R-347U

Bus TRIP Participants Guideline

Task D

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September 12, 1980

Prepared for:
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Contract Number: DTRS-57-80-C-00007

PREFACE

This report describes the Task D portion of the contract to "Develop the Groundwork and Prepare the Back Up Information Necessary for the Establishment of a Bus TRIP Data Bank," (hereafter referred to as Bus TRIP). The purpose of Task D was to define, recommend and produce a Bus Guideline for the implementation and operation of Bus TRIP. This task was performed under Contract Number DTRS-57-80-C-00007 from the U.S. Department of Transportation, Transportation Systems Center (TSC) which was awarded to DRC in December, 1979.

EXECUTIVE SUMMARY

This document is a user's manual for transit property personnel interested in participating in Bus TRIP. The purpose of this document is to provide a description of the objectives, operation, and uses of the Bus TRIP data bank.

Bus TRIP is a government initiated program to assist the bus transit industry in satisfying its need for transit bus reliability information. It will provide this assistance through the implementation of a bus reliability data bank that will collect, store, and analyze bus maintenance data generated by operating properties in the course of transit service. The results of this data analysis will be distributed to Bus TRIP participants and other contributors.

This manual is a user's handbook describing the requirements and operations of the data bank. The participation section describes the information needed by the Bus TRIP staff to prepare the data bank for property input data and the procedures for submitting hard-copy or computer-readable data. The information produced by the data bank along with its reliability analysis will be described and distributed to users.

One section of the guidelines illustrates the approach and development of the Generic Part and Master Reliability Equipment Lists. A procedure for modifying the lists for adding new equipment is included. Another section of this manual contains practical approaches for applying reliability techniques and analysis for transit problems using information produced by the Bus TRIP data bank.

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SECTION 1 - BUS TRIP OVERVIEW

The Transit Reliability Information Program (TRIP) is a government-sponsored program to collect and evaluate national transit equipment reliability information. The collected data will be disseminated to the transit operating properties, equipment suppliers, and federal agencies to assist in highlighting reliability problems, improving maintenance operations, and thereby, assist in reducing maintenance costs.

In September 1978, DRC was awarded a contract to implement the TRIP program for Rapid Rail Vehicles (RRV). RRV TRIP is divided into two major phases:

Phase I

- Define, document, and present the 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 data bank for RRVs.

At present, Phase I of RRV TRIP involves the operation of an experimental data bank which collects data from five properties covering the friction brake, door, and propulsion systems on 1300 RRVs.

A parallel contract to develop the background for adding bus information to TRIP was awarded to DRC in December 1979. The purpose of this contract (Bus TRIP) was to prepare the back-up information necessary for establishing a bus reliability data bank. Bus TRIP is an extension of the RRV TRIP program and applies the existing TRIP structure and experience in collecting and procesing RRV information to transit buses.

This Bus Guidelines document is intended as both a user's manual for participation in Bus TRIP, and also to describe the information that will be produced by the data bank, and the uses to which this information can be put. Transit bus reliability related information provided by Bus TRIP may be used to support a wide variety of transit industry activities, including: hardware reliability assessment; bus equipment reliability specifications for bus procurement; product improvement programs; and transit bus operating and maintenance cost reduction.

The Bus TRIP data bank is a computerized system for the collection, processing, storage, retrieval, analysis, and reporting of reliability related information pertaining to transit buses. Bus TRIP will solicit and collect voluntarily submitted data covering the configuration, operation, maintenance, and repair of transit buses. This collected data will provide a central source of information concerning the use of reliability related factors for these vehicles. The collected data will be analyzed to determine equipment reliability indicators and associated trends, and the results of these analyses will be reported to Bus TRIP participants, and other users.

1.1 - USES AND BENEFITS OF BUS TRIP

The principal benefit of Bus TRIP will be to provide an integrated, industry wide source of transit bus reliability related information through the operation of a reliability data bank. This information will be organized to address the following objectives of Bus TRIP:

- Consolidate transit industry reliability efforts.
- Provide reliability information in a transit industry context.
- Provide maximum information output while minimizing burden on properties.
- Provide a comprehensive and uniform data source for:
  - Equipment reliability comparison,
  - New equipment specifications and procurement,
  - Product improvement programs, and
  - System analysis efforts.

Access to the Bus TRIP data bank and the information it contains will be provided by the various outputs produced by the system. These reports will be of two general types: routine reports covering utilization, consumables, road calls, scheduled maintenance, and unscheduled maintenance information, based on bus operating, and maintenance data which will be continuously submitted to the data bank; and special reports, based on individual Bus TRIP user requests, covering information not otherwise reported routinely, but available in the data bank.

An important feature of the data bank is the wide variety of data which it will collect and store. Types of data will include:

- Static (reference) data, including background information concerning bus properties, models, classes of equipment, route structure and environment

- Dynamic data, including transit bus utilization and maintenance information, and

- "Generic Assignment" data, including a vehicle roster, property component numbers, property maintenance action codes, and property vendor codes.

The output information that will be produced routinely from these types of data will include:

- Utilization (mileage) by individual bus, fleet, and property;

- Inspections and road calls by bus, fleet, property, and equipment system;

- Consumables usage by bus, fleet, and property; and

- Repairs by bus, fleet, property, industry and system.

These routine periodic reports will provide the basis for the assessment and comparison of the reliability performance of various vehicle and equipment types. Comparison of Bus TRIP output data for equipment and vehicles in different applications and environments will be made possible through the use of uniform analysis and reporting methods for all data being collected. The continued production of routine reports will also permit the assessment of both reliability indicator trends and seasonal variations.

In addition to routine reports, the Bus TRIP data bank will also provide a limited number of special reports in response to requests for information from Bus TRIP participants and users. These special reports will draw upon the full range of static and dynamic data being stored in the data bank and will typically present information described as follows:

- Retrieval of data stored, but not routinely reported (e.g. narrative information on equipment modification/retrofit programs), and

- Simultaneous retrieval of both static and dynamic data in a single report for the purposes of comparison and interpretation.

Special reports may be requested by Bus TRIP users to support detailed analyses and also may be requested in order to provide additional insight into data that is reported routinely.

Another important feature of the Bus TRIP data bank is the integration of all data types, both static and dynamic, into a single storage system. The integrated nature of this data base will permit the efficient and comprehensive retrieval and analysis of all data being collected.

The benefits of the use and application of Bus TRIP will be realized in each area supported by the system. Bus TRIP may be utilized to aid in specification development and procurement of new buses by providing realistic reliability related statistics on existing bus equipment. The availability of reliable statistics prior to acquisition will permit the projection of the maintenance requirements for new buses and initial replacement parts inventory which may be desired.

Another benefit of Bus TRIP will be to provide information on second-source vendor performance. This reliability information may aid bus properties in selecting parts vendors by describing past reliability related performance of parts from specific vendors. The long-term implications of monitoring vendor reliability indicators will be reduced maintenance costs as well as improved overall reliability.

Bus TRIP will provide reference information on maintenance procedures as well as information on equipment modifications or retrofits in the industry. Thus, Bus TRIP will be a forum for the transfer of information from bus property to bus property. If property 001 has designed a new brake lining that has proven to have a longer life than the original linings on a specific bus model, property 002, which operates the same equipment, may wish to contact property 001 about using its newly developed brake lining.

Besides identifying the major equipment reliability related problems, Bus TRIP will have the capability to identify subtle equipment problems as well through the long term reporting of reliability indicator trends. In total, Bus TRIP will provide useful support for transit bus properties to review the equipment reliability experience of other operators using similar or identical vehicles. Also, Bus TRIP will provide potentially valuable support for smaller properties that do not have the resources to provide engineering services but could use Bus TRIP for reliability assessment through the availability both of routine and special-request report types.

SECTION 2 - BUS TRIP DATA BANK OVERVIEW

The purpose of the Bus TRIP data bank is to provide a system for the collection, analysis, and reporting of transit bus reliability information. In order to achieve this purpose, the following capabilities, shown in Figure 2.1, will be structured or to the data bank.

- Data Submission, including the transmission of transit bus operating, maintenance, and reference data, in a variety of formats.

- Data Preparation and Processing, including the acceptance of the input and the accuracy and validity verification of that data.

- Data Organization and Storage, including the assignment of "index labels" to input data in order to maximize retrieval efficiency, and the capability to store the anticipated large quantity of data.

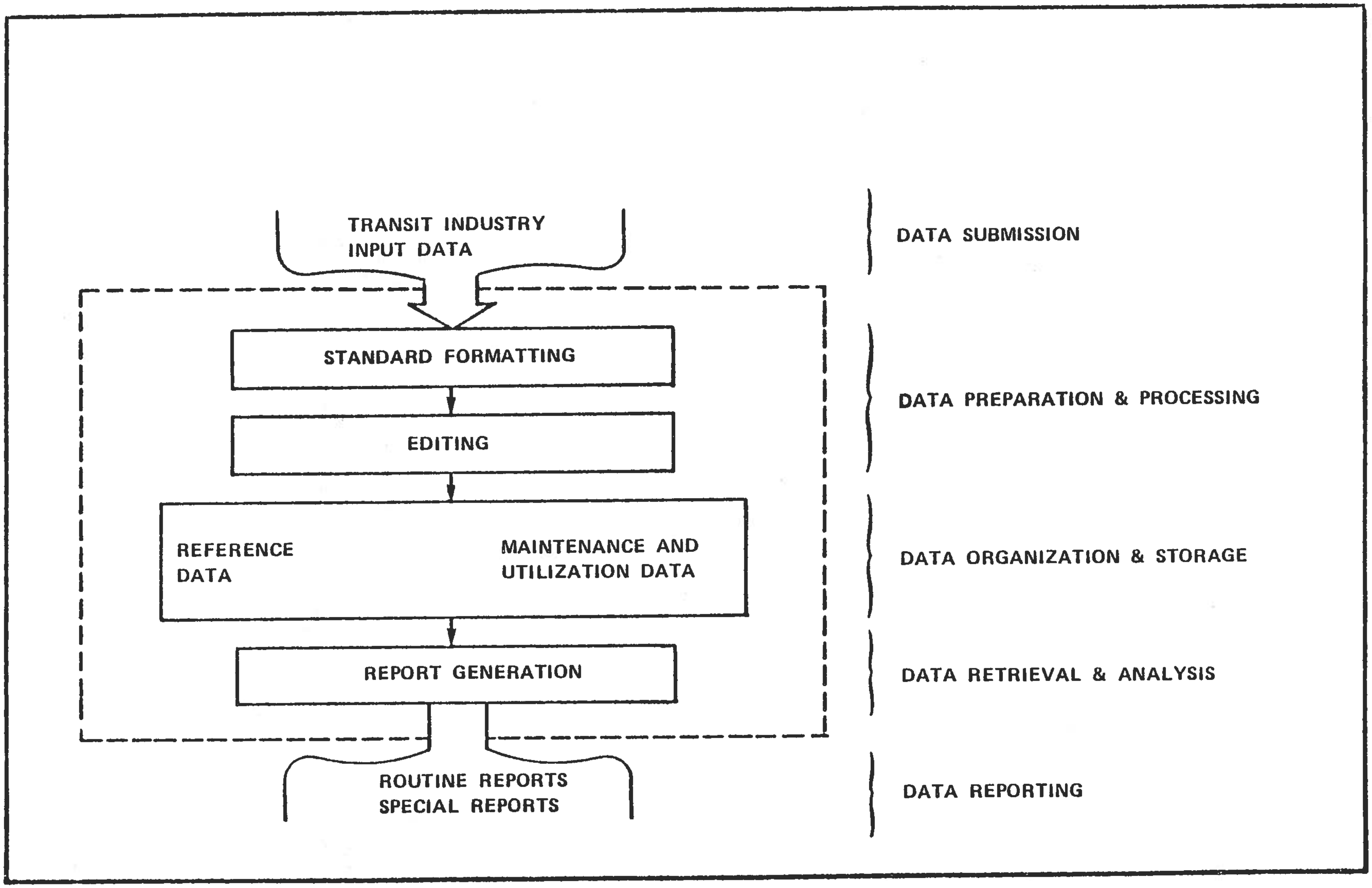


Figure 2.1 - Bus TRIP data bank capabilities.

- Data Retrieval and Analysis, including the retrieval of data for verificaiton prior to report generation, and analysis in the following categories:

  - standard statistical analysis,
  - reliability/maintainability analysis, and
  - vendor equipment monitoring analysis.

- Data Reporting, including the production of routine reports, reference information reports, and special request reports in order to meet the specific needs of Bus TRIP users.

This overview of the Bus TRIP data bank describes only the input data types and the output reports. A more in-depth discussion of the entire Bus TRIP operation appears in Chapter 3.

2.1 - INPUT DATA TYPES

The three types of data that will be submitted to the Bus TRIP data bank include:

- Static (reference) data,
- Dynamic data, and
- Bus TRIP generic assignment data.

Static (reference) data is information that describes the configuration, characteristics, and operation of a transit system, vehicle type, or equipment on a vehicle type. This reference data will be used in the evaluation of the outputs and reports generated by Bus TRIP. Such information may be used to interpret differences in reliability related performance of bus models based on passenger load and/or environmental conditions (such as climate, or terrain) and to interpret differences in reliability indicators of bus models based on the application of each model (such as operation on routes with numerous stops versus express routes).

Dynamic data consists of information covering the maintenance (such as scheduled and unscheduled repair) of transit buses. Dynamic data will provide the basis for determining reliability related performance and maintenance requirements for transit buses. Dynamic data types include bus utilization, consumables (such as fuel, oil, coolant, and tires), road calls, and scheduled and unscheduled maintenance information.

Bus TRIP generic assignment data has been designed as Bus TRIP's uniform system of vehicle and component identification and uniform system of cross-referencing components by parameters which effect the performance & subsequent reliability indicators of the components. This data includes fleet bus-number tables for each property, parts lists for each property and each model, maintenance codes for each property, and vendor codes for each property. This data will allow Bus TRIP to assign Bus TRIP "generic" codes to property-specific codes. For example, the repair code to add antifreeze may be 03 in one property and 367 in another property. With the use of the table of maintenance codes for each property, Bus TRIP will translate these property codes to a common "generic" code 05 rather than the property-specific codes.

The definitions of static and dynamic data characteristics, which are further detailed in the following subsections, cover the types and content of information that will be received by the Bus TRIP data bank.

2.1.1 - Static Data Characteristics

Static (reference) data will be used to interpret the outputs generated by Bus TRIP and will include information describing transit properties, vehicle types, and classes of equipment. The definition of static data elements for Bus TRIP is based upon definitions developed for RRV TRIP, and is grouped as follows. (See Appendix A for specific definition.)

