulated buses (151) in the U.S. Plans call for an expansion of the fleet in 18 months to include 204 additional articulated buses. METRO noted that the articulated buses are the most economical to operate and are used extensively during peak traffic periods.

METRO uses a system breakdown to identify six major equipment groups. Within these groups, component groups are listed and within these, specific components are recorded. At all levels of the breakdown, numerical codes are used with the equipment. Maintenance of the fleet is accomplished by 286 men who cover all aspects of bus repair and care. The mechanics employed perform all duties and are not specialized, with the exception of mechanics who repair electrical/electronic equipment, which have a higher degree of design sophistication. A reasonably high overall skill level has been maintained by the mechanics and supported with an effective training program for new personnel. METRO uses an extensive preventive maintenance program including

brake checks every 1000 miles and major inspections every 2000 miles. The hilly nature of Seattle's terrain prompts careful brake inspection periodically. Review of maintenance problems revealed that transmission (V730) has been the most significant problem followed by problems with brakes and electrical systems. However, these problems are not severe enough to negate METRO's maintenance program from achieving reasonable bus availability.

METRO employs an IBM 370 in its data collection system. Data from road calls is collected manually after it is transmitted by radio from the bus operator to a coordinator. This data then is sent to the computer for processing. While programming is accomplished in-house, software packages have been purchased as the occasion demanded. Data output covers a wide range of information. Consumable data, inspection scheduling, inventory, and SIMS reporting is provided by both automated and manual collection. The current system is being updated to improve the types of data that can be provided. Although Seattle has not purposely done so, it has the capacity to perform historical trends, focus on special problems, and monitor component rates. A noteworthy area of the METRO system is the significant success those experienced in buses with

lifts. Handicapped ridership has increased and lift equipped buses provide a substantial service to the population. Appendix A.10 provides a detailed description of METRO's data.

2.3 - Data Summary

This section summarizes the data gathered from the ten candidate bus properties (described in Section 2) and presents the results of this evaluation. Due to the large volume and variety of data collected, the information has been summarized and grouped into five major categories, each representing a specific characteristic of the data. The categories are (1) fleet information, (2) bus equipment breakdown for maintenance data recording, (3) maintenance practices and procedures, (4) maintenance data collection systems, and (5) data reports produced by the properties. Within each category, the property's contribution is again summarized to highlight major topics of interest.

Fleet information is presented in Table 2.3-1. This information illustrates the type of buses Bus TRIP would be monitoring. It covers all ten evaluated properties and indicates the quantity of ADBs, NLCs, and articulated buses that each property possesses. In addition, a projection of new orders is shown based on available information; and a characterization of each property's relative size is indicated.

The bus equipment breakdown utilized by each property for maintenance data recording is presented in Table 2.3-2. The equipment breakdown mentioned here is property-unique and is used to classify maintenance failures. Five of the ten properties employ their own equipment breakdown codes for data recording to cover either specified systems or major equipment groups. One property has a breakdown but does not use it and the remaining properties do not employ a breakdown. Of the ten properties investigated, six have codes to identify problems.

Maintenance practices and procedures are summarized in Table 2.3-3. All properties use preventive maintenance schedules with varying degrees of frequency. The larger properties tend to have a more formal follow-up procedure for repairs than the smaller properties. In addition, five of the ten properties have computerized inventory systems.

Table 2.3-4 summarizes maintenance data collection systems. Of the ten properties, two are automated and two others have some automation capability. The remaining six properties depend upon manual means for data collection. However, within several years, seven properties will have some form of computerized maintenance data collection.

Data reports produced by the properties are summarized in Table 2.3-5. Five properties report information on a regular basis. One property has an on-line capability and can recall information as needed.

The ten-property investigation indicated a wide variation in the amount and type of data that could be used as input to a Bus-TRIP data bank. The common types of data found between properties are road calls, periodic inspections, consumables, and coach repair record. Within each of these data types, there are common elements to all properties such as:

- Road calls - date, time, bus number, route identification, trouble narrative
- Periodic inspections - date, bus number, mileage
- Consumables - date, bus number, fuel consumed, oil consumed, coolant consumed
- Repairs - date, bus number, mileage, repair-done narrative.

Although the preceding information reflects commonality, it should be noted that such data is recorded in different ways and with different emphasis. The type of equipment, road experience, maintenance problems, and manpower available for repairs makes each property a unique data contributor with information dependent upon many variables. Hence, the total supply of transit bus data can be viewed as complex and involved, requiring a profound engineering effort to screen and guide the data into the collection system. A profound engineering analysis effort is necessary to retrieve the data, interpret it, and present the results in a manner useful to the industry.

Table 2.3-1 - Fleet information.

Property	Size	ADB		NLC			Total ADB & NLC	Artic AMG Man	Other	Total Fleet	New Orders
		GMC	FLX	GMC	FLX	AMG					
Atlanta	M		134	572	125		831	10		841	NA
Baltimore	L	60		723	245		1028		10[a]	1038	NA
Chicago	L			1944	456		2400	20		2420	NA
Columbus	S			273			273			273	NA
Detroit	S	123		208			331			331	NA
Houston	M	151	325	302			778		112[b]	890	2 (FLX ADB)
Los Angeles	L		230	1150	1147	200	2497	30	60[c]	2817	940 (GMC ADB)
Providence	S	77		163			240			240	7 (GMC ADB)
San Antonio	S	121		252			373		57[d]	430	123 (GMC ADB)
Seattle	M			251	99	224	574	151	200[e]	925	204 ARTICS 98 FLYERS 40' (expected late 1980-81)
TOTALS		532	689	5838	2072	424	9325	211	439	10,205	1372

a. Dodge Mobility buses with lifts and 13 seats
b. 55-EAGLE coaches, 57 minibuses
c. 58-Dodge minibuses, 2 NEOPLAN buses
d. 10-Transcoach Minibuses, 12-Over the road Challenger Coaches, 10 Chance minibuses, 25 Dodge Tradesmen B300 Maxi-Vans
e. 35-35' FLYER, 128-40' FLYER, 37 TRAVELLER

Table 2.3-2. Bus Equipment Coding System for Maintenance Data Recording.

Property	System Breakdown	Codes
Atlanta	No equipment breakdown	No system codes
Baltimore	System Breakdown - 22 systems	System and road call codes
Chicago	Defined for equipment	Extensive coding
Columbus	Defined for equipment	Codes for major equipment
Detroit	No equipment breakdown	No system codes
Houston	Defined equipment groups but not used	Codes for major equipment
Los Angeles	Defined for major components	Road call codes, but no system codes
Providence	No equipment breakdown	No system codes
San Antonio	No equipment breakdown	No system codes
Seattle	Defined for equipment	Equipment Codes

Table 2.3-3. Maintenance Practices and Procedures[1].

Property	Maintenance	Inventory
Atlanta	PM schedule Cleanliness of buses is stressed Engine testing (dynamometer) All repairs done in-house	Computerized system with automatic parts reordering
Baltimore	PM Schedule Repairs followed-up Extensive inspections Guidelines for all maintenance activities	Manual system
Chicago	Totally computerized PM Schedule Jobs logged into machine by terminal input	Not interfaced with computer system
Columbus	PM schedule Guidelines for safety Significant improvement planned with computerized system	Manual inventory
Detroit	PM schedule All repairs done in-house (except reboring engines) Repairs follow-up by foremen Failure analysis program	Computerized system with automatic parts reordering
Houston	PM schedule (indicated on computer printout of coach mileage) Computer system expected to improve maintenance data collection	Computerized system

[1] All properties have a variety of forms to cover all maintenance activities.

Table 2.3-3. Maintenance Practices and Procedures (concluded).

Property	Maintenance	Inventory
Los Angeles	PM schedule Computerized road call information Computer system being developed to improve maintenance data collection Informal guidelines for maintenance activities	Computerized system
Providence	PM schedule Informal guidelines for maintenance activities	Manual system
San Antonio	PM schedule Informal follow-up on repairs Repairs are timed	Manual system
Seattle	PM schedule Inspection guidelines Computer system collects data	Computerized

Table 2.3-4. Maintenance Data Collection Systems.

Property	System	Remarks
Atlanta	Manual	Comprehensive collection
Baltimore	Manual	Flow of forms for collecting data is well-documented
		Computerized system being developed
Chicago	Automated	Completely automated, All on line No forms used
Columbus	Manual	Computerized system to be installed in the future
Detroit	Manual	Computerized system to be installed in the future
Houston	Manual Computerized listings of mileage and consumables	Computerized system being developed
Los Angeles	Manual Computerized road call information	VMS to be installed in the future
Providence	Manual	Minimum number of forms used
San Antonio	Manual	Coach record, key document
Seattle	Automated	ARMS, CORS, SIMS, MSA systems

Table 2.3-5. Property Data Reports.

Property	Report Frequency	Content of Report
Atlanta	N/A	Do summarize data as needed
Baltimore	Monthly and Annual	Fleet mileage, consumables, fuel and oil consumption (MPG and MPQ), inspections, road calls (by system, miles/call, and miles/mechanical call)
Chicago	None	On-line capability permits full recall of any information desired
Columbus	N/A	Can trace problems with raw data
Detroit	Weekly and Monthly	Total miles/ division, accidents, vandalism, fleet status, monthly fuel consumed, MPG, oil consumed, MPQ, parts and units purchased
	Daily and Monthly	Fuel, oil and miles summary
	Monthly	Summary of road failures and coach changes
Houston	Daily	Summaries of road call analysis, maintenance performance indicators, central shop unit overhaul performance indicators

Table 2.3-5. Property Data Reports (concluded).

Property	Report Frequency	Content of Report
Los Angeles	N/A	Consumables and road calls reported by division
Providence	N/A	Overall maintenance activities are summarized
San Antonio	N/A	Fleet status summary at morning and evening peaks
Seattle	Daily and Monthly	Daily CORS and monthly management

SECTION 3 - GOVERNMENT - INDUSTRY DATA

This section presents information obtained from government and industry sources. The purpose of this investigation was to gather information to provide supplemental material to the Bus-TRIP data bank for developing and formulating standards, guidelines, and equipment descriptions of buses. Ultimately, this data can be used as a measure of design performance and can be related to the data generated from the bank. This data will be made available to properties. The information is presented in two groups: government, data collected primarily for standards; and industry, data collected for equipment breakdowns quality and warranty.

3.1 GOVERNMENT

The TSC in Cambridge, MA, and the UMTA Office of Capital Grants in Washington, DC were contacted for information.

A discussion concerning specification and standards was held with TSC's Urban Systems Division (Transit System Branch). A historical review of material was presented by

the branch with concluding remarks concerning present day activities. It was found that very little material is available to apply to the present designs of buses. Most of the material which currently exists is not applicable since it covers design concepts which are not used in today's bus designs.

UMTA's Washington Office of Transit Assistance, supported the findings at TSC's Urban Transit Branch. UMTA indicated that most of the material is obsolete and would be of no use to Bus TRIP. Also, the application of specification that do exist may have been used for the development of Trans bus and should not be applied to Bus TRIP.

It was also made evident that properties generate maintenance procedures on an individual basis. Such procedures may be based on vendor supplied data. This data may vary extensively and, in some cases, may be obsolete. Furthermore, most manuals do not provide training guidelines and therefore would not help as a standard. It was concluded that there is a need and desire to develop maintenance guidelines which instruct in fault analyses.

3.2 - INDUSTRY

Industry data was collected from the General Motors Corporation (GMC) Truck and Coach Division and from the Grumman FLXIBLE Corporation (FLX). The information obtained from each is highlighted in this subsection. American Motors General (AMG) was not contacted due to the fact that they no longer manufacture buses.