<u>Transit System Configuration Static Data</u> (Figure A-1 in Appendix A) provides summary reference information concerning the physical characteristics of an entire bus property. These characteristics include total route miles, passenger stop spacing and number, passenger volume, total number of buses, and street types (collector, arterial, and freeway).

<u>Transit System Route Configuration Static Data</u> (Figure A-2) provides reference information concerning the specific route on a bus property over which a specific vehicle type may be operated. This information includes route miles, passenger stop spacing and number, and grades (maximum uphill and downhill). Such data will permit the comparison of the physical demands made on vehicles operating on different routes.

<u>Transit System Route Operating Static Data</u> (Figure A-3) provides reference information concerning the scheduled

operation of vehicles on a specific route. This data includes scheduled speed, headways, passenger stop dwell times, passenger load information, and the number of scheduled runs per day.

Vehicle Fleet Information Static Data (Figure A-4) provides reference information concerning the general characteristics of a bus model. This data includes the quantity of buses of that model, the bus manufacturer and year delivered, and the frequency of scheduled maintenance.

Vehicle Specification Information Static Data (Figure A-5) provides reference information concerning the physical characteristics and performance specification of a bus model. This data includes performance information such as speed, acceleration, deceleration, and turning radius.

Vehicle Configuration Information Static Data (Figure A-6) provides reference information concerning the physical characteristics, types, capacities and ratings, and manufacturers of the major functional systems and major assemblies for each bus model. This information may be used to relate a specific type of hardware on a bus with respect to the reliability indicators for this equipment class for various bus models.

Hardware Specification Information Static Data (Figure A-7) provides detailed information, on a component-by-component basis, of the physical characteristics'and intended application of this hardware. This data includes the quantity and type of component by bus model, manufacturer code, and part number, and component physical characteristics and capabilities/ratings. With the aid of this data, reliability-related information could be interpreted for specific classes of equipment based on the configuration and design ratings of specific equipment types.

Static data will be collected from properties participating in Bus TRIP for bus models that they operate and specific components on those models. Transit system and route configuration, and route operating information static data will be taken from engineering and scheduling information.

Vehicle and hardware static data on those vehicles being monitored by Bus TRIP will be obtained from vehicle parts books and maintenance manuals, as well as from vehicle specification documentation. As new vehicles and components are added to the Bus TRIP data bank, static data for these equipments will be collected and entered into the reference portion of the Bus TRIP data bank.

2.1.2 - Dynamic Data Characteristics

Dynamic data, consisting of bus operating and maintenance information, will be the basis for reliability related analysis and associated output reports by the Bus TRIP data bank. Dynamic data which is reported by a property as a result of revenue service, scheduled and unscheduled maintenance. This data will be collected, typically on a monthly basis, for input to Bus TRIP. Such data will characteristically be supplied in the following forms.

- Computer-readable formats from automated data collection systems:
  - Tape and
  - Disk.
- Hard-copy forms from manual data collection systems.

The dynamic data types that have been developed for Bus TRIP parallel those developed for RRV TRIP as follows. (The data elements for each dynamic data group are described in Appendix B.)

- Vehicle Utilization Information
- Vehicle Consumables Information
- Vehicle Road Call/Incident Information
- Vehicle Scheduled Maintenance Information
- Vehicle Repair (Unscheduled Maintenance) Information
- Vehicle Component Repair Information

Vehicle Fleet Utilization Dynamic Data (Figure B-1 in Appendix B) provides information, on a periodic basis, concerning the number of miles and/or operating hours accumulated by individual buses in a fleet. This data is necessary for the calculation of maintenance and replacement rates such as Mean Miles Between Maintenance Actions and Mean Miles Between Replacements with respect to revenue service operation.

Vehicle Fleet Consumables Dynamic Data (Figure B-2) provides information on a periodic basis concerning the consumption of such items as fuel, oil, coolant, or tires.

This data will be used to calculate miles per gallon of fuel, miles per quart of oil, and miles per gallon of coolant. These usage factors, along with the direct measures of consumables use, may be important factors for the indication of potential equipment problems.

<u>Vehicle Road Call/Incident Dynamic Data</u> (Figure B-3) provides information concerning reported equipment problems encountered during revenue service. This information may be used to compare suspected problems with actual repairs, by correlating repairs on particular systems with the road calls on those systems.

<u>Vehicle Scheduled Maintenance Dynamic Data</u> (Figure B-4) provides information concerning the periodic inspection and associated repair of buses. This data includes: the inspection type; expendable components and supplies replaced (along with the vendor); and repair, including the replacement of components. From this data, reliability related factors for equipment with respect to scheduled maintenance frequency (mean miles between inspections) can be determined. By recording the parts vendor, maintenance activity for parts from specific vendors can be monitored.

Vehicle Repair Dynamic Data (Figure B-5) provides the primary source of data for the Bus TRIP Data Bank. This data includes part replacement data, failure/defect description, and maintenance/repair action or no-trouble-found. From this data, unscheduled maintenance rates, equipment replacement rates, repair rates with no components replacement and no-trouble-found rates can be calculates. These rates will be primary input for the reliability-related analysis and output reporting from Bus TRIP. Again, monitoring replacement parts by vendor will aid in the determination of maintenance activity for parts from specific vendors.

Vehicle Component Repair Dynamic Data (Figure B-6) provides information concerning the repair of equipment that has been removed from a bus. This data includes the component or major assembly being repaired, the type of repair, and the components replaced during the repair. The equipment repaired should, if possible, be linked to a specific bus, so there will be a complete view of the hardware failure mode and subsequent repair. If the equipment repaired is not linked to a specific bus, this repair data will still be stored in the Bus TRIP Data Bank to account for off-vehicle equipment repair, on an independent basis, and the resources used to make the repair.

2.1.3 - Bus TRIP Generic Assignment Data Characteristics

Generic assignment data will be used to produce "generic" indexing numbers and maintenance codes for data to be stored in the Bus TRIP Data Bank. The generic index numbers will be used to identify each group, or "record", of data in the Data Bank by associating it with hardware function, rather than the way the hardware is assembled (i.e., hardware configuration). Because of this generalized indexing method, data for a particular functional hardware type may be retrieved from the Data Bank, regardless of who submitted the data, and how that data was described in property-specific terms.

Generic maintenance codes will also be assigned using a similar method. These codes will translate property-specific incident, failure, and repair codes into a set of Bus TRIP generic codes so that information can be more easily retrieved and analyzed. By performing this translation, only the generic code need be used for searching and retrieval, rather than a number of individual property codes, all of which may having the same meaning.

This assignment will be done using a similar technique described for GPN assignment. For example, a typical symptom might be "doors will not open". At Seattle METRO, the code for this symptom might be 0711; at CTA, the code might be 063; and at RIPTA the code might be 152. These codes will be cross-referenced to a single Bus TRIP generic code (e.g., 5102). The generic codes will become the basis for data retrieval, output generation, and technical analysis, based on maintenance actions grouped both within and across properties.

The data bank will be arranged in chronological order by GPN and GSN. This logical arrangement of the data provides a "filing cabinet" of data with a "folder" for each unique part. All "folders" are in order by part numbers and of each part, all occurrences are grouped together. The data in the "folder" is in chronological order by most recent to oldest occurrence for each serial number to facilitate quick access to more recent data. For example, all air conditioners that failed or required routine maintenance during a given month would be stored together, with the most recent failures/repairs accessed first.

These generic values are assigned using the following property supplied information:

- Vehicle roster
- Property component numbers
- Property maintenance codes
- Property vendor codes

The assignment of generic values is described in more detail in Section 4.2.3.

The vehicle roster is used to assign a Generic Serial Number (GSN) to a dynamic data record. The GSN enables buses to be grouped by bus models both within and across properties. The GSN consists of the transit property designation, the bus series designation, and the bus number. The assignment is done using a "fleet table" which is based on the vehicle roster. The vehicle roster is a list of all buses being monitored by their bus number and series designation.

Property component numbers of the equipment being monitored by Bus TRIP are used to assign a Generic Part Number (GPN) to a dynamic data record. The GPN is assigned using three types of information: the transit property designation, the bus series code, and a property-specific component number. It enables the translation of different property component codes to uniform Bus TRIP generic parts number. A list of GPNs, along with the same three fields, is compiled into a Generic Parts List (GPL) (one list per property and bus series). Each GPL is identified by a GSN which identifies the property and bus series described by the GPL. The use of the GPL is discussed in Chapter 5.0.

Property maintenance codes are used to compose the generic maintenance codes file, which relates a property-specific maintenance code to a Bus TRIP generic code. Each record in this file is composed of the transit property designation, a code type indicator (defect, repair, symptom, and test), and a property-specific code. The generic maintenance code enables vehicle maintenance actions to be grouped both within and across properties.

Property vendor codes are used to construct the generic vendor code file, which relates a property-specific vendor code to a Bus TRIP generic code. Each record in this file is composed of the transit property designation and the property-specific code. The generic code enables the translation of different property vendor codes to Bus TRIP generic codes.

2.2 - OUTPUT CAPABILITIES

During the Task A investigation, bus property maintenance reporting systems were studied in order to determine the output requirements of a Bus TRIP system. Based on the types of data collected and generated by the properties participating in the investigation, the reports produced by Bus TRIP will include the following:

- Monthly Reports, covering:
  - Utilization by bus, fleet, and property;
  - Inspections (scheduled maintenance) and road calls by bus, fleet, property, and system;
  - Consumption by bus, fleet, and property; and,
  - Repair (unscheduled maintenance) by bus, fleet, property, industry, and system.

- Quarterly Reports, covering:
  - Maintenance actions by bus and system.

- Annual Reports covering:
  - Utilization by bus, fleet, and property, and industry;
  - Inspections and road calls by bus, fleet, property, industry, and system;

- Consumption by bus, fleet, property, and industry; and,
- Repair by bus, fleet, property, industry, and system.

- Reference Information Reports, covering:
  - Bus properties system configuration, route configuration, and route operating information;
  - Vehicle types (bus models); and,
  - Equipment on each vehicle type.

- Special Reports (covering analysis not reported routinely), covering:
  - Vendor maintenance actions by component and vendor;
  - Maintenance actions trends by component;
  - Equipment modification/retrofit; and,
  - Miscellaneous.

Example of the proposed reports are given in Appendix C. These preliminary formats represent outputs generated by the Bus TRIP data bank based on reference and dynamic input data described in Section 2.1 and Appendices A and B. These report formats and contents will be modified based on feedback from Bus TRIP participants. In addition, based on participant feedback, reports may be added or eliminated and their frequency may be changed.

2.2.1 - Routine Reports

2.2.1.1 - Monthly Routine Reports

Proposed report types to be produced most frequently (monthly) will present summary information covering utilization, consumption, inspections and road calls, and repairs. Each report will cover and summarize information by individual bus, fleet, property, and, where appropriate, system or component.

The proposed monthly reports to be produced by the Bus TRIP data bank are described as follows.

Monthly Utilization Report (Figures C-1 through C-3) will present the cumulative number of miles operated, for the period reported and the preceding period for each bus, each fleet, and each property. This mileage data will be used to determine inspection, road call, repair, and failure rates.

Monthly Consumption Report (Figures C-4 through C-6) will present fuel, oil, coolant, and tires consumption by volume and rate. This consumption data will be presented by bus, by fleet, and by property. It will be used to highlight potential maintenance problems, as well as to predict future fuel and oil consumption.

Monthly Inspection and Road Call Report (Figures C-7 through C-10) will present the number of inspections, miles per inspection, number of road calls, and miles per road call. The number of inspections will be separated by inspection type. The number of road calls will be separated by systems and number of road calls that caused a vehicle to be out-of-service. This report will identify systems that are generating the greatest number of road calls. The data will be presented by bus (Figure C-7), by fleet (Figure C-8), by property (Figure C-9), and by system (Figure C-10).

Monthly Repair Report (Figures C-11 through C-14) will present the number of repairs, number of scheduled maintenance repairs, miles per unscheduled maintenance repairs, number of part replacements, and miles per replacement. This data will be presented by bus, by fleet, by property, and by system. The report will be used to determine change in repair and replacement rates, as well as to forecast future parts inventory and repair rates.

2.2.1.2 - Quarterly Routine Reports

Proposed report types to be produced quarterly will present summary information covering scheduled and unscheduled maintenance actions information by system (Figure C-15) and bus (Figure C-16). These reports will present the number of maintenance actions in the reporting period, mean miles between maintenance actions, maintenance actions/mile, repair times, and mean time to repair. This information will show reliability indicators for a component/system in revenue service.

2.2.1.3 - Annual Routine Reports

The annual reports cover the same information presented in the monthly routine reports, but in a graphical manner. These reports present both summary information monthly and for the entire year.

2.2.2 - Reference Information Reports

To aid in the evaluation and comparison of information that will be presented in the routine monthly, quarterly, and annual reports produced by Bus TRIP, reference information reports will also be produced, presenting the static data stored in the data bank. These reports will present data concerning the configuration characteristics and operating policies of transit systems and routes, and vehicle descriptions and equipment on vehicles. Reference information reports will be used for the comparison of operating requirements and conditions. They will permit the comparison of the configuration and physical characteristics of specific vehicle and equipment types as they relate to repair rates.

These reports will be produced in total on a one-time basis, since the static data may be collected only once. If updates of the static data are submitted, a reference information report will be produced to reflect the updated information. Additional reports will also be issued when a new property is added to Bus TRIP.

There are several types of reference reports that could be produced. Three of those are described below.

Transit Property Reference Report (Figure C-17) presents information covering system and route configuration and operating characteristics. The proposed content of this report includes total route miles, total fleet, average passenger stop spacing, and operating characteristics including average speed throughout system, trip time, and passenger utilization. This report will provide summary information that will be used for the comparison of property configuration and will allow comparison of operating demands placed on each vehicle type.

Fleet Reference Report (Figure C-18) presents information concerning the physical and operating characteristic by fleet type. The proposed content of this report includes dimensions and weights; speed, acceleration, and deceleration performance; and, quantity and age of buses by fleet. Information presented in this report will be used to compare vehicle fleets based on their physical and performance characteristics as indicators of operating stress placed on these fleets.

Equipment Reference Report (Figure C-19) will be produced for each "generic" component, major assembly, subsystem, and functional system monitored by the Bus TRIP data bank. This report will describe, by vehicle type on which this equipment is used, information which includes the "generic" configuration of which this equipment is a part, quantity of units and manufacturer part number, physical characteristics, performance ratings, and current cost per unit. Information presented in this report will be used to compare and evaluate the routine reports for equipment repairs, including physical characteristics as an indicator of reliability related repair factors; manufacturer's identification information to identify reliability factors with respect to use of identical equipment in different applications (that is, on different vehicle types); and, the relative impact of replacement rates for this equipment based on unit cost.