GMC Truck and Coach Division is engaged in a variety of bus activities which are beneficial to the Bus TRIP program. The warranty operation of this division is presently involved in developing a data bank based on failure information obtained from the field. Although data collection is handled manually, GMC is planning to automate this system by a trial completion date of six to eight months and a full-scale operation date of September 1981. A significant part of this activity is the development of a bus equipment breakdown with numerical codes. These codes identify various levels of equipment and permit the monitoring of failures. By applying such a system, GMC can determine where the problems are concentrated. The specifics of this activity were solicited from GMC, but since the information is of a proprietary nature higher level permission to release any information is required.

The service publications supervisor at GMC noted that continuous effort is applied in updating and revising GMC parts manuals. It is an ongoing task since design and operational maintenance changes create constant revisions. A sample manual provided a description of the equipment and its assembly features, and also included an equipment assembly breakdown and a pictorial description of the equipment. Furthermore, it contained a series of steps which provide responses to trouble symptoms and explain the potential cause of the problem. This manual provides an excellent guide in developing the GPL.

The parts and service manager suggested the benefit of additional visits to quality control, reliability, and test groups since they could provide better insight into bus performance. GMC personnel wanted to be assured that the creation of a Bus-TRIP data bank and the utilization of the GMC manual would not result in government regulations on bus equipment coding (which would cause GMC to reconstruct their parts-coding system). For adequate use of the GMC manual, it was agreed that the specific date of issue (ADB manual dated 1/79, NLC manual dated 7/75) be published so that future readers would be aware of the possibility of outdated information.

FLX Corporation maintains a modern engineering and manufacturing facility for the production of buses. The engineering organization utilized at FLX includes a quality control program to insure that FLX buses meet the required performance necessary for sustained operation. From the first prototypes which were road tested extensively, to the current production models, FLX inspects and checks each bus produced to insure that it meets prescribed standards. To support this engineering effort, Grumman maintains a quality assurance manual illustrating policy and procedures designed to guide a reader through the use of a quality program. Typical aspects of the quality assurance program are required monitoring and recurring inspection, of vendors identification of critical parts, hardness testing of aluminum alloys, assembly planning, and handling of defective items.

Destructive testing of production parts is significant to the quality assurance program. This testing is based on Class I failures, "failures that could lead to an injury and represent a severe crash situation." To support the above test criteria for safety, FLX has identified no less than 38 components which could lead to a problem if a failure

occurred. Hence, on a random basis, quality assurance will select these components from production and test to destruct, based on failure analysis. This activity works to measure and verify the quality of the components being produced.

FLX also collects data from various properties on the equipment problems experienced during the warranty period. After adding this data to the in-house test data, FLX has a good data base from which to assess problems. (Note that all of this data is collected and processed manually.)

As with any new design, deficiencies are sometimes revealed when a bus is introduced into full operation. As such problems are reported, FLX maintains a policy to respond and service each property's needs and to correct every problem encountered. Furthermore, to insure that buses are maintained properly, FLX has specified a procedure for repairs.

During a tour of the FLX plant the intricacies and precision of the production line was observed. At key points, inspection stations are maintained so that the

manufacturing process can be checked. It was noted that epoxy was used extensively as a bonding agent in the assembly of the buses. At the conclusion of the tour, manuals were requested for both the ADB and NLC models. FLX agreed to provide a copy of each model's manual.

SECTION 4 - CONCLUSIONS

The evaluation of candidate bus properties provided a significant insight into the maintenance reporting systems employed by the bus transit industry. The results of this study showed that there is a strong requirement for a common, standard data bank such as Bus TRIP. This need is essential to the bus transit industry because the industry currently collects an abundance of data, complex in nature, from a variety of data sources, subjective and tailored to each property's needs. It was also made evident that this fragmented data base cannot provide objective vehicle equipment measurements for use in comparing data from different sources.

Although this disparity in the industry exists, properties interviewed did reveal that there is an interest in modernizing and improving their data base. Most properties are planning to automate their data systems and there is a trend towards accomodating and using reliability data. This trend is encouraging since it makes it easier to collect more meaningful maintenance data and should enhance Bus TRIP data bank operations and use.

Based on this investigation the following specific conclusions were reached:

- None of the properties can compare equipment performance objectively since they do not share similar bus equipment breakdown codes or codes reflecting symptoms, defects, tests or repairs. Half of the properties have developed bus equipment breakdowns and of those, two use them to describe road calls and repairs.

- Only one property can objectively pinpoint component failure modes. Of the ten properties evaluated, only one performs failure analysis to determine the cause of equipment failures. A second property is planning to implement a similar program. This type of analysis pinpoints the specific component that caused the failure and eliminates subsequent failures.

- None of the properties currently collect or use reliability data, such as failure rates or mean time to repair (MTTR). Data to generate such rates exist in various forms at the properties. However, there is a trend among the properties toward collecting and using reliability data.

- None of the properties use coach records which can relate failure symptoms to replaced components. Most properties use some form of coach history record to log all maintenance performed on that coach. However, these forms do not necessarily correlate failure symptoms or defects with replaced components recorded on the coach form.

- Among the properties, there is a lack of formal correlation between spares consumption and repairs/replacements effected. More parts may be consumed than the number of parts used to correct actual failures.

- Among the properties there is a minimum effort to issue formal maintenance reports. While all of the properties can summarize their operational and maintenance activities in various ways, only three properties issue formal periodic reports which include data on road calls, consumables, inspections, and repairs. One other property has an on-line capacity to summarize data for any report that calls for a status.

- There is a significant lack of exchange of comprehensive data on maintenance and engineering throughout the industry. Isolated maintenance experiences, when collected, can provide evidence that points to significant problems. Innovative ideas and design modifications data developed by bus properties which lead to improved performance and equipment life are not necessarily made available to the bus industry as a whole.