2.2.3 - Special Request Reports

In addition to routine and reference information reports, the Bus TRIP data bank will provide a limited number of special reports based on requests for information by Bus TRIP users. These special reports will utilize the full range of static and dynamic data stored in the data bank and may present information based on the following procedures for production of these reports:

- Retrieval of data sorted in data bank, but not routinely reported (such as equipment modification/retrofit, that will be reported in narrative form);

- Simultaneous retrieval of both static and dynamic data for presentation in a single report for purposes of comparison and analysis (such as equipment unscheduled maintenance repair rates versus physical characteristics); and,

- Presentation of routine report information in a different format or covering a different time period.

Examples of potential special reports are shown in Appendix C. These outputs are described as follows.

Vendor Maintenance Actions Special Report (Figures C-20 and C-21) presents, by component and vendor maintenance actions, factors including mileage, number of maintenance actions, maintenance actions per mile, and mean miles between maintenance actions. This data will be used to determine vendor performance and thus, vendor selection and quality. This data also may aid in forecasting inventory levels for specific components.

Maintenance Action Trends Special Report (Figure C-22) presents, by component, reliability-related rates over a period of years for a component on a special fleet and property. These trends will indicate a component's reliability over an extended period of time and will aid in the forecast of replacement rates and inventory levels.

<u>Equipment Modification/Retrofit Special Report</u> (Figure C-23) presents, in narrative form, a description of equipment modifications/retrofits on specific fleets or individual buses. Bus TRIP users could use this report to suggest equipment improvements to similar equipment that they operate.

A number of different special report types may be produced from the static and dynamic data stored in the Bus TRIP data bank. The consideration that will be evaluated with respect to these reports is the cost associated with their production. Each special report, depending on its complexity, will require labor for the set-up of the data retrieval, analysis, and output format of the information and computer resources for the production of the report.

SECTION 3 - PARTICIPATING IN BUS TRIP

This chapter describes input requirements and procedures necessary to the operation of Bus TRIP. The requirements cover the information necessary for the Bus TRIP data bank to accept data from bus properties. The procedures cover the submission of computer-readable operating and maintenance data, and the submission of hard-copy operating, maintenance, and reference data for bus properties and their vehicles.

3.1 - DATA REQUIREMENTS

A property anticipating participation in Bus TRIP should have an in-place automated or manual maintenance information system (MIS) from which its operating and maintenance data is reported. If it does not have an MIS, it may elect to collect data for Bus TRIP only, without needing an MIS.

The minimum reference data that is needed from a property includes the following:

- A vehicle roster including all bus numbers and models that will be monitored.

- Description of all codes and their definitions pertaining to maintenance actions (defect, symptom, repair, and/or test codes).

- Parts catalogs giving the component numbers and description for equipment that will be monitored.

- Operation and maintenance manuals with both the functional and schematic descriptions of each component.

- Description of all vendor codes pertaining to parts purchased.

- Samples of data that will be supplied to Bus TRIP, i.e. maintenance forms

Once this information has been provided, the Bus TRIP personnel will prepare the Bus TRIP system for input from the participating bus property. The procedures for preparing Bus TRIP for property input will be described in Chapter 4.

3.2 - DATA SUBMISSION

Bus TRIP personnel will develop a data submittal schedule which describes the frequency most convenient to each property with which input data will be submitted. This data can be in either computer-readable or hard-copy form, depending on whether the participating property has an automated MIS or a manual data collection system. The following two sections describe the procedures for participants to submit computer-readable and hard-copy data.

3.2.1 - Computer-Readable Data

For bus properties that operate an automated MIS, data that has been produced by the property's computer system can be supplied to Bus TRIP. This computer-readable data can be readily processed and input into the data bank with a minimal amount of manual labor for data preparation.

The following steps are recommended for the submission of computer-readable data.

1. Definition of data types to be submitted by a bus property, including:

a. Data groups (e.g., utilization, consumption, inspection, road call, repair)

b. Data elements for each data type

2. Definition of the content of each data element, including:

   a. Form of data (e.g., alphabetic, numeric, or alphanumeric)

   b. Range of numeric data

   c. Definition of codes

3. Definition of data as recorded on computer-readable magnetic media, including:

   a. Computer hardware/software system from which data was generated

   b. Magnetic tape characteristics, including:

      - labeling
      - density and recording rate
      - blocking
      - code set (BCD, ASCII, EBCDIC)

   c. Organization of data as recorded

4. Hard-copy listing of the first sample of data supplied on magnetic tape to be used for a verification of accuracy of Bus TRIP input processing. All subsequent samples will not need such a listing.

In order to insure that the information contained in the Bus TRIP data bank is accurate, it is important particularly to clearly identify the following data elements:

- Bus property that is submitting the data;
- Bus number associated with each data type;
- Data type on a record-by-record basis (e.g., utilization; consumption; inspection; road call; repair); and
- Date and/or reporting period associated with each data type (e.g., date of repair; date on which mileage was recorded or computed).

Based on the description supplied by each bus property concerning data types and content and format of the data as supplied on computer-readable media, automated procedures will be provided by Bus TRIP to process data that is submitted for entry to the data bank. These procedures, described in Chapter 4, will permit the efficient input of data to Bus TRIP, while requiring minimal effort on the part of the bus property to supply this information.

3.2.2 - Hard-Copy Data

For bus properties that have a manual MIS, the hard-copy data that has been generated from the MIS can be supplied to Bus TRIP. The labor involved in preparing this hard-copy data for data bank input will be provided by the Bus TRIP operations staff, so the bus properties need only supply copies of the information that they are already generating, or have generated specifically for Bus TRIP submission.

Procedures will be developed by Bus TRIP to convert hard-copy data to computer-readable input as described in Chapter 4. However, in order to adapt these procedures for the specific information supplied by a specific bus property, the following steps are recommended for the submission of hard-copy data.

1. Description of the data types to be submitted, including:
    a. Data form types (e.g., utilization, consumption, inspection, road calls, repairs)
    b. Description of the flow of these forms in the maintenance process

2. Description of the content of each data type, including:

   a. Data fields on each form

   b. Description of required and/or related fields

3. Description of the content of each data field, including:

   a. Form of data (e.g., alphabetic, numeric, or alphanumeric)

   b. Range of numeric data

   c. Defintion of codes

   d. Definition of abbreviations and/or special terms

To provide the same assurance for hard-copy data, as with computer-readable data, that information entered into the data bank is accurate, it is important that the following data elements be clearly defined:

- Bus property submitting the data,
- Bus number associated with each data type, and
- Date and/or reporting period associated with each form.

3.2.3 - Reference Data

Reference data will include background information concerning bus properties, vehicle types, and components when the tracking of this equipment at a given property in the Bus TRIP data bank is initiated. This data for bus property system route configuration and operating information will be extracted from engineering and scheduling information solicited from each bus property. The desired data elements will be extracted from this information by Bus TRIP personnel.

The reference data needed to support the input processing methods is described in Section 2.1.1. When the reference data has been checked for accuracy and all errors have been corrected, a complete listing of the data for each bus property will be returned to that property for validity verification. The validity checking of reference data covering system bus model and equipment information can be most efficiently accomplished by the property which has supplied this information.

3.3 - DATA OUTPUT

Output reports from Bus TRIP, as described in Section 2.2, will be distributed to the participating properties. Ultimately, these reports will be used by the properties to:

- Aid in specification development and procurement of new buses,
- Examine second-source vendor performance,
- Contact other properties about equipment retrofits or modifications to similar bus models, and
- Identify subtle equipment problems.

The application of reliability analysis to Bus TRIP outputs is discussed in detail in Chapter 6.

3.4 - COST FACTORS FOR BUS TRIP PARTICIPATION

The costs of participation can be divided into two categories:

- Costs associated with data submission, and
- Costs associated with Bus TRIP operations.

The first type of costs is supported by the various bus properties participating in Bus TRIP. The second type of costs is incurred after the data is received by Bus TRIP personnel, and is assumed by the Bus TRIP operations group.

3.4.1 - Data Submission Cost

Data submission costs are based on the resources, including labor, required by each participating property to submit data to Bus TRIP. These costs may be estimated based on the media (computer-readable or hard-copy) on which the data is generated and the cost to transmit the data to the Bus TRIP facility, including shipping or electronic transmission.

The cost of submitting computer-readable data can be estimated by accounting for the following cost elements:

- Labor required to develop automated procedures for extracting data for automated Bus TRIP submission.

- Computer resources required to extract data based on:
  - Number of data records extracted, and
  - Frequency of data submission.

- Labor required to submit data periodically in order to:
  - Initiate automated extraction procedures, and
  - Review extracted data for applicability prior to Bus TRIP submission.

- Costs required to transmit data to the Bus TRIP facility.

The cost of submitting hard-copy data can be estimated by accounting for the following cost elements:

- Labor required to sort the data that will be submitted to Bus TRIP,

- Labor required to reproduce property operation and maintenance data forms for Bus TRIP submission,

- Labor required to review and clarify forms prior to submission, and

- Costs required to transmit the forms to the Bus TRIP facility.

3.4.2 - Bus TRIP Operations Cost

Costs for Bus TRIP operations will be incurred after the data is received by Bus TRIP personnel. These costs can be separated into three categories:

- Data input,
- Data storage, and
- Data output.

Based on the bus propety investigations conducted and the projected operating cost factors developed for Bus TRIP, the following cost estimates are given:

3.4.2.1 - Data Input

Cost estimates for data input are separated into labor costs for hard-copy input preparation and entry; and computer charges for computer-readable input entry and extraction.

HARD-COPY INPUT PREPARATION AND ENTRY

This estimate is based on the labor-hours necessary to prepare and enter hard-copy input data. Assuming that 120 hours/month/5000 records are consumed in this activity, the burdened labor-rate is $20/hour, and that each property is capable of generating 141,000 records/year (and operates approximately 1,000 buses)

$$\frac{120 \text{ hours}}{5000 \text{ records}} \times 141{,}000 \text{ records/year/property} \times \$20 \text{ hour} \approx \$67{,}000\text{/year/property}$$

COMPUTER-READABLE INPUT ENTRY AND EXTRACTION

This estimate is based on the computer cost of entering and extracting computer-readable input data (there is practically no labor time involved in this activity). Assuming that it costs $50/10,000 records/month for entry and extraction:

$$\frac{\$50/10{,}000 \text{ records}}{1 \text{ month}} \times 12 \text{ months} \times 141{,}000 \text{ records year/property} \approx \$8{,}000\text{/year/property}$$

3.4.2.2 - Data Storage

This estimate is based on the cost of storing the data. Assuming that it costs \$.0000065/character/month and there are approximately 85 characters/record:

\$.000065/character/month x 12 months x 85 characters/record x 141,000 records/year/property ≈ \$9,000/year/property

3.4.2.3 - Data Output

At this point in time, it is not possible to estimate the costs assocaited with output reports. This is due to the fact that once Bus TRIP begins operation, the output reports may be refined until the reports are finalized for routine production. The experience with RRV TRIP EDB output reporting has shown that once routine reports are finalized, their production costs will be minimal. The typical cost to produce an output report once the report software has been developed is shown as follows:

Computer costs	\$ 60
Data technicial labor	\$ 40
Printing costs	\$ 40
Engineering review	\$160
TOTAL	\$300/report

However, as long as the reports are being reformatted and refined, each new report must be treated as a special-request report, thus requiring additional programming and engineering personnel to generate such reports. It can be estimated, based on RRV TRIP experience that the development cost (in labor hours) of an output report can range from 40 labor hours (for a special request report) to 1,000 labor hours (for a routine report, including at least one reformatting and refining cycle).

SECTION 4 - BUS TRIP DATA BANK OPERATIONS

Before data is submitted to the data bank, several procedures and programs must be developed subsequent to the receipt of property reference information as described in Section 3.1. These procedures and programs include:

- Software and procedures to translate input data from hard-copy forms to a computer-readable format,

- Procedures and utility software to translate property-specific computer-generated input data into a common host computer-readable format,

- Software to organize and reformat input data to common data types,

- Software to standardize data types into functional hardware categories,

- Software to identify each input data record with specific property, vehicle, and vendor,

- Software and procedures to perform extensive input data verification, and

- Software and procedures to provide data security by using back-up, off-line storage techniques.

Also, Bus TRIP internal data, described in Section 2.1.1, must be developed before data is entered. The fleet file will be created from the vehicle roster, provided by the property, which includes all bus numbers and models that will be monitored. The generic parts file (one per bus model and property) will be developed from the list of property part numbers of equipment that will be monitored by Bus TRIP. The generic maintenance codes file will be developed from the list of maintenance codes and their definitions provided by the property. The generic vendor codes file will be created from the list of vendor codes provided by the property.

The following sections describe Bus TRIP operations from data submission to data reporting. A simplified Bus TRIP system flow diagram is shown in Figure 4.1.