- Government agencies (TSC and UMTA) could not provide specifications and standards that could be used in the Bus TRIP program.

- None of the properties track or collect information on the reliability of components supplied by either OEM or non-OEM vendors. This data would be a valuable addition to the industry. Due to the variety and unique characteristics of each data source, a sound engineering effort and analysis is required to produce useful information to the industry. Data from these sources are collected by a wide range of techniques and systems covering a variety of bus models, types and uniquely modified vehicles. Consequently, there exists a complex and extensive data base in the industry disassociated and varied in form.

- There is a visible and strong trend amongst the properties to automate their data collection systems. Among the properties that collect data manually there is a lack of uniformity in the use and types of maintenance records from which equitable equipment comparisons can be made. The use and volume of these records vary from a few in some properties to over one hundred in others and are sometimes redundant.

Looking ahead, we may conclude that there are long range benefits to be derived from the use of a Bus TRIP data bank. Typical of these are:

- Test program plans using TRIP information as a criteria for determining realistic component and major equipment reliability goals.

- Development of failure rates based on factual information that will withstand the test of time and result in a high degree of confidence in published values.

- Monitoring of component performance of Original Equipment Manufacturer (OEM) and non-OEM sources and identifying the component replacement rates of different vendor supplied equipment.

- Similar properties comparing a variety of data from a uniform and standardized base.

- Improved specifications and standards resulting from the utilization of historical information (such as MTBF for brakes or doors).

- Unlike information gathered from only one property, the collected weight of failure evidence from several properties may draw attention to a major problem which otherwise would be considered an isolated case.

SECTION 5 - RECOMMENDATIONS

The conclusions have provided a significant amount of evidence which shows that there is a need for a Bus TRIP data bank. This need makes it necessary to recommend that the development of the Bus TRIP data bank is an essential factor in the continued progress of the bus transit industry. To best proceed with this development, it is suggested that initially a limited number of components be monitored and processed through the data bank to gain experience in providing such a data service. Following this step, the bank can be expanded to provide greater coverage having formulated procedures for receiving, processing and retrieval of data, by utilizing the experience gained from the initial development.

Consistent with the development of the bank, Bus TRIP should be organized to provide a variety of data reports to satisfy the needs of the bus transit industry. In addition, the data bank should be capable of accepting special data requests to produce special reports as the need arises. Significant to the development of the data bank should be its ability to accomodate, process and publish reliability type data indicators which will serve to measure equipment performance.

Specific recommendations for the data bank are as follows:

- Procedures similar to those developed for RRV TRIP to process hard-copy maintenance data from the rail properties should be employed by Bus TRIP to process its hard-copy maintenance data.

- A generic coding scheme describing equipment characteristics similar to that developed for RRV-TRIP should be developed for Bus TRIP. This will permit indexing and monitoring of data in the bank.

- It is suggested that report types, useful to properties and other Bus TRIP users include:

  - Fleet unscheduled maintenance (bus type, fleet size, total miles, total maintenance actions, miles/maintenance actions, total replacements, miles/replacement, mean time to repair)

- Fleet fuel and oil consumption (bus type, fleet size, total miles, total number of gallons, miles/gallon, total number of quarts, miles/quart)

- Fleet road calls (bus type, fleet size, total road calls, miles/road call)

- Component road calls (component, bus type, fleet size, total road calls, miles/road call)

- Vendor performance (component, supplier, OEM reliability)

- Special requests (component failure rates, failure trends, performance forecasts)

- Initially, a limited number of components should be monitored in the Bus TRIP data bank. This would permit data bank development experience to be gained so that problems may be more easily identified early. These components should be

selected on the basis of their failure rates and significant maintenance demands. Typical components would be transmissions, brakes, and air conditioning equipment.

- After the initial trial stage, the number of components processed by the data bank should be expanded. This will allow greater coverage of data and make use of procedures to engage in a full scale data bank. However, the components should be limited to those systems/components which experience the most frequent failures. Items such as nuts, bolts, gaskets, and general hardware (miscellaneous parts) should be excluded from consideration.

- The cost, time, and resources necessary for implementing Bus TRIP should be carefully considered. Because most of the properties manually process their information, there will be a significant time and manpower to process bus data. Most data will be taken from forms and records.

- Publications from Bus TRIP should provide a variety of reports. The generated reports should offer options where comparisons between similar properties, identification of OEM and non-OEM component data, failure rates, and trends in equipment failures can be made available. Furthermore, accommodations for special requests should be an important consideration in the types of reports supplied.

- Guidelines should be developed to illustrate methods for inputting data, processing data, and producing output reports. Furthermore, the applications and techniques of reliability analysis should be applied to buses and the benefits of such analysis should be distributed to the industry.

- There is a need to develop maintenance manuals that will instruct in fault detection and analysis. This facet of problem solving should be made available throughout the industry.

- The data bank should be designed to accomodate component reliability information and to generate component failure rates as the data is accumulated. This data provides the best means for predicting equipment performance and determining component failure causes.

In addition to the above recommendations, the following observations are appropriate. These observations, while not critical to the input of the data bank, offer suggestions to the properties to improve the quality and type of data they submit to the Bus TRIP data bank.

- Although Bus TRIP has the ability to accept data from the properties as is, properties could derive added benefits by performing failure analysis to determine the cause of equipment failures and contributing such data to Bus TRIP for comparative assessment.

- It may be valuable for properties to correlate spares provisioning with the number of repairs/replacements affected to determine exactly what components were consumed during maintenance.

- It may be advantageous for properties to collect additional maintenance data, such as equipment modifications affected by the individual properties, and monitor parts reliability supplied by either OEM and non-OEM vendors.

SECTION 6 - REFERENCES

1. AM General Corporation, South Bend, Indiana, Diesel Articulated Transit Bus, Service Manual, Models 10255 & 10260.

2. GMC Truck and Coach Division, GMC, Pontiac, MI. Maintenance Manual, C-7921 RTS Coach Models TH-7203, T7H-203, TW-7203, T7W-203, TH-7603, T7H-603, TW-7603, T7W-603, TH-8203, T8H-203, TW-8203, T8W-203, TH-8603, T8H-603, TW-8603, T8W-603, January 1979.

3. Grumman Flxible Corporation, Deleware, Ohio, Transit Coach Maintenance Manual Model Nos. 53102-6-1&8-1.

4. Report No. E-4852U (Revised) - Transit Reliability Information Program (TRIP) Task 1 Report (Revised 12-21-78).

5. Grumman Flxible Corporation, Deleware, Ohio, Transit Coach 870 Maintenance Manual, Serial Nos: 91402-91438, 92871-92886.

SECTION 7 - APPENDIX A

Appendix A--1. ATLANTA, GA (MARTA)

REFERENCE DATA

MODEL	NO. OF BUSES	MANUF.	YEAR IN SERVICE
4518	20	GMC	1963
5303	93	GMC	1963-67
5303A	1	GMC	1967
5304A	3	GMC	1972
5305A	36	GMC	1968-70
5306A	4	GMC	1970
5307A	415	GMC	1974-76
111CD-D061	125	FLX	1973

MODEL	NO. OF BUSES	MANUF.	YEAR IN SERVICE
870	134 (ADB)	FLX	1978
SG220	10	AMG	1978

Total fleet = 841
10 Models

COMMENTS

- Top priority is given to keeping buses clean.
- Buses are painted frequently.
- Key effort on keeping buses on time and running.
- Has averaged high schedule adherence.

BUS EQUIPMENT BREAKDOWN

DEFINED SYSTEM STRUCTURE

- Not Defined
- No Codes
- No System Breakdown

MOST TROUBLE

- Air cond. compressors on FLX ADB
- Pressure switches on FLX ADB
- Leaking fuel tanks on FLX ADB
- Stress panels buckling between engine cradle & A-frame on FLX ADB
- Low-profiles, tires on FLX ADB's
- Windows debonded on FLX ADB's
- Rear axle on FLX ADB
- Faulty wiring on heat sensors in FLX ADB

COMMENTS

- Property does not employ a system breakdown structure or codes for tracking components
- Most significant problem—Air Conditioners

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Maintenance personnel ratings
- Follow-up inspection by special inspection foreman
- Training program for mechanics
- Guidelines for all inspections & preventive maint.
- Guidelines for dynamometer, transmission & engine tune-up
- Body & wreck repairs done @ Browns Mill Road Shop
- Unit overhaul at Browns Mill Road Shop
- GM diesel service manual

SCHEDULED & PREVENTIVE MAINTENANCE

- Cleanliness of rolling stock
- Daily inspection
- Weekly inspection
- Inspection, 7K miles
- Dynamometer engine test & tune-up, 25K miles
- Major components
- Before ADB's, 70K miles/air conditioner failure
- 300K miles/new engines
- 200K miles/rebuilts
- 40K miles with Goodrich tires

SPARES INVENTORY/PARTS

- Computerized inventory—automatically issues PO whenever stock in bin gets down to minimum as set on stock record cards
- Other shops (Pine Street, Brady Avenue) maintain stockrooms for just services they perform (Browns Mill Road is main storeroom)

COMMENTS

- If bus requires—1 gallon or more of coolant, it is taken into the shop for a complete cooling system inspection
- Excessive water added to batteries indicates immediate inspection of electrical system
- Excessive exhaust smoke indicates immediate inspection
- 1977—20K miles/delay & sched. adherence = 99.3%

DATA COLLECTION

DATA SYSTEM

- All forms processed manually
- Computerized inventory

PROGRAMMING/COMPUTER

N/A *

FORMS

- Monthly Maintenance Record (0140-1) (each bus)
- Actual work on bus (0188)
- Air Cond. PM (0810)
- Dynamometer test (0570)
- Daily bus record (0102)
- Interior cleaning (0195)
- Special inspec. for charters (0603)
- Garage-foreman's report of bus trouble (0149)
- Work order (0130)
- Equip. in Garage (0114)
- Gas Only (0763)
- Sight insp. (0143)

COMMENTS

- Maintenance coverage is all manually processed

DATA REPORTS

MAINTENANCE
N/A

OPERATIONAL
N/A

CONSUMABLES
N/A

INCIDENTS/ROAD CALLS
N/A

COMMENTS

- No reports issued that we know of
- They do not collect data, but have an annual summary of maintenance and operational costs from which expenditures can be tracked.

*Not Available

Appendix A--2. BALTIMORE, MD (MTA)

REFERENCE DATA

MODEL	NO. OF BUSES	MANUF.	YEAR IN SERVICE
TDH4517	2	GMC	1960-61
TDH4519	6	GMC	1963-67
TDH4521	1	GMC	1969
2411WC	10	Dodge	1976
TDH5105	29	GMC	1957-59
TDH5303	126	GMC	1963-64
TDH5304	123	GMC	1965-67
T6H5306A	374	GMC	1968-71
53096-8-1	40	FLX	1974
T8H5308A	62	GMC	1972-74
53096-8-1	205	FLX	1975
785603	60	GMC	1978

Total Fleet = 1038
11 Models

COMMENTS

- Information presented here is abbreviated due to the extensive and wide variety of information that Baltimore currently collects.
- 5 Divisions: Bush, Retreat, Kirk, Harford, Eastern

BUS EQUIPMENT BREAKDOWN

DEFINED SYSTEM STRUCTURE

- Road Call (Trouble) Codes
- System Breakdown—26 systems
  - 19 Mechanical Trouble Codes
  - 7 Misc. Trouble Codes