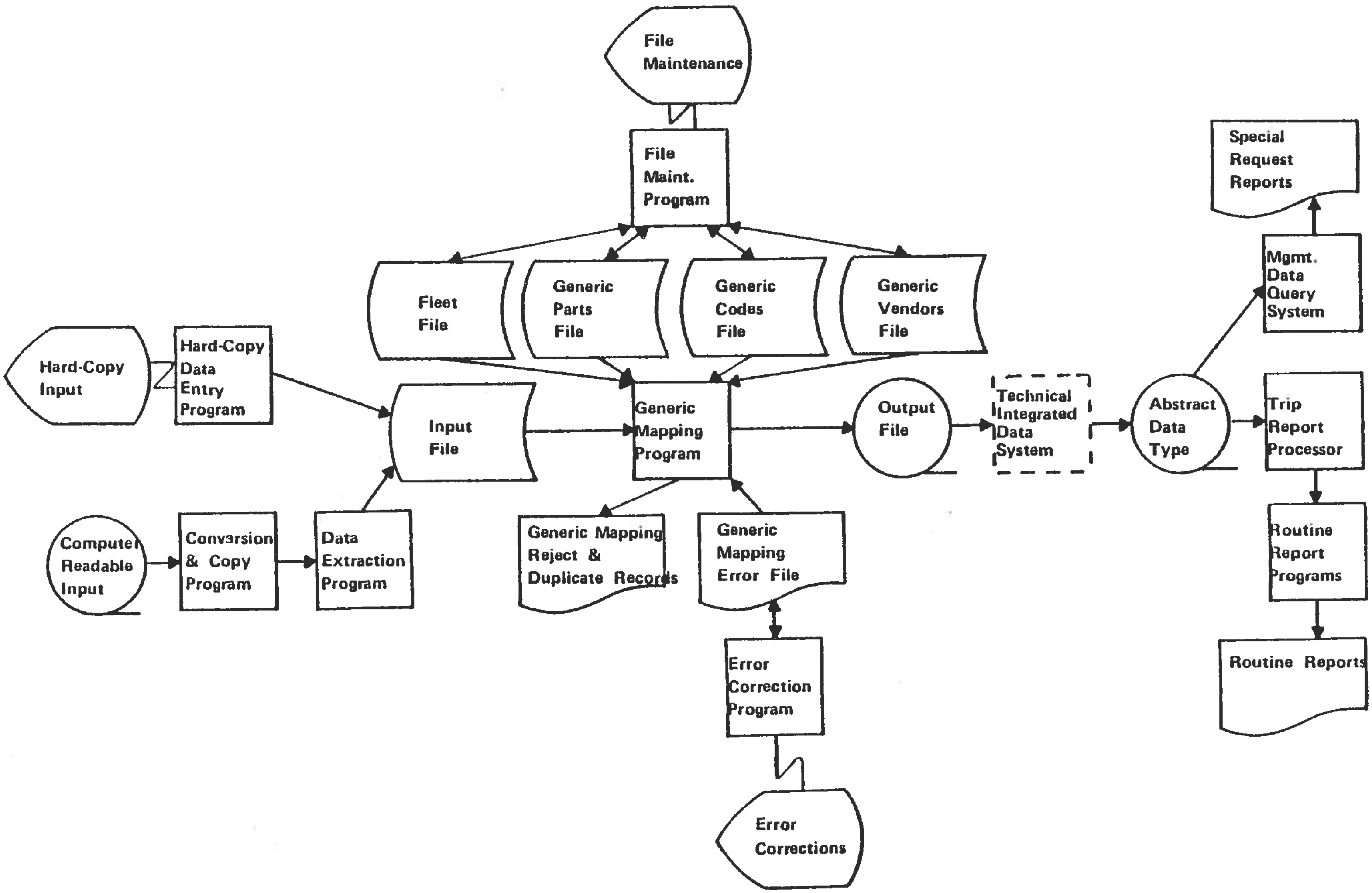


Figure 4.1 - Simplified Bus TRIP system flow diagram.

4.1 - DATA SUBMISSION

When a data transmission is received by the Bus TRIP staff, the data is audited and the data submittal schedule, described in Section 3.2, is annotated. Then, the data is reviewed to determine if it is reasonable and complete.

If the data is in magnetic tape form, the tape is copied onto a Bus TRIP operations tape and a sample of records is printed out to verify the data. The property tape is returned to the property after the data has been copied. In addition, Bus TRIP personnel keep a log of all data receipts and returns.

4.2 - INPUT DATA PREPARATION AND PROCESSING

4.2.1 - Computer-Readable Input Data Translation and Extraction

If input data is provided in a computer-readable format, it will be converted into the host computer's format and the appropriate data types will be extracted by the "data extraction" software. This data extraction software will be developed after each property provides the description of data types, content and format of the information supplied on computer-readable media, (see Section 3.2.1).

4.2.2 - Hard-Copy Data Preparation and Entry

If input data is provided on hard-copy property forms, it will be converted to a computer-readable format by the "hard-copy entry" software (see Section 4). This software will be developed after each property provides the description of data types and content of the data supplied on hard-copy forms (see Section 3.2.2).

The hard-copy entry program accepts hard-copy input data entered on-line through a video display terminal (VDT). The program interfaced with the VDT has the following capabilities:

- Menu-like selection of any screen formats into which bus property reference and dynamic data may be entered on-line into the Bus TRIP system,

- Automatic generation of a specific record type as dictated by a screen format that is selected from the menu,

- Automatic entry of data elements into the data record,

- Automatic translation of data elements into codes, and

- Testing for:
  - Valid alphanumeric characters based on the data type,
  - Valid data present in "required" data fields,
  - Right-justified and zero-filled numeric fields,
  - Valid property IDs,
  - Valid date fields (month 12, days 31, year current year),
  - Valid time fields (hours 24, minutes 59), and
  - Valid part numbers.

- Data editing and error correction before data is reformatted and entered into the Bus TRIP data bank,

After all tests are performed on the data, any errors that have been found during this process are listed. The user can correct the errors or discard the information completely. After the corrections are made and no subsequent errors are detected, the software sends the data to the appropriate file for data reformatting.

4.2.3 - Data Reformatting and Cross-Referencing

Once the data extraction or hard-copy entry program has been executed, the data will be reformatted into a standard (or generic) form. This standard formatting involves the assignment of a generic part number (GPN) and generic serial number (GSN) to each property-specific data record.

The GPN is a code which classifies a component by the function it provides, the location of the component and the classification of the component by type. Bus TRIP has employed the GPN structure shown in Figure 4.2.

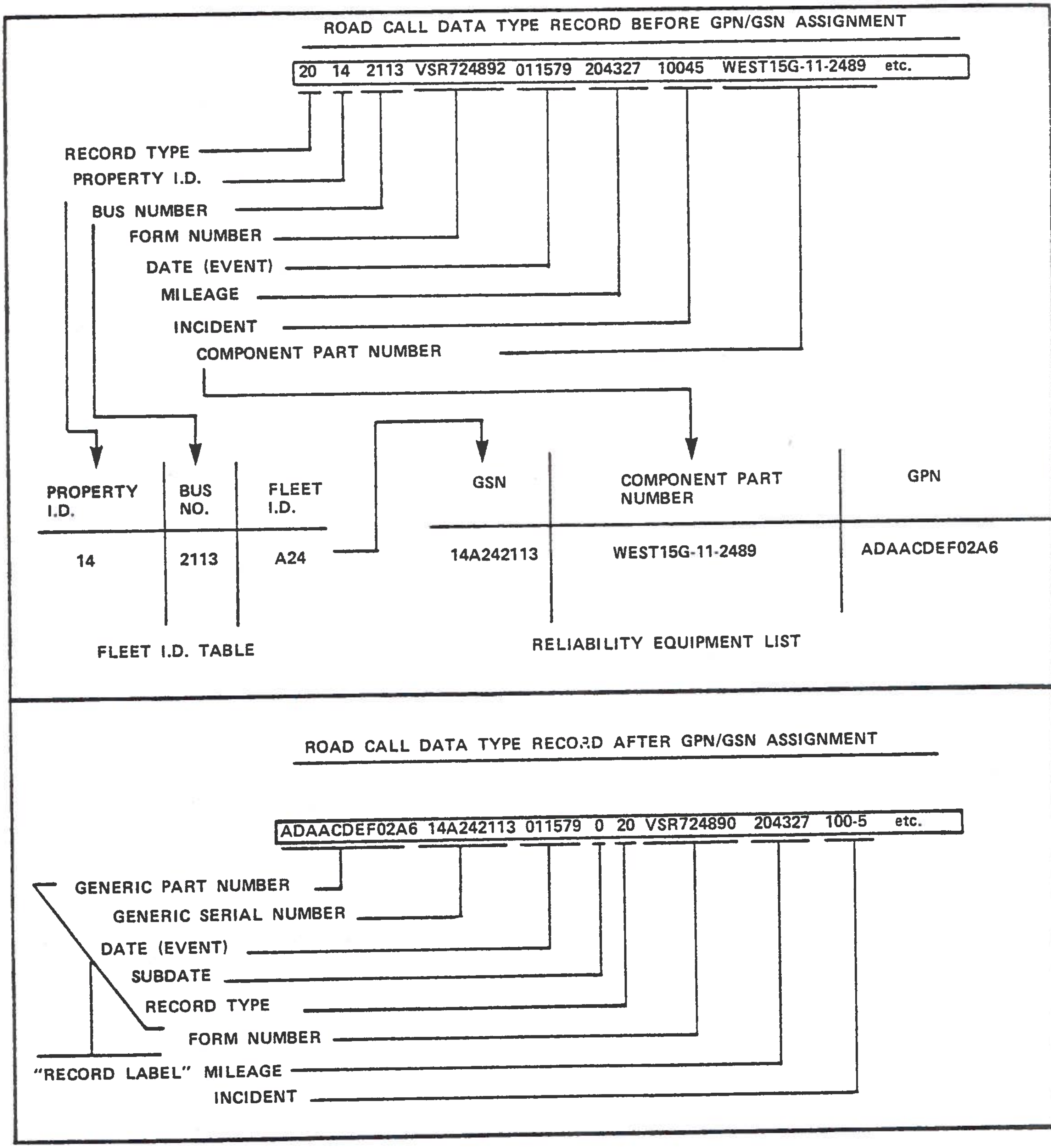


Figure 4.2 - Road call data type record before and after GPN and GSN assignment.

The GSN is a code consisting of the transit property ID, the bus model (series) designation, and the bus number. Whereas a GPN alone identifies a component by standard attributes, the GPN in combination with a GSN identifies a specific component used on a specific bus.

The assignment of a GPN and GSN to a data record, as shown in Figure 4.2, and the reformatting of certain data elements form the data record label. This process is accomplished through the use of the fleet file, (see Sections 2.1.1 and 4) and the Bus Reliability Equipment List (BREL), described in Chapter 5. The record label consists of:

- Generic Part Number (GPN),
- Generic Serial Number (GSN),
- Date,
- Subdate (used only if there are two records with the same GPN, GSN, and date), and
- Record Type

The record label provides a unique description of the data record and, as such, is the mechanism by which the various records are integrated into a common data base. The individual elements of the record label can be used independently or in combination to support efficient data access, retrieval, (section 4.4) and the basis for analysis.

Any incorrect combination of Property ID, Bus Number, and component part number will result in a "not found" situation against the fleet file and/or BREL, and an error message will be generated. If no errors are detected during this process of assigning the record label elements, the data record is successfully reformatted into the data bank format.

Translation of the property-specific maintenance codes into the Bus TRIP generic codes cannot be accomplished until the record label assignment process has been completed. Different property codes describing maintenance activities will be correlated with a generic maintenance code representing the same activity.

Those data types that cannot be assigned record labels and/or generic codes (thus, causing an error message to be generated) will be corrected by Bus TRIP personnel and resubmitted for bus data bank reformatting. All data types that were assigned record labels and generic codes are, at this point in the procedure, ready for the data editing/verification procedures in the operation of the Bus TRIP data bank. (For more details, consult Task C report, Section 5.3.4.)

4.3 - DATA ORGANIZATION AND STORAGE

The Bus TRIP data bank can be defined as an integrated data base based on the following characteristics:

- All data will be stored in one central location allowing easy access to any data item.

- The data base consists of data logically related by GPN and in chronological order to permit rapid and efficient reporting.

- Reference and dynamic data can be stored by GPN in order to organize data related to the same equipment.

The centralized storage of data permits the efficient retrieval and analysis of different data types. For example, since reference and dynamic data are stored by GPN, reference data could be analyzed on the basis of dynamic data parameters such as fleet mileage or fuel consumed.

Each unique data type is identified and stored in the data bank using a record label, permitting direct access and retrieval of each data type. This "indexed sequential" organization allows random access to the specific data items desired without having to read all the stored data to locate that data item. This direct access capability is provided by the Data Dictionary[1] which describes the type, content, and relationship of all the data stored in the data bank.

4.4 - DATA RETRIEVAL AND ANALYSIS

The data base can be accessed by specifiying the record label. For example, if Chicago wishes to know the number of repairs that were done on its fleet of GMC T8H-603 for front axles during June 1980, as well as the amount of fuel consumed by that fleet, the following information must be specified.

---

[1] The Data Dictionary provides format instructions for all data at all points in the Bus TRIP system. It allows data to be received and input in any format by a system user without having to restructure the information. This also assures the data in the data base is identically formatted for ease of retrieval. The "Dictionary" also provides standard report and output formatting.

- Two RECORD TYPES will be needed:
  - Unscheduled maintenance records, and
  - Consumption records to determine the amount of fuel.

- The DATE for these RECORD TYPES, which must fall in the range of 6/1/80 through 6/30/80.

- The GENERIC SERIAL NUMBER containing:
  - The Property ID for Chicago and
  - The Fleet ID for the GMC T8H-603.

- The GENERIC PART NUMBER for front axles.

Once this data is selected from the data bank, it will be sorted on RECORD TYPE to separate the unscheduled maintenance records from the consumption records. After the sort is completed, a count of the repairs recorded on the unscheduled maintenance will yield the number of repairs on front axles. By summing the fuel figures contained in the consumption records, the total amount of fuel for the fleet of GMC T8H-603 is determined.

Data retrieval should be performed routinely as should data analysis and reporting. The frequency of routine data retrieval, analysis, and reporting will be determined on the basis of the frequency and volume of data submitted.

The types of analysis that can be done on the retrieved data are varied due to the diversification of the data types that are being stored. This analysis is described in Chapter 6.

4.5 - DATA REPORTING

Before periodic reports can be generated from Bus TRIP, a pre-report program is executed in order to compute period mileage from the available utilization data and to audit other dynamic data types (scheduled maintenance, repairs, etc.). If there are errors resulting from the computation of period mileage, those errors must be resolved since the period mileage is the basis of the computation of consumption, inspection, and repair rates.

Once all errors have been corrected by Bus TRIP personnel, the periodic reports may be generated. Routine reports will be issued at intervals, the frequency of which will be determined at the beginning of Bus TRIP operation.

These periodic reports will be generated on a scheduled basis by the computer operations staff within the Bus TRIP data bank facility. The computer operations staff will execute scheduled report programs, and submit the reports to the Bus TRIP data bank personnel for review, including proper data content and valid analysis. Following this review, the reports will be distributed to Bus TRIP users. Special requests will be submitted to the Bus TRIP data bank personnel. Report formats and algorithms will be developed to support these requests along with projected completion dates for report production to satisfy the requests.

SECTION 5 - BUS MASTER GENERIC PARTS LIST

PURPOSE AND DESCRIPTION

The evaluation of bus reliability involves the collection and processing of large quantities of reliability related data. This data, which covers a wide range of maintenance information, describes the many repairs which are performed in the bus transit industry. The purpose of Bus TRIP's data bank is to provide the "tool" for this data processing effort.

To properly input, process, and report meaningful reliability related information, a standard format for identifying components and storing data associated with these components in the data bank is required. This standard format is necessary so that data, regardless of its source or composition, can be stored in the bank by a common and uniform method which permits identical classification for like equipment.