MOST TROUBLE

- (FY79) – % of equip. road calls
- 19.7% Road Calls = Clutch, transmission
- 18.8% Road Calls = Engine
- 11.7% Road Calls = Cooling system
- 11.6% Road Calls = Mechanical brakes
- 10.4% Road Calls = Starting & charging

COMMENTS

- Codes are designated for calls and system breakdown structure

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Specific guidelines for insp.
  - Checklist for major & minor inspection
- Follow-up on repairs by foreman

SCHED. & PREVENTIVE MAINTENANCE

- A/C Insp. @ 3K miles
- Brake Insp. @ 1K miles on older coaches
- Tire inspection

SPARES INVENTORY PARTS

- Daily Diesel Fuel & Oil Purchase Report
- Daily Inventory of Storage Tanks
- Monthly inventory & motor fuel & oil distribution
- Fuel & Oil Delivery Log

COMMENTS

- Do provide a flow diagram for the control of the maintenance operation

DATA COLLECTION

DATA SYSTEM

- Data collection is manual, & hand processed
- Form flow is well documented

PROGRAMMING/COMPUTER

- Done by outside consultant
- Few in-house programmers

FORMS

- Inspection – 8 forms
- Road calls/defects – 7
- Availability – 12
- Miles, Fuel & Oil Consumed – 9
- Repairs/Replacement – 7
- Coach Record – 1
- Work Log – 1
- Inventory – 3

COMMENTS

- An automated, computerized system is currently planned. It will cover an extensive amount of data and will be under the authority of the Dept. of Transportation, Maryland.
- Use a large number of forms to cover much information. Those indicated are a good sample.

DATA REPORTS

MAINTENANCE

- Monthly Maintenance Reports
- Annual Maintenance Reports
  - Fleet Mileage, Consumables, Fuel & Oil Avgs.
  - Inspection, Cleaning, Painting
  - Road Call Summary
  - Component Mileage

OPERATIONAL

- Veh. Inventory & Availability
- Veh. Disposition & Mid-week Report on Vehicles Down for Major Repair

CONSUMABLES

- Monthly & Annual Fuel & Oil Summary & Averages

INCIDENTS/ROAD CALLS

- Road Call Summary by System
- Road Call Summary – Miles/Call
- Road Call Summary – Miles/Mechanical Call

COMMENTS

- Reports provide a detailed breakdown of information.

Appendix A--3. CHICAGO, IL (CTA)

REFERENCE DATA

MODEL	NO. OF BUSES	MANUF.	YEAR IN SERVICE
TDH5301	70	GMC	1962-63
TDH5303	5	GMC	1965
TDH5307A	1069	GMC	1972-74
F2D6V401-1	266	FLX	1965-67
F2D6V351-1	20	FLX	1966
F2D6VT401-1	170	FLX	1968-69
T8H5307A	800	GMC	1975-77
SG220-10255	20	AMG/MAN	1979

Total Fleet = 2420
8 Models

COMMENTS

- Planned maintenance and minor repairs done at 10 divisional garages
- All unit rebuilding, heavy maintenance including brake work done at the main shop
- Repairs—24 hrs/day, 7 days/week
- Buses may be scheduled for repair at different garages as the load will permit
- 10 Divisions

BUS EQUIPMENT BREAKDOWN

DEFINED SYSTEM STRUCTURE

- Extensive coding system for bus equipment
- One identifying code for maintenance work—6 digits:
  - 2 digits for job category
  - 2 digits for detailed description of item
  - 2 digits for repair (completion) code

MOST TROUBLE

- Transmissions (VS1 converters)
- A/C
- Engine

COMMENTS

- Mileage has no impact on component failure rate
- Completely automated code system
- Will track inventory automatically in the future
- All components are cycled regardless of condition, once removed for repair

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Personnel input employee and information about the task they are currently working on through a computer terminal. When the task is completed, the employee logs the job off via the terminal.

SCHEDULED & PREVENTIVE MAINTENANCE

- PM—every 6K miles
- 2K miles—brake adjustment
- 4K miles—oil sample
- 36K miles—torque fluid change

SPARES—INVENTORY/PARTS

- Inventory not interfaced with VMS

COMMENTS

- Part-vendors must meet CTA and OEM specifications through a vendor testing program
- Training program—3 to 5 year refresher
- 4-year apprentice program
- 330 completed repair jobs/day record on computer
- Failure analysis performed

DATA COLLECTION

DATA SYSTEM

- Automated, on-line, real time system (named Vehicle Maintenance System)

COMPUTER

- IBM 370/158 Mainframe
- Amdahl
- IBM System 7 minicomputer (as backup)

PROGRAMMING

In-house

FORMS

- None—terminals input of maintenance information at every division to computer

COMMENTS

- Examples of data reports that could be generated on-line are: Bus Availability Report, Vehicle Technical Data, Hours & Cost Per Job, Planned Maintenance for Components on Vehicle, Road Call Summary by Vehicle, Fleet Garage, Time, etc.

DATA REPORTS

None due to the on-line capability of VMS. Hard-copy reports containing particular data types can be generated on-line from a terminal, also.

COMMENTS

- Consumables are not input to VMS.

Appendix A--5. DETROIT, MI (SEMTA)

REFERENCE DATA

MODEL	NO. OF BUSES	MANUF.	YEAR IN SERVICE
TDH5301	17	GMC	1959-61
TDH5305	66	GMC	1963-69
TDH4619	9	GMC	1964-65
TDH5305	15	GMC	1968-69
TDH5307A	13	GMC	1972
T6H5307A	48	GMC	1975
T8H203	114(ADB)	GMC	1978-79
TW7203	9(ADB)	GMC	1979
TDH4517	12	GMC	1960-62
TDH4519	11	GMC	1963-67
SDM5302	6		1965-67
SDH4502	2		1967
TDH4521	2		1969
T8H5307A	7		1972

Total Fleet = 331
14 Models

COMMENTS

- o 50 ADBs expected in July
- o Bus-rehab. program in progress--21 rehabed so far and 13 to be rehabed
- o 3 Divisions:
  - Wayne
  - Macomb
  - Oakland

BUS EQUIPMENT BREAKDOWN

DEFINED SYSTEM STRUCTURE

- o No codes

MOST TROUBLE

- o V730 transmission (1st & 3rd clutches fail most often)
- o Brake linings--use different linings than GM specifies
- o Electrical system
- o Front end suspension system

COMMENTS

- o V730 transmission causes 6 times maintenance/1000 man-hrs. 60K miles/V730 (used to be 400K)
- o 60% of V730 transmissions have been removed
- o Battery--life = 4-5 yrs.
- o Brake--life with different linings = 120,000 miles
- o $9000 for V730 transmission--most costly repair

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- o All repairs followed up by foremen
- o Repair-diagnosis time tracked
- o Inspection guidelines
- o Perform failure analysis of equipment--determining failure modes

SCHEDULED & PREVENTIVE MAINTENANCE

- o Pit inspection every 3 weeks at 12K, 24K, etc. miles
- o No. parts & material cost/bus reported @ inspection
- o Mileage, fuel, coolant & oil recorded daily
- o Torque converter checked @ daily fill-up

SPARES--INVENTORY/PARTS

- o Computerized inventory system with automatic reordering (when bin @ minimum)
- o Terminals budget--$250,000 parts/terminal

COMMENTS

- o Use strong engineering analysis for failure evaluation
- o 10K miles between road calls
- o 40% less tire-life with ADBs
- o 75% maintenance employees go to training school
- o 94% availability experienced currently
- o All maintenance done in-house except for reboring engine blocks
- o 130 maint. employees--25% all-around mechanics

DATA COLLECTION

DATA SYSTEM

- o Manual data collection system

PROGRAMMING/COMPUTER

N/A *

FORMS

- o Inspection
- o Symptom & repair
- o Road call
- o Daily mileage, fuel, oil, & coolant
- o Failure analysis
- o No. parts & material cost/bus
- o Pit inspection
- o Consumables

COMMENTS

- o Plans are underway for automating data collection system

DATA REPORTS

MAINTENANCE

- o Weekly
- o Monthly including
  - -- Total operating fleet
  - -- Road calls
  - -- Overtime
  - -- Fuel & oil usage--MPG, MPQ
  - -- Miles between breakdowns

OPERATIONAL

- o Availability recorded

CONSUMABLES

- o Recorded in weekly & monthly inputs

ROAD CALLS

- o Recorded in weekly & monthly reports

*Not Available

Appendix A--6. HOUSTON, TX (METRO)

REFERENCE DATA

MODEL	NO. OF BUSES	MANUF.	YEAR IN SERVICE
RTS II	151 (ADB)	GMC	N/A
EAGLE	55	EAGLE	"
870	325 (ADB)	FLX	"
5307A	100	GMC	"
5303	64	GMC	"
5305	34	GMC	"
4517	34	GMC	"
5301	68	GMC	"
5302	2	GMC	"
Minibus	57	N/A	"

Total Fleet = 890
10 Models

COMMENTS

- Active fleet = 556
  - 31 FLX870s down as of 2/25/80 for repairs
  - 22 RTSIIs down as of 2/25/80 for rebuilt, a/c & overhauls
  - 2 FLX870s expected to complete order
- 4 Divisions
  - Greens Rd.
  - Market
  - Milby
  - Polk

BUS EQUIPMENT BREAKDOWN

DEFINED SYSTEM STRUCTURE

- Defined, but not used
- Bad Order Bus & Road Call Codes detailed--see Comments

MOST TROUBLE

- FLX panels, doors & gas tanks

COMMENTS

- Bad Order Bus & Road Calls Codes categorized by: Power Train & Accessories; Body; A/C & Heating; Undercarriage; Electrical
- Significant number of basic hardware problems such as equipment falling off the buses.

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Checklists for performing inspections

SCHEDULED & PREVENTIVE MAINTENANCE

- Insp. @ 6, 12, 18, 24, 30K miles
- When due for insp--flagged on computer printout of scheduled (rte) miles

SPARES--INVENTORY/PARTS

- Computerized inventory with many problems

COMMENTS

- Significant problems with attracting and retaining good mechanics. Unemployment (Houston area) at 2% makes labor market highly competitive
- Problems with maintenance force language barrier.

DATA COLLECTION

DATA SYSTEM

- Data collection is manual
- Computer for inventory, mileage & fuel & oil consump.

PROGRAMMING/COMPUTER

- Purchased system
- New system is planned
- In house programming

FORMS USED

- Repair Order
- Fleet Performance
- Road Call Anaysis (Daily)
- Daily Maint. Perf. Indicator
- Daily Bad Order Bus Summary
- Weekly Personnel Status
- Central Shop Unit Overhaul Perf. Ind.

COMMENTS

- Data Collection system has many inaccuracies
- Much information entered is not valid, has errors and does not verify actual values as in the case of inventory stocks.
- Current plans call for a complete revision of data collection and processing

DATA REPORTS

MAINTENANCE

- No monthly or annual reports
- Daily maint. performance indicator
- Daily bad order bus summary
- Overhaul performance indicator
- Raw data available

OPERATIONAL

- Fleet performance summary: (by day of week)
  - Buses assigned
  - Pulled, AM
  - AM runs cut, % runs cut
  - % AM lates
  - Pulled, PM
  - PM runs cut, % runs cut
  - Late PM pulled
  - % PM lates
  - Total & % Bad Order Buses

CONSUMABLES

- Monthly fuel & oil consumption report

INCIDENTS/ROAD CALLS

- Daily road call analysis

COMMENTS

- Data Reports will be consistent with the modified data collection system

Appendix A--8. PROVIDENCE, RI (RIPTA)