As a primary basis for this standard formatting, a Bus Master Generic Parts List (Bus MGPL) has been developed. The Bus MGPL is a master list for cataloging component data when submitted to the bank and is also a systematic index for retrieving data when required for analysis. The Bus MGPL is also derived from Generic Parts Lists (GPL) which relate property and manufacturer's part numbers for a specific bus type. This means that each bus type has its own GPL identifying its own part numbers to the property. Using this concept, we may select data from different properties, classified and indexed at the same level (i.e. system, assembly, and component) and compare them for results on a functionally equivalent basis. Using the Bus MGPL, data covering bus equipment down to the lowest replaceable unit can be indexed and later retrieved as needed for analysis.

The Bus MGPL is a comprehensive list derived from combining individual parts lists, each generated for an individual bus model to be monitored. These lists are structured breakdowns of the systems that make up each bus model, starting with the top assemblies down to the lowest replaceable component. In combining these model lists, duplicate components were deleted while all unique components were retained. Thus, the Bus MGPL is capable of translating data from any property operating any specific bus model and assigning the data to its proper index and classification for storage in the data bank.

The Bus MGPL will be configured into a Bus Master Reliability Equipment List (Bus MREL), which will identify specific hardware to be tracked in the data bank. The approach here was to concentrate on those components which carry the majority of maintenance activity, are most costly, and generate the greatest interest in the industry. By limiting the number of components using the above criteria, the size of the data bank will be reduced. While this reduction serves the prime interests of the transit industry by concentrating on their more immediate problems, it also eliminates many of the minor components which may not impact severely upon Bus operations. Equipment placed on the Bus MREL will be that hardware selected by cost, failure, repair, frequency or interest expressed primarily by the users of the data bank.

5.1 - BUS GPL AND REL STRUCTURE

Data reporting on the Bus Transit industry usually centers around equipment failures. This information describes equipment malfunctions and the impact on bus performance and maintenance cost. To support this type of reporting requires a data organizational structure that is compatible with the kind of information that will be reported from the bank. This structure has been configured to accomodate a variety of information from numerous properties and is capable of presenting this data in a consistent and uniform manner. Furthermore, the structure must be designed to provide a practical means for retrieving data and presenting it in a manner that best serves a user's need. The structure, therefore, must provide an index in terms of system function and assembly so that a component may be registered in its appropriate functional position within a system.

The Bus MGPL will require a Generic Part Number (GPN) format for identifying equipment entered into the bank. The GPN is made up of a series of characters (12 total) which can identify equipment from a specific vehicle source down to a specific component type. This structural arrangement lends itself to having a data entry inserted into the bank by its functional level, from which it may be extracted for analysis with a minimum of sorting and selecting. This arrangement also serves two other interests. First, it provides a functional hierarchy of the equipment from the vehicle level down to the lowest replaceable unit identified. Second, it describes the hierarchy of component assembly so that the "packaging" and mounting of equipment may be known.

GPNs' are assigned to equipment by identifying three different levels of equipment. The first level using but one character indicates the type of vehicle to be tracked in the bank, in this case a bus. The next level identifies the equipment's assembled hierachy, descriptive of a system and its assembled structure. The third level relates to specific components and their types.

The GPN format (Figure 5.1) shows the levels of equipment that will be contained in the Bus MGPL. The first character identifies the vehicle model. In this case it will identify the vehicle as a Bus (B). The next group of characters (seven each) indicate the system breakdown within that BUS model from the system itself down to the subassembly. Any functional system, such as engine, electrical, doors, brakes, etc., may be identified by the system character. The subsystem is covered by the third and fourth characters. This is followed by two more lower equipment levels, assembly and subassembly, each of which have two character positions, the fifth and sixth characters for the assembly, and the seventh and eighth characters for the subassembly.

Table 5.1 provides an example of a portion of a generic parts list. This example contains a section from the Body, and Structural System and a section from the Suspension,

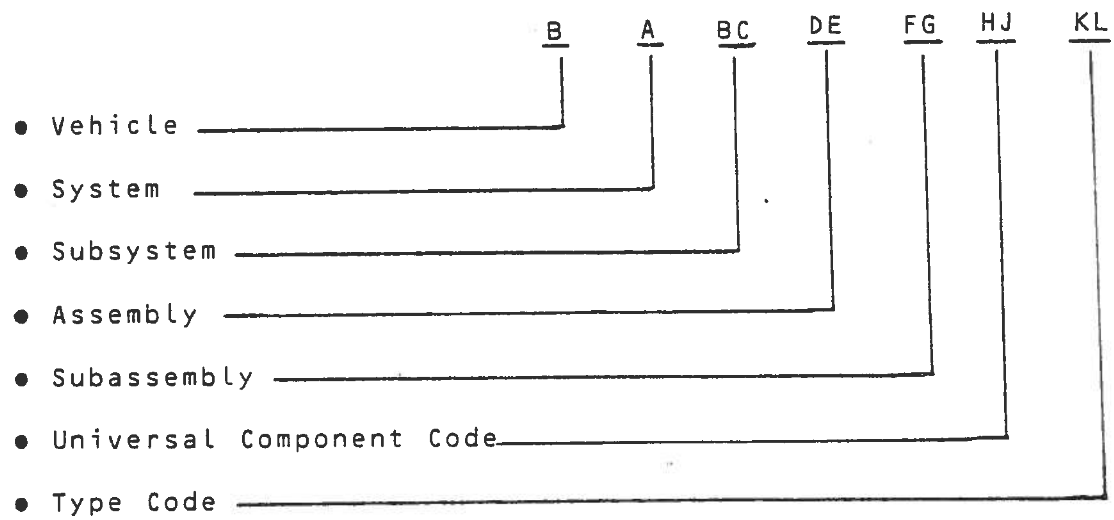


Figure 5.1 - Bus TRIP generic part number format.

Table 5.1 - Generic Parts List Example.

BODY AND STRUCTURES SYSTEM

- Emergency Escape Side Windows
- Emergency Escape Rear Windows
- Windshield Glass
- Standee Glass
- Door Glass
- Rear Window Glass
- Side Window Assemblies
  - Outer Frame
  - Brace
  - Hinge
  - Block Stop
  - Block Catch
  - Spacer
  - Outer Frame Seal
  - Water Seal
  - Window Spacer
  - Inner Frame
  - Sash End
  - Glass
  - Sliding Sash Channel
  - Nylon Glide

Table 5.1 - Generic Parts List Example (continued).

- Nylon Glide
- Spine
- Seal
- Latch Assembly
- End Seal
- Seal
- Spline
- Slide Assembly
- Handle Assembly

Destination and Run Number Signs

Windshield Wipers

- Wiper Motor
- Transmission Shaft
- Arm Driver
- Intake Fitting
- Elbow Fitting
- Wiper Arm
- Wiper Blade
- Control Valve
- Control Valve Knob

Table 5.1 - Generic Parts List Example (continued).

SUSPENSION, STEERING AND TIRE SYSTEM

- Drain Plug
- Universal Joint
- Drive Shaft
  - End Yoke
  - Journal Cross
  - Bearing
  - Snap Ring
  - Lubrication Fitting
  - Slip Joint Sleeve Yoke
  - Dust Cap
  - Drive Shaft Tube
  - Fixed Joint
- Steering Column and Bevel Gear
  - Steering Shaft
  - Steering Column Tube
  - Steering Shaft Lower Bearing
  - Tube to Housing Bolt
  - Bevel Gear Bearing
  - Bevel Gear Screw
  - Housing Cap Assembly
  - Housing Cap Bearing
  - Bevel Gear

Table 5.1 - Generic Parts List Example (concluded).

- Bevel Gear Housing
- Housing Bearing
- Retainer
- Pinion Gear to Shaft Nut
- Steering Shaft Pinion Gear
- Woodruff Key
- Housing Upper Cover Bearing
- Shim Pack
- Housing Vent Assy.
- Housing Upper Cover
- Steering Shaft Washer
- Upper Steering Column
  - Horn Button
  - Retainer
  - Steering Wheel Nut
  - Hardened Washer
  - Receiver Cup
  - Steering Wheel
  - Cancelting Cam
  - Flat Steel Spring
  - Switch Assembly
  - Turn Signal Housing
  - Steering Column

Steering and Tire System. The purpose of the example is to illustrate a typical breakdown structure and component nomenclature that will be found in the lists. The bus GPN format can be applied to this equipment and functions as a code for processing and retrieval of this equipment.

The last group of characters deal with component level information. A universal component code (character position nine and ten) describes an individual component such as pump, valve, battery, light, resistor, cable, etc. A further description is considered by the type code (characters eleven and twelve). This type code serves to denote the position within a subassembly or other level that a component may occupy. For example, within a given subassembly may be located a resistor bank containing 10 identical resistors. The type code serves to identify which of the ten resistors was recorded in the data bank. In this sense, the GPN serves to provide a complete identification of any component entered into the bank from the vehicle on down.

5.2 - MONITORED EQUIPMENT FORMAT (MRELs RELs)

As defined by the Bus MGPL, the TRIP data bank can accept any bus component identified. However, as noted previously only those components which are of prime interest to the users of the data bank will be monitored. By monitoring these components, the quantity of data will be reduced to a specified coverage with a reduced level of effort for processing.

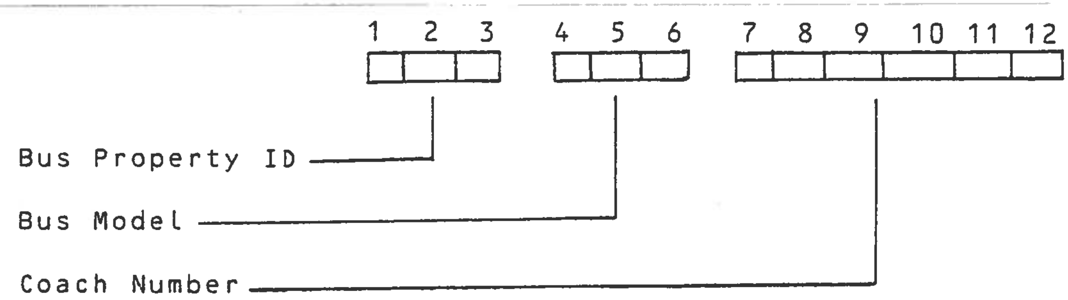
Each bus model will have its own Generic Parts List (GPL), making a GPL unique to a bus model. This is because each GPL contains all and only those GPNs descriptive of each model's equipment.

The GPL also includes the bus property and bus manufacturer's numbering scheme associated with identifying the bus models and their equipment. Each GPL also has its own Generic Serial Number (GSN). The GSN serves to identify the property, bus model, and vehicle number for a specific GPL that will be tracked in the bank. This arrangement permits accommodation of data generated from many bus models operating from a variety of properties without misidentification.

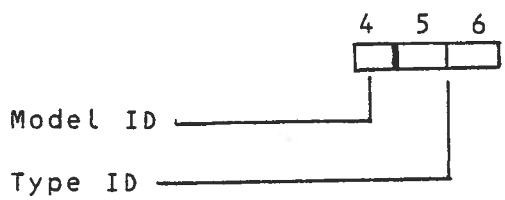
The GSN's format is composed of a 12 character code, of which the first three characters identify the bus property. The next three characters occupying positions four through six are reserved for denoting the specific bus models to be monitored. Since five bus models are to be monitored, the alphabet code can accommodate up to 26 models and easily satisfies the coding coverage required. Characters five and six are to be used for bus model types. These types are further distinctions of model configurations and can also be used to reference property unique modifications made for specific bus models. Figure 5.2 illustrates the format of the Generic Serial Number.

The Bus Reliability Equipment List (Bus REL) is derived from the GPL. The Bus REL contains a list of components from a specific bus model that will be monitored in the data bank. The Bus REL also retains both the manufacturer's and bus property part numbers of the components that will be monitored. Since the Bus REL identifies the components for which data will be accepted, it will be used during the data input phase to interpret information pertaining to those components which will be monitored for developing into a common indexing format.

The Bus Master Reliability Equipment List (Bus MREL) is a concise version of the Bus Master Generic Parts List (Bus MGPL). The Bus MREL is created by merging the BREL's for each bus model into one master list, deleting duplicate components and their associated GPN. The Bus MREL has only



<u>Bus Model</u>



<u>Bus Models ID</u>

GMC-ADB - A

GMC-NLC - B

FLX-ADB - C

FLX-NLC - D

MAN -
Articulated - E

Figure 5.2 - Generic serial number.

GPNs for identifying the components that are being monitored. Therefore, the Bus MREL is a list of the active components with their corresponding GPNs at any given time in the data bank.

5.3 - MREL CHANGES

During the operation of the data bank, it may be advantageous to add equipment to the Bus MREL, supplementing the hardware already being monitored. It may also be advisable at some time, to modify equipment presently recorded in the Bus MREL and/or to alter the procedures being used to store and report data in the bank.

There are two ways to effect a change in the bank: first by a user's request and second, by the Bus TRIP operating staff. Approving the changes in the bank would be a Bus MREL Change Control Board, made up of the APTA BUS TRIP Liaison Board, the Bus TRIP sponsoring agency Technical Representative, and members from other bus transit groups.

The Change Control Board members who represent the industry, serve as a clearing house for all modifications and changes to the bank. These members will most likely be composed of representatives from those properties who are participating in the program and have a direct interest. However, because the data in the bank will serve the total industry, changes in equipment to be monitored should meet the overall needs of the industry rather than the needs of a specific user.

ADDITION/MODIFICATION REQUEST PROCEDURE

The following procedure addresses the alteration of the BREL as a result of a TRIP user's request.

- Bus TRIP user/participant submits Bus MREL Equipment Addition/Modification Request Form (Figure 5.3) describing equipment of interest to be added to the data bank to the Bus TRIP operations staff.

- Request form is "logged in" by Bus TRIP operations and a copy is transmitted to the Bus MREL Change Control Board.

- Following approval of the Request by the Bus MREL Change Control Board, Bus TRIP operations staff sends copies of the Equipment Description form (Figure 5.4) to all Bus TRIP data suppliers.

- Equipment Description forms are completed and returned by data suppliers and are used by Bus TRIP operations staff to:

  a. Assign Generic Part Numbers (if applicable) to the new equipment,

  b. Modify Data Bank input, editing, and output routines to accept data for the new equipment, and

  c. Include equipment reference data in the Data Bank.

- Inform Bus TRIP users and data suppliers of the change in the Bus MREL by sending each group an Equipment Addition/Modification Notification form (Figure 5.5), including the data on which data solicitation for this equipment will be initiated, the date for the first report covering this equipment, or the date on which the change in the Bus MREL will take effect.