REFERENCE DATA

MODEL	NO. OF BUSES	MANUF.	YEARS IN SERVICE
TGH-3102	6	GMC	1954-1960
TGH-3501	6	GMC	1964-1965
TDH-4519	91	GMC	1966
TDH-4521	30	GMC	1971
TDH-5306	9	GMC	1971
TDH-5306A	6	GMC	1971
TDH-4523A	9	GMC	1976
SDM-5302	4	GMC	1966-1967
TDH-5303	2	GMC	1967
TW-7603	77 (ADB)	GMC	1978

Total Fleet = 240
10 Models

COMMENTS
- Providence is a well organized and managed facility with a manual data collection system.
- 7 more GMC ADBs expected
- 257 bus fleet

BUS EQUIPMENT BREAKDOWN

DEFINED SYSTEM STRUCTURE
- Not defined
- No codes
- No system breakdown

MOST TROUBLE
N/A *

COMMENTS
- RIPTA — Requires a complete system structure breakdown code.

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES
- Manuals are used from GMC for buses
- Informal guidelines for performing main. under supervision of foreman

SCHEDULE & PREVENTIVE MAINTENANCE
Inspection — 21 day inter. P.M. at 9, 27, 54K miles
Oil change 9K miles
Oil, gas — 1st & 15th of each month—tally

SPARES INVENTORY/PARTS
- Track all spares required a max-min review of all parts is made
- Parts consumption tracked monthly
- With careful review can account for monthly and annual consumption

COMMENTS
- Requires a correlation between what is used (repaired) in inventory with what is reported as problems in maintenance

DATA COLLECTION

DATA SYSTEM
- Data Collection is strictly manual
- All info. hand processed

PROGRAMMING/COMPUTER
N/A*

FORMS
- Bus defect each day
- Daily work assignment
- Coach record
- Bus master mileage
- Road call summary
- Minor inspection
- 9K miles
- 27K miles
- 54K miles
- 209—Supply Req.
- TA282 Material issued

DATA REPORTS

MAINTENANCE
- Monthly Maintenance Cost Summary

OPERATIONAL
- Bus Master Mileage Summary
- Coach Record

CONSUMABLES
- Oil and Gas Summary

INCIDENTS/ROAD CALLS
- Road Call Summary

COMMENTS
- Reports are not issued as an annual or monthly report of all activities. Summaries are made of the top level results. Do not have time or personnel to track details—No actual reports.

*Not Available

Appendix A--10. SEATTLE, WA (METRO)

REFERENCE DATA

MODEL*	NO. OF BUSES	MANUF.	YEAR IN SERVICE
35'	35	Flyer	1980
40'	128	Flyer	
40'	98	Flyer	1980-81 (scheduled to arrive)
40'	224	AMG	
ARTIC	151	AMG/MAN	
T8H 5305	70	GMC	1968
F2D6V-401-1	99	FLX	
TDH 5105	105	GMC	1954
Auto transmission	28	GMC	1954-68
TDH 4512	35	GMC	1954-68
Manual transmission	13	GMC	1954-68
PD-4104	37	Traveler	1954

Total Fleet = 1021
11 Models

COMMENTS

- 163 coaches with lifts (ridership of handicapped = 70/day)
- As much as 18° grade effects coach operation significantly
- Operate in 6-hour peaks in AM & PM, instead of convenience 2-hr. rush peaks
- 5 Divisions:
  - Jefferson
  - South Base
  - East Base
  - North Seattle
  - Atlantic Base

BUS EQUIPMENT BREAKDOWN

DEFINED SYSTEM STRUCTURE

- Coding system for bus equipment & repair types

MOST TROUBLE

- Transmission--V730
- Brakes--life = 30-35K miles in rear and 40-50K in front
- Electrical system

COMMENTS

- 6 major repair & equipment categories: Brakes/Wheels/Suspension, General Repairs, Engine/Transmission/Exhaust, Body Exterior, Body Interior & Electrical

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Inspection guidelines for regular and articulated coaches
- Training program

SCHEDULED & PREVENTIVE MAINTENANCE

- Coach inspection types: 5,A,B,C,D,F
- Articulated inspection types: S,A,C,D,G,H
- 1K miles safety inspection--brakes primarily
- 2K miles for major components
- Oil change @ 6K miles for articulated coaches, 12K for other coaches
- Other PM @ 4K, 6K, 12K, 24K, 36K, etc.

SPARES--INVENTORY/PARTS

- Computerized inventory system (MSA) for inventory control, purchasing, & dispersement rates. Also, automatic reordering with qutomatic min & max setting.

COMMENTS

- Trouble call standard of 3K miles
- Clerk enters data from forms into computer

DATA COLLECTION

DATA SYSTEM

- Automated data collection utilizing ARMS (financial accounting system), CORS (Coach Operations Reporting System), SIMS (Service, Inventory and Maintenance System), and MSA inventory control (Management Science of America)

PROGRAMMING/COMPUTER

- King County IBM 370
- In-house programmers
- CORS-batch system

FORMS

- Inspection forms
- Trouble call forms
- Bad Order form
- Coach Repair record

COMMENTS

- CORS Phases in METRO:
  - Remote data entry;
  - Coach history reporting;
  - Print coach history @ base

DATA REPORTS

MAINTENANCE

- SIMS report of mileage, scheduled inspections, consumables, fuel economy. Daily on-line mileage based on assignment, not hubodometer
- Daily Coach Problem Report from CORS

OPERATIONS

- Monthly Management Report
- Daily CORS operations report
- Cost/mile by fleet from CORS upon request

CONSUMABLES

- SIMS daily reports on consumables

ROAD CALLS

- Daily CORS report isolating Trouble Calls and Bad Orders

COMMENTS

- Capability of trends analysis, parts cost & labor cost per component.

*List does not include 109 AMG Electric Trolleys, 1979-80, which will be in service as soon as the power distribution network is ready.