The first reliability report for equipment which has been added to the Bus MREL for Bus TRIP data recording will

REQUESTING AGENCY: ______________________

DATE OF REQUEST: ______/______/______
mo dy yr

REQUESTED BY: ______________________

REQUESTED FOR COACH MODEL: ______________

EQUIPMENT DESCRIPTION

PART - NAME : ______________________

PART - NUMBER : ______________________

PART - FUNCTION : ______________________

____

PART - QUANTITY(EST) : ______________________

NEXT HIGHER ASSEMBLY DESCRIPTION

ASSEMBLY - NAME : ______________________

ASSEMBLY - NUMBER : ______________________

ASSEMBLY - FUNCTION : ______________________

ASSEMBLY - QUANTITY(EST): ______________________

MAJOR FUNCTIONAL SYSTEM CONTAINING THIS PART: ______________

____

REASON FOR REQUEST: ______________________

____

REQUEST NO: A-______________ DATE RECEIVED: ____/____/____
mo dy yr

Figure 5.3 - Bus TRIP Bus MREL equipment/addition modification request.

DATE____/_____/_____
mo dy yr

BUS PROPERTY I.D.: ______________________________

MODEL: ______________________________

EQUIPMENT DESCRIPTION

PART NAME: ______________________________

MANUFACTURER'S PART NUMBER: ______________________________

PROPERTY NUMBER(S)

PART: ______________________________

STOCK: ______________________________

MISC. CODE: ______________________________

EQUIPMENT ASSIGNMENT
NEXT HIGHER ASSEMBLY

ASS'Y NAME: ______________________________

ASS'Y PART NUMBER: ______________________________

EQUIPMENT REFERENCE DATA

QUANTITY IN SERVICE: ______________________________

PART FUNCTION: ______________________________

FAILURE RATE(S) - NOMINAL (SPEC): ______________________________
- LAST REPORTED: ______________________________

COST PER PART - O.E.M.: ______________________________
- LATEST: ______________________________

PHYSICAL CHARACTERISTICS - LxWxH: ______________________________
- WEIGHT: ______________________________

PERFORMANCE (CAPACITY/RATING) - NOMINAL: ______________________________
- OVERLOAD: ______________________________

Figure 5.4 - Bus TRIP equipment description for Bus MREL addition/modification.

DATE____/____/____
mo dy yr

EQUIPMENT ADDITION DESCRIPTION

GENERIC - PART NUMBER : ____________________
- PART NAME : ____________________
- PART FUNCTION : ____________________
- SYSTEM NAME : ____________________
- SUBSYSTEM NAME : ____________________
- MAJOR ASSEMBLY NAME: ____________________

EQUIPMENT TRACKING COVERAGE

BUS PROPERTY I.D.	MODEL I.D.	PART QT'Y IN SERVICE

DATA COLLECTION TO BEGIN ON:_____/_____/_____
mo dy yr

FIRST REPORTING DATE:_____/_____/_____
mo dy yr

REPORTING FREQUENCY:____________________

REASON FOR ADDITION/MODIFICATION:____________________

____

____

Figure 5.5 - Bus TRIP equipment addition/ modification notification.

also include a listing of the reference data concerning this equipment.

EQUIPMENT CHANGE - ADDITIONS

Equipment additions may also be made to the Bus MREL based on changes in priority. These changes are those determined by the Bus TRIP operating staff and are related to coach hardware. As a result of their experiences with the data bank, the Bus TRIP staff may determine that it would be advantageous to track additional equipment. This decision may be based on the receipt of new reference information on equipment or due to recent analysis which suggest a change. Procedures for adding equipment to the Bus MREL by the Bus TRIP staff will be essentially the same as mentioned previously.

EQUIPMENT CHANGE - MODIFICATIONS

Changes in equipment priority may prompt the Bus TRIP operating staff to recommend modification of the Bus MREL. The staff may propose that certain equipment types currently being carried in the bank need no longer be reported. Such recommendations could be the result of a significant reduction in failure/replacement rates which no longer makes the equipment a prime concern; or accumulation of a sufficient quantity of data for equipment already recorded to which the addition of data would not change failure/replacement rates being reported. Procedures for recommending modification of the Bus MREL equipment would be identical to the Bus MREL Addition/Modification Request Procedure.

SECTION 6 - RELIABILITY ANALYSIS - A PRACTICAL APPROACH

The ever increasing complexity of equipment and the need for cost effectiveness presents a constant challenge to bus transit property operations. The constant demand for vehicles to meet schedules taxes their equipment and maintenance. Add to this, vehicle modification programs and new vehicle buys that properties may undertake, and it becomes apparent that some measure of assessing bus transit vehicle performance is essential. This information requirement can be met by monitoring and analyzing equipment failures as a means for improving transit vehicle performance and reducing costs. Such equipment failures are best evaluated through reliability analysis since reliability is concerned with the time degradation of equipment. In this respect, reliability analysis can serve as a useful tool for management decisions where fleet maintenance and operations are concerned.

To properly employ reliability analysis requires a fundamental understanding of its principles. To provide this understanding of reliability and its uses, the object here will be to take a practical approach towards illustrating applications. This approach will provide a description of the many techniques and applications of reliability and also consider how transit data may be used in supporting reliability evaluations. Coupled with this approach is the need for a data source to support various analysis. No data source ever provides all the data necessary in quantity or quality. However, the better the input data the more confidence can be placed in the output. To obtain better data, a prime source would be the Bus TRIP data bank. This bank would provide a more comprehensive supply of information for analysis. The bank would supply sufficient data from which logical conclusions may be gained through analysis.

6.1 - APPROACH

Reliability represents an engineering discipline dedicated to assessing equipment performance over time. It is related to other disciplines such as maintainability and is a factor in determining availability and dependability. Of all the product assurance disciplines, it is by far the most familiar and often used. As a result, reliability, as used in many cases, covers the many engineering techniques product assurance disciplines offer. These techniques range from sophisticated mathematical applications to basic hardware investigation and usually cover maintenance, test, safety, and operating considerations. A further extension of reliability use would apply to warranties, specifications, and requirements which imply defining hardware performance criteria. In a broad sense, reliability can be used in many ways. Parallel to the use of reliability is maintainability with its own techniques and applications. The intent here will also be to present maintainability with its distinctive applications as it relates to reliability engineering.

Essential to the use of reliability are two important considerations. First, a clear definition must be given for each technique used and its objective, and second, a determination must be made as to what data is available and how best to use that data. Data collection systems in the bus transit industry are generally not meant to supply data in terms of reliability parameters, nor are most data systems. However, much data is generated and can be used in addition to the uses originally intended. Extracting this data and relating it to reliability, it is possible to indicate in some systematic way the characteristics of bus vehicle reliability. However, the data is best used only when it is possible to determine what data is useful and that failures (repairs) have been identified for application to reliability analysis.

Figure 6.1 illustrates a general relationship between transit data and reliability/maintainability applications and use. The transit data elements cover the more frequently recorded information that maintenance data systems supply. Since each property may use its own terminology, the items shown in the transit data blocks serve to provide an overall description of the varied data that is recorded.

The reliability/maintainability techniques shown in Figure 6.1 generate calculated values derived from using basic data parameters. The exception to this is the last three items shown under reliability/maintainability techniques, FMEA (Failure Modes and Effects Analysis), Failure Analysis, and Worst Case Analysis, which apply exclusively to hardware evaluation. The techniques listed are the more prominent ones although others do exist which can be applied as needed.

Those items listed under applications are again the more visible and practical ones where these techniques are required. They represent a range of different uses, from technical requirements and planning, to predictive applications. Like the techniques mentioned above, an explanation of their use and rationale will be provided in

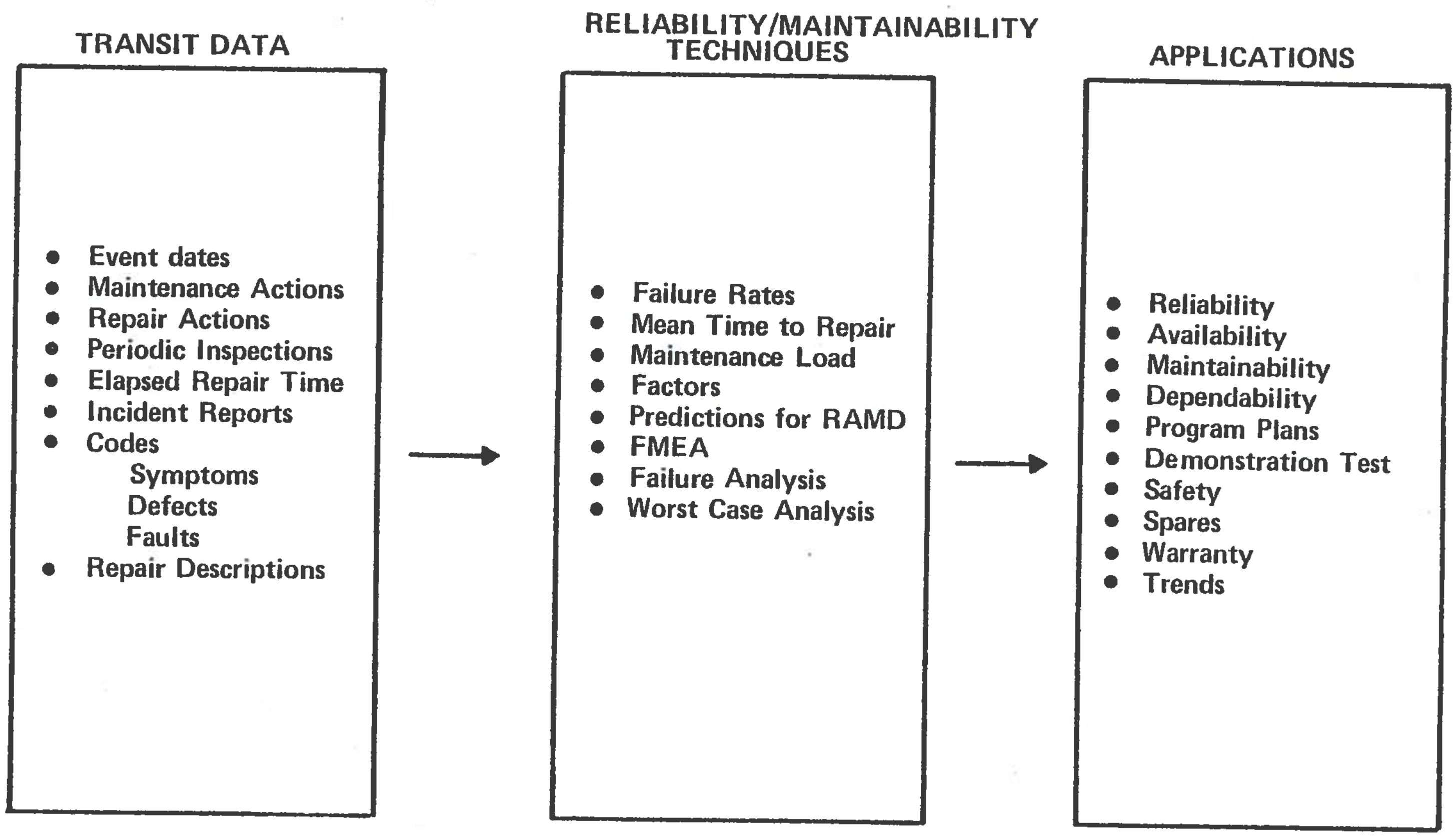


Figure 6.1 - Transit data-reliability use relation.

following sections. It should be noted that the mathematical descriptions of the techniques will be presented in a fundamental way and that no elaborate derivation of the technique itself will be provided.

6.2 - TRANSIT DATA

The reference, utilization and repair data as provided by transit properties can be extensive and varied. However, most of the data reported usually conforms to general descriptions used throughout the industry. Listed in this section are those data descriptions which are typical and at a minimum serve to provide the information necessary to determine reliability parameters.

- Event dates - dates of incidents, vehicle entering and leaving service, modifications, major component changes.

- Maintenance Actions - the number of times a vehicle is brought back from service for maintenance.

- Repair Actions - the number of actual repairs performed on a vehicle, system, vehicle series, or fleet.

- Vehicle Mileage - the number of miles a vehicle has operated over a specified time period. Mileage can be specified for a vehicle series, fleet, or component use as desired.

- Periodic Inspection - scheduled maintenance on a prescribed interval to maintain or repair vehicles.

- Elapsed Repair Time - that time interval when a vehicle is taken out of service to when it is returned to service.

- Incident Reports - reports derived from operation of vehicles providing a description of a vehicle experiencing a problem. The report usually, but not always specifies vehicle ID, route system, component affected and the following:

Codes - Symptom, what was first noticed as a problem,

- Defects, a more cosmetic type of problem, and

  - Fault, what was usually repaired as a result of being a problem with a repair description.

- Repair Description - an explanation of what was found and done to correct the problem. This information usually details the specific action and component being repaired.

6.3 - RELIABILITY

The reliability techniques presented herein represent a combination of mathematical and hardware-related analyses intended to serve specific needs. The mathematical analyses involve calculations based on data obtained from vehicle operations and are used to generate rates and predictions for assessing vehicle performance. The hardware analyses are based on the data generated from incident and maintenance reports and serve to examine cause of failure and pinpoint root problems. Each technique and its rationale is described as follows:

Failure Rate Determination - Failure rates are numerical figures of merit that express the frequency of failure (repairs) observed over a specific time interval. Failure rates can be expressed in failures per hour or more commonly in transit operations, failures per miles. Since mileage can only be accumulated by operation of a vehicle over time, the use of miles for the failure rate implies a conversion from time to distance.

In determining failure rates (λ), the failures are defined as those incidents where a component was found to be inoperative or exceeded its design limits and therefore did not perform its intended function. Hence, a distinction is made between maintenance actions, where minor repairs are made versus repair actions, where a component is repaired due to catastrophic failure or where it is operating beyond its limits. Using event dates to identify failures (repairs) and associated mileage at failure, we may calculate failure rates as follows:

$$\text{Failure Rate } (\lambda) = \frac{\text{number of failures}}{\text{specified miles}}$$

The reciprocal of the failure rate (λ) represents MTBF (Mean Time Between Failures). The MTBF is the average operational time between equipment (vehicle, system, etc.)

interruptions (i.e., time between failures). It is expressed as: $MTBF = \frac{1}{\lambda}$ and may represent in service time of a component system, vehicle, vehicle series, etc. The time element can be substituted by mileage so that MTBF can be translated into MMBF (Mean Miles Between Failures) and perform the same measurement. In the same manner, MMBMA (Mean Miles Between Maintenance Actions) and MMBRA (Mean Miles Between Repair Actions) may be calculated by dividing the number of miles for a specified period by the number of appropriate actions to give a measure of the maintenance burden being experienced.

Predictions - To assess equipment performance, we may determine the probability of successful operation by a variety of measurements. We may determine this assessment by predicting the equipment's reliability in the following way:

Reliability - The probability (chance) that a component/system will perform satisfactorily over a specified time period, expressed as:

$$R = e^{-\lambda t}$$

where λ = failure rate (in time or miles)

t = time (miles can be used)

For example: given a component with $\frac{20 \text{ failures}}{10^6 \text{ miles}}$

that is, a failure rate of 20 failures per one million miles, what would its reliability be for 1,000 miles of operation? We may substitute into the formula, the following:

$$R = e^{-\lambda t} = e^{-\left(\frac{20}{10^6}\right)(1000)}$$ where 1000 miles was substituted for t

$$= e^{-\left(\frac{20}{1,000,000}\right) \times (1000)}$$

$$= e^{-\frac{20}{1,000}} = .02$$

$$R = e^{-.02}$$

$$R = .98$$

It should be noted that whenever miles are used in the failure rate, miles must be substituted for t.

Consequently, the component has a 98 percent chance of operating successfully over 1,000 miles. Using repair actions as failures where MMBRA (Mean Miles Between Repair Actions) can be substituted for MTBF, we have:

$$MMBRA = MTBF = \frac{1}{\lambda}$$

we may use repairs and vehicle mileage for t (time) in the reliability formula, ($R = e^{-\lambda t}$) and calculate component reliability. The above formulation is applicable to an individual component or component in series, that is, where all the components must work in a system. As a result, if a system contains a series of components which must all work for system success, we are able to determine system reliability by calculating the product of all the component reliabilities.

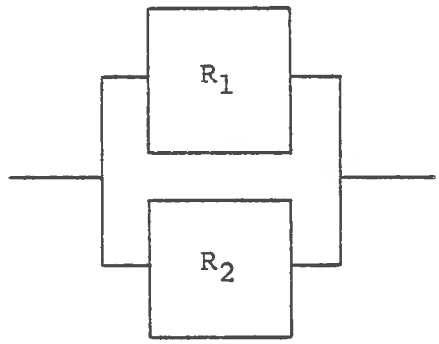
If we consider the use of redundancy in a system, a change in formulation is required to account for the gain in reliability that redundancy provides. To illustrate this principle, let us consider the following:

- Two redundant components R_1 and $R2$ equal to each other

- $R_1 = R2 = 98\%$ reliability (.98)

- Both R_1 and $R2$ are working and only one of the two is required for successful system operation and continuity.

We can best express the above condition with the following model illustration and symbols:



Using logic symbolism:

+ = OR, a choice and mathematically additive

X = AND, both needed and mathematically a multiplier

Since $R_1 = R_2$ is either working (R) or it is failed (Q), we may show a component's state as, 1 = R + Q.

Expressing the model in logic terms, we have:

$$R_S = R1 + Q1 \times R2$$ which is:

System success (R_s) = R1 working OR R1 failing AND R2 working (or vice versa). Thus with either R1 or R2 working or failed but not both failed, we have success.

Continuing: $R_S = R_1 + Q_1 \times R_2$ and $Q = 1-R$

$$R_s = R_1 + Q_1 \times R_2$$
$$= R_1 + (1-R_1) \times R_2$$
$$= R_1 + R_2 - R_1 R_2 \text{ and } R_1 = R_2 = R$$
$$= R + R-R^2$$
$$R_s = 2 R-R^2$$

Substituting R = .98 into the formula we have

$$R_S = 2 (.98) - (.98)^2$$
$$= 1.9600 - .9604$$
$$R_S = .9996$$

Therefore with redundant components, R_s as a system has increased from 98 percent to 99.96 percent reliability.

6.4 - MAINTAINABILITY

By definition, maintainability is the probability (chance) of completing a repair in a specified time period. However, it is rarely measured in such terms and is usually expressed in a more simple way such as MTTR (Mean Time to Repair) and load factors. The real value of measuring a MTTR is to determine those characteristics which result in lengthy repairs such as the difficulty of fault detection, ease of remove and replacement of a component, checkout, availability of tools, etc.. By evaluating these time repair characteristics, maintenance policy may be adjusted and reduction in routine repair time and maintenance efficiency may be addressed. Such repair time reductions also help to improve availability.

- Mean Time To Repair - Mean Time to Repair (MTTR) represents the average time it takes to perform a number of repairs. It can be expressed as:

- $$MTTR = \frac{\text{Summation of a number of repair times}}{\text{Number of repairs}} = \frac{T_R}{N_R}$$

MTTR traditionally represents only that time associated with the repair of hardware and usually excludes waiting time (i.e., waiting for the tools or parts) and idle time (work breaks). However, including the above exclusions, MTTR can represent an operational MTTR which reflects a vehicle or a component's out-of-service time. Using elapsed repair times for components/vehicle as taken from transit data we make calculate an MTTR representative of a component/vehicle out-of-service time.

As a substitute for MTTRs we may use MLHTR (Mean Labor Hours to Repair). This factor requires that both the number of total labor hours and the number of repair personnel be known to calculate the MLHTR. While this calculation is more inclined to represent the actual time spent on repairing a bus, by adding a contingency factor for tools and waiting time, we may approximate elapsed repair time for a vehicle. Thus, like the operational MTTR we can approximate a vehicle's out-of-service time.

Using MTTRs, a repair rate may be shown by taking the reciprocal of the MTTR. This is expressed by:

$$\frac{1}{MTTR} = \mu = \text{Repair rate}$$

A repair rate can be used as an indicator of the time spent in performing various repairs. Component repair impact can be compared from one item to another and ranked accordingly using a repair rate.

<u>Maintenance Load Factors</u> - Maintenance Load Factors are expressed as numerical values (without units) which reflect the repair load being experienced to maintain a component/vehicle. It is indicative of the unavailability of a vehicle due to the maintenance of specific equipment

and is determined by the product of a given item's failure rate and MTTR. Thus, it not only describes how often something fails but also how long it takes to repair it (out of service), and illustrates the total maintenance impact of a component/ vehicle. In some cases, the most frequent failure or the most lengthy repair is not necessarily the item causing the greatest maintenance impact. For example, consider a system composed of components A, B, and C with the following failure rates and MTTRs:

Component	Failure Rate	MTTR	Load Factor
A	50	5	250
B	30	15	450
C	10	20	200

While A is the highest failure contributor and C is the highest contributor in terms of repair time, neither is the most significant contributor in terms of out of service and maintenance, since B has the highest load. The product of failure rate and MTTR shown below in their units illustrates how a unitless value for load factors is determined.

Failure Rate X MTTR

$$\frac{\text{failures(N)}}{\text{hour(t)}} \times \text{hour(t)} = \frac{N}{t}(t) = \text{N(failures)}$$

Where failure rates are expressed in failures/mile, a simple equating of miles to average miles per hour (speed) can convert the rate to be expressed in terms of hours. Therefore, MMBRA (Mean Miles Between Repair Actions) can be converted to a failure rate, ($\frac{1}{MMBRA}$) and expressed as failures per miles. To a maintenance manager such a numerical indicator serves as a valuable tool because load factors not only indicate what components are the major influence on vehicle unavailability but also where the maintenance requirement (loading) for the vehicle is most significant. Load factors can be formulated for individual components, assemblies, vehicles, vehicle series, and fleet for comparisons.

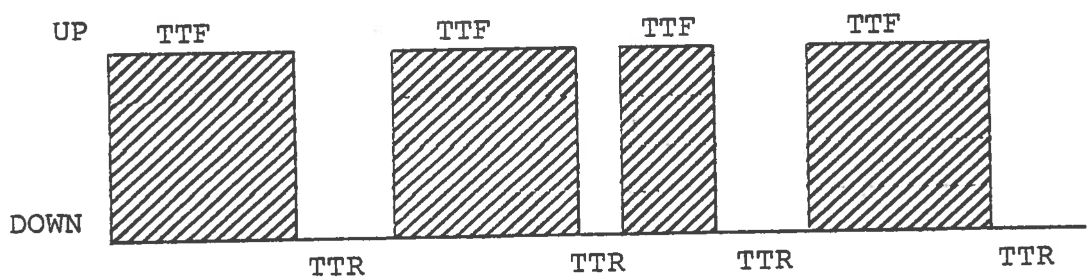
Maintainability is associated with the design characteristics of equipment as contrasted with maintenance where equipment is repaired and maintained in the most efficient manner. Nevertheless, they are both interrelated and maintainability serves to make maintenance routines easier and efficient.

6.5 - AVAILABILITY AND DEPENDABILITY

By definition, <u>availability</u> is the probability (chance) that an item (vehicle) is not in a failed state at any time (i.e., is ready to operate). It is affected by both the reliability and maintainability of an item (vehicle). Availability can be expressed as a percentage of a vehicle's operating profile and indicates its readiness for service regardless of whether it is being used or not. The derivation of Availability (A) from reliability and maintainability can be shown as follows:

Consider a vehicle's operational profile where:

OPERATIONAL PROFILE



where the average of TFF (Time To Failure) = MTBF and the average of TTR (Time To Repair) = MTTR so that:

$$A = \frac{UP}{UP + DOWN} = \frac{\text{SUM OF TTF}/N}{\frac{\text{SUM OF TTF + TTR}}{N}} = \frac{\text{MTBF (MMBF)}}{\text{MTBF (MMBF) + MTTR}}$$

where N = number of times to failure followed by a repair

As previously stated, MTBF = $\frac{1}{\lambda}$, which is the reciprocal of the failure rate, and is a function of reliability, while MTTR is a function of maintainability.

Now if we divide the total expression by the MTBF we may express A as follows:

$$A = \frac{MTBF}{MTBF + MTTR} = \frac{\frac{MTBF}{MTBF}}{\frac{MTBF}{MTBF} + \frac{MTTR}{MTBF}}$$

$$A = \frac{1}{1 + \frac{MTTR}{MTBF}} \text{ and } \frac{MTTR}{MTBF} = (MTTR)\ (\text{Failure Rate or } \lambda)$$

as previously noted MTTR x Failure Rate = Load factor and A can be expressed as:

$$A = \frac{1}{1 + (MTTR)(\text{Failure Rate})} \text{ OR } \frac{1}{1 + \text{Load Factor}}$$

Also, MMBRA (Mean Miles Between Repair Actions) or MMBF (mean miles between failures) can be converted into a failure rate as previously illustrated to determine Availability.

Thus, A (Availability) can be expressed as a direct function of equipment performance. The expression of A above is indicative of components in series (that is, a system in which all the components must work). However, if redundancy exists, be it hardware or a man-machine relation, the formulation for availability becomes more complex and involved for predicting availability. However, the use of the above expression provides an excellent estimation for series type evaluations and a good "ball park" estimate for redundant type systems. In either case, it provides a reasonable way for measuring availability.

By definition, dependability is the probability (chance) of an item (vehicle) being operationally ready. Dependability (D) can be equated to a measure of effectiveness of equipment and can also be expressed as the product of reliability and availability. In plain terms, it can be stated as the chance that a vehicle will be ready for service (availability), and the chance of the vehicle working well during service (reliability). Mathematically we may express dependability (D) as:

$$D = A \times R$$

where A is a function of MMBRA and MTTR (load factor) and R is a function of MTBF (MMBRA). D in a direct measurement sense can be equated to MMBSF (Mean Miles Between Service Failures). This is indicative of the interruptions experienced during a vehicle's service on a given route.

Extending D to include cost would measure the cost effectiveness of the vehicle in terms of equipment performance. To better focus on equipment costs we may consider maintenance costs where MLHTR (labor impact) and MMBF (failure impact) are factored in to give us the cost of maintenance over a given period of operation. These factors can be expressed as the system effectiveness, S_E of the vehicles (fleet) where a total assessment of fleet operation can be made.

6.6 - RELIABILITY HARDWARE ANALYSIS

- FMEA

FMEA (Failure Modes and Effect Analysis) is a hardware related analysis which characterizes a specific failure and the consequences of that event. FMEAs are used to trace the resulting effects of a problem from its initial symptoms down to its root cause. FMEAs also serve to suggest corrective action which can be applied to eliminate the problem. For example, a descriptive FMEA may point to a design change, a material change like protective coating (such as epoxy), or a change in maintenance procedures to correct the problem. FMEAs also provide insight into the behavior and operation of equipment when they identify failure modes. These modes are the mechanism by which components fail such as contacts fusing, bearing seals leaking, or excessive mechanical wear due to heat and stress. FMEAs serve a useful purpose by providing information to reduce failures, improve performance, and expedite maintenance.

From bus transit data incident and repair reports, which provide symptoms, defects, faults, and repair descriptions, FMEAs may be developed. Also, incident reports indicating the component, assembly, and system affected provides traceability of the event and permits the identification of the impact. Using FMEAs to provide corrective action, the intended result is the tangible step taken to improve the equipment. Corrective action where a component is removed and replaced only corrects the symptom and not the problem. Therefore remove and replace actions are not really corrective actions in the true sense of the word.

It should be understood that transit data will not in all cases provide the combination of symptoms and faults necessary to conduct an ideal FMEA, nor will the repair description provide all the evidence necessary to define the real problem. However, the intent here is to describe the method and format that can be used when such data is available. To illustrate a format for describing FMEAs we may use the following table, where each equipment level is shown along with its fault impact:

FMEA

Vehicle Symptom	Mode	Component	Assy.	System	Correction Suggested

Needless to say, variations of the above table can be constructed to accommodate the conditions and problems that exist. Table 6.1 provides a basic example of FMEAs, denoting problems in the Drive Train portion of a bus. In an FMEA, the correction suggested is accomplished by performing a failure analysis as shown in the following section.

- Failure Analysis

Failure analysis is that type of evaluation where root causes of component failures are investigated. Given high failure contributors and/or trends in equipment which affect vehicle performance, failure analysis serves to eliminate

Table 6.1 - FMEA - Transmission.

VEHICLE SYMPTON	MODE	COMPONENT	ASSEMBLY	SYSTEM	CORRECTION
• Noise in Gear	Worn Bearing Race	Mainshaft Bearing	Transmission	Drive Train	Check for proper lubrication.
• Jumping out of Gear	Worn Gear Teeth	Gear Clutch	Transmission	Drive Train	Check and inspect gear periodically for play, tolerances and lubrication.
• Oil Leak	Leaking, Defective Seal	Seal	Transmission	Drive Train	Check seal for proper fitting and for appropriate material.

such problems by defining causes, which may then be corrected. Failure analysis usually start with the development of repetitive failure modes after which the affected component may be examined in detail for a corrective solution. Transmission problems may be traced to poor lubrication due to leakage from seal material which does not stand up to the stress. Electrical parts epoxied with a poor quality of material may crack to permit moisture collection and eventual electrical shorts. The number and variety of failure analysis applications depend upon the severeness of the problem and the benefits to be gained from it.

- Worst Case Analysis

Worst Case Analysis is a technique used to evaluate equipment under the worst possible combination of conditions to determine its compliance and performance with requirements. Such an analysis is best served in the design stage of vehicles and when major modifications take place. In the latter case, such changes may affect equipment performance and therefore, it becomes necessary to examine system performance continuity under the most difficult situations. Equating the engineering performance to system specifications acts as a guide and a measure of the adequacy of the modification itself.

6.7 - APPLICATIONS

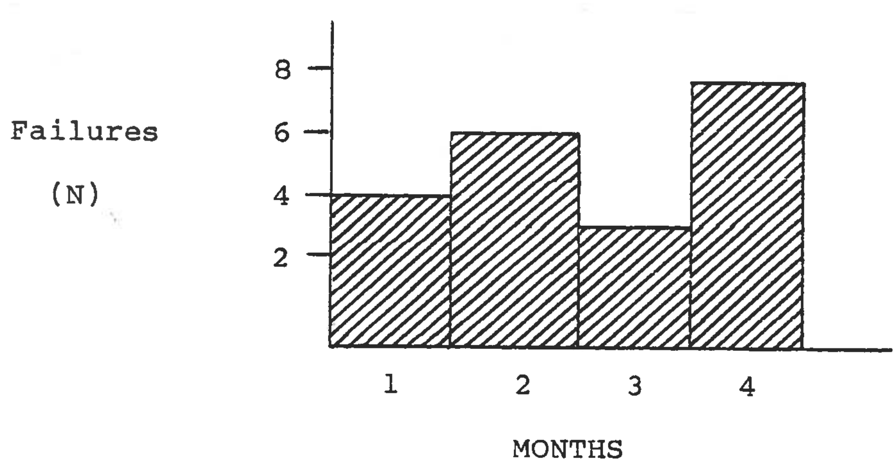
- <u>RAMD Predictions</u>

Reliability techniques can be used for a variety of engineering applications. These applications can range from mathematical predictions to program plans and specifications for equipment. Most significant in the use of predictions are the equipment estimates that can be made in terms of reliability, maintainability, availability, and dependability (RAMD). These predictive techniques, previously illustrated are essential to assessing equipment performance. For example, in predicting reliability, we determine how well equipment may function and in predicting maintainability, we may determine how efficiently equipment may be repaired. As noted previously, both of these disciplines serve as factors in determining availability which is an important measure of equipment readiness for service. Furthermore, with the predictions of availability and reliability, one can forecast dependability and, adding cost, evaluate the cost effectiveness of equipment.

As an example of using these techniques and analysis, let us consider a bus modification program where a fleet has been modified to improve performance. This modification included the changing of equipment and or the physical repositioning of other equipment.

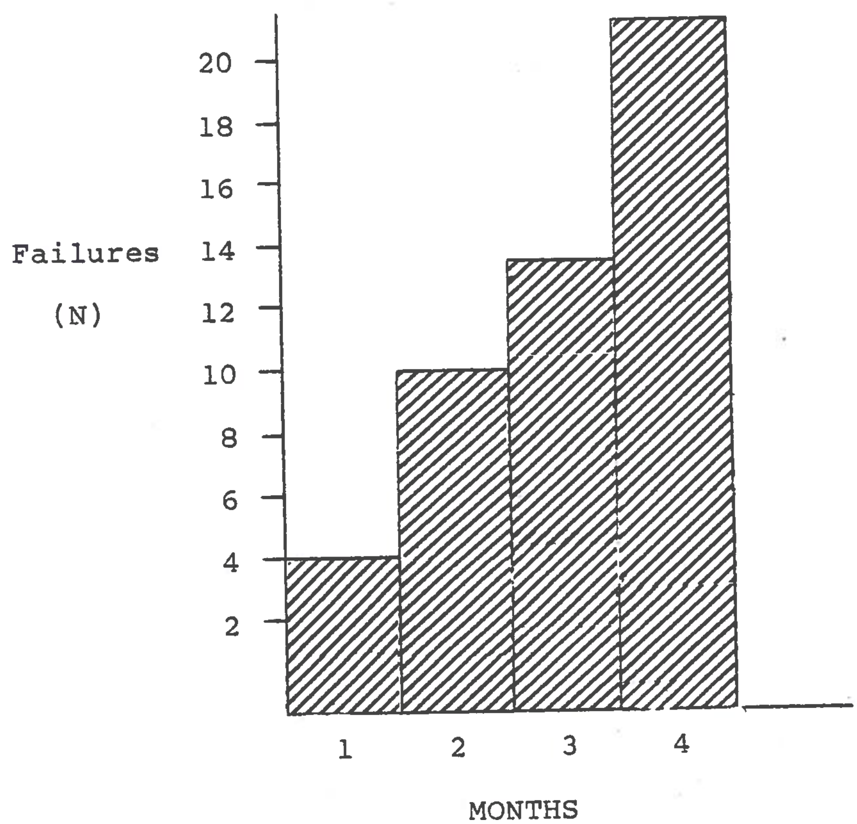
First, a reliability and availability estimate of the vehicles in the fleet should be made prior to the modification in accordance with the techniques illustrated previously. After the modification, predictions at 6-month intervals should be made to assess the changes and their impact on performance. With the modification made, we may look at the failure (repair) distribution experienced over a period of time as follows:

Vehicle Failures



As can be seen the number of failures varied each month. Projecting these failures in a cummulative fashion, we may see what trend is suggested, that is, are the failures experienced increasing or decreasing with time and is it significant. Illustrating this graphically we have:

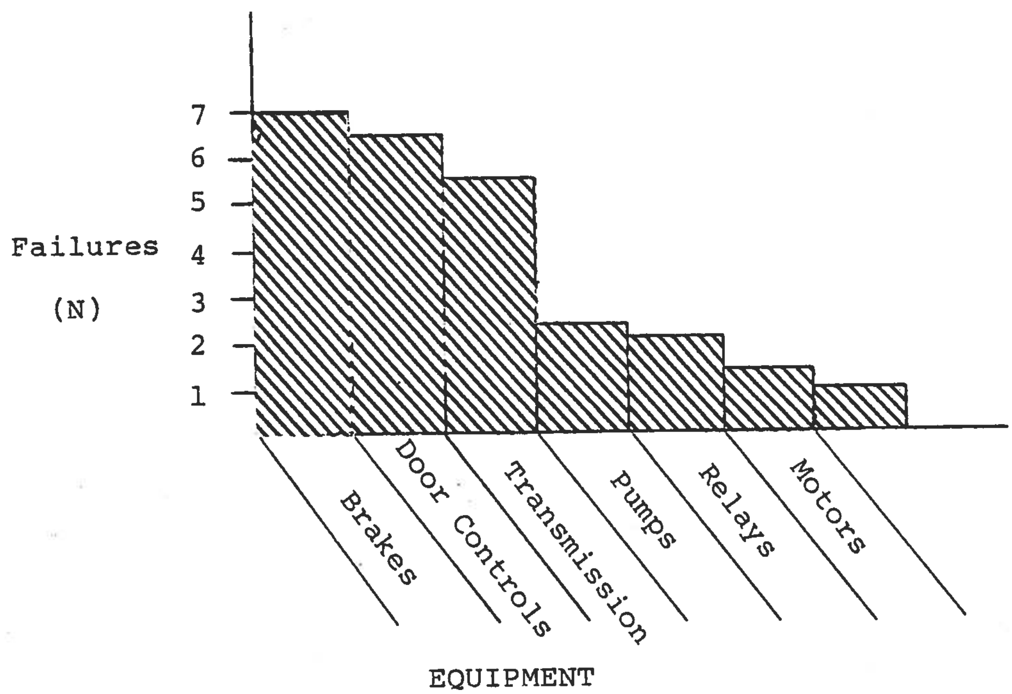
Vehicle Failures



From the trend indicated, we may seek to focus on the most significant equipment failure contributions to reduce their impact. This can be accomplished by ranking the equipment failures in decending order starting with the highest failure contributor as shown in the following illustration:

EQUIPMENT FAILURES

RANKING



Using the above hypothetical illustration, it appears obvious that we should concentrate on the first three items shown since they represent the most significant failure contributors. The number and type of equipment to be evaluated will vary as vehicle experience dictates.

From the above decision we may proceed to use an FMEA to determine the causes of failure of the equipment under evaluation, and if necessary, use failure analysis to discover the root problem. Correcting these problems would result in an improvement in component reliability and availability and affect the fleet accordingly. With the modifications made, assessment of R and A should continue and be compared to the original estimate so that the modification can be assessed for its performance.

Supporting the above activity requires a data base sensitive to the needs for evaluating equipment performance. This data base must collect, process, and evaluate a wide range of information so that the varied and necessary analyses to support reliability assessments can be made. Futhermore, the data base must be able to support other analysis not specifically mentioned in the above example. To provide such a service requires a data bank of the type and magnitude currently projected for the Bus TRIP data bank. Without such a service, no tangible evidence can be generated to properly assess bus vehicle performance.

- <u>Program Plans</u>

Program plans serve the purpose of providing a total procedure for executing a reliability service. Plans can be developed for any of the RAMD applications and can also be used for safety. Typically, a plan will state an objective, describe requirements (numerical goals), specify analytical techniques (predict reliability) and their application and indicate the tests (demonstration) to be performed. The plan will usually call for component ranking (criticality list) and specify vendor monitoring. Accompanying the plan are the usual schedules and milestones for measuring progress. Essentially, the plan functions as an overall format for identifying the specific steps that will be used to implement and service a property's reliability needs. As in any application, the plan can vary to adjust to the needs of the property. The use of a program plan should fit the conditions for the program it serves. Therefore, each application must be tailored to meet the objectives with specific techniques to attain specific goals.

- <u>Demonstration Tests</u>

In buying new equiment, the quality and performance verification of the equipment requires some format that will demonstrate that these requirements can be met. A demonstration test plan provides an overall procedure for developing and conducting a test to verify that requirements can be met. The demonstration plan defines the equipment, test criteria procedures, equipment sample, decision criteria, maintenance and corrective action associated with each equipment buy. To verify test results, a failure criteria specifying the classification and relevancy of failures is prescribed. The use of this format assures that each equipment buy has been thoroughly examined and checked for compliance with prescribed requirements.

Furthermore, the concept of the test provides a means for the manufacturer to prove his equipment's capability and that it has been properly designed to meet operating conditions. Each buy will vary and in this regard, some criteria for selecting a sample for test that is indicative of the equipment becomes necessary. Since equipment is produced in lots of various sizes, it is necessary to project the number of samples required (as in the case of vehicles), to properly represent the total buy.

- Safety

Reliability techniques can be applied to safety analysis. Safety analysis of equipment requires a format that will define the chain of events for a potentially hazardous occurence and its resulting impact. The use of the analysis will borrow from FMEAs depicting individual failure modes and showing how these modes interact to result in the failure of equipment (i.e., vehicle). While the above reflects safety evaluation from an analytical point of view, other considerations are necessary. Evaluation of material, installation, procedures, and checks all serve to enhance the safety of a vehicle and insure proper operation with a minimum of risk. Incorporating all of these characteristics requires a plan which, when executed, serves as a procedure for insuring that all aspects of safety have been employed. In support of such a plan, the use of reliability techniques works to measure the effectiveness of the safety features employed.

- Spares, Warranty, and Trends

Spares provisioning can be determined by the use of failure rates where the frequency of failures over a specified period of time (annual), implies the number of replacements required. The failure rate alone does not determine the quantity in stock required, since different systems in a vehicle can have similar components and quantities can be economized. However, the rate does provide the foundation from which the number of replacements can be determined. Coupled with spare's procurement time, failure rates can serve to forecast spares stockage.

Warranties specified for equipment require some criteria upon which to base reliability requirements. Fundamental to warranties are the number of failures, the kind of failures, and the conditions under which failures occur and are verified. As such, these criteria are best specified when reliability techniques are used to determine the failures and associated conditions. Consequently, reliability techniques can be used in defining warranties.

Trends serve to perform a forecast where an increase or decrease in equipment performance can be noted. As a consequence, trends rely on data generated by reliability techniques which show the relative performance of the equipment. Trends can be used for a variety of applications and be indicative of different conditions.

APPENDIX A

REFERENCE DATA FORMATS

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	
System Miles: Total	N	3	MI
Street Construction:			
Percent on Collector Street	N	2	PERCENT
Percent on Arterial Street	N	2	PERCENT
Percent on Freeway	N	2	PERCENT
Stops: Number	N	3	STOPS
: Average Spacing	N	5	FT
Passenger Volume: Average	N	6	PAX/HR
: Base	N	6	PAX/HR
: Peak	N	6	PAX/HR
Buses: Total	N	4	VEH
: Available for Service, Daily	N	4	VEH/DAY
: Required for Service, Daily	N	4	VEH/DAY

Figure A-1 Reference data transit property system configuration.

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	
Route ID	A/N	4	
Route Miles, Total	N	2	MI
Stops : Number	N	2	STOPS
: Average Spacing	N	5	FT
: Minimum Spacing	N	4	FT
: Maximum Spacing	N	5	FT
Grades : Percent of Route	N	2	PERCENT
: Maximum Uphill Grade	N	3	% GRADE
: Maximum Downhill Grade	N	3	% GRADE

Figure A-2 Reference data transit property route configuration.

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	
Route ID	A/N	4	
Speed : Scheduled	N	2	MI/HR
: Average	N	2	MI/HR
Headway: Minimum	N	3	SEC
: Maximum	N	3	SEC
Dwell, Station: Maximum	N	3	SEC
: Minimum	N	3	SEC
: Average	N	2	SEC
Scheduled Runs: Number, Buses	N	3	BUSES
Load Factor : Base, Actual	N	3	
: Peak, Actual	N	3	
: Maximum	N	3	

Figure A-3 Reference data transit property route operating information.

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	
Fleet ID	A/N	4	
Total Number of Buses	N	3	BUSES
Bus Numbers: Low	N	5	BUS NO.
: High	N	5	BUS NO.
: Increment	N	1	-
Bus Manufacturer	A	16	
First Year in Service	N	4	YEAR
Scheduled Maintenance, Routine : Mileage Interval	N	5	MI
: Time Interval	N	2	WEEKS
, Major : Mileage Interval	N	5	MI
: Time Interval	N	2	WEEKS

Figure A-4 Reference data transit vehicle fleet information.

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	
Fleet ID	A/N	4	
Number of Buses	N	3	BUSES
Bus Manufacturer	A	16	
Dimensions: Length	N	4	FT
: Width	N	4	FT
: Height	N	4	FT
: Wheelbase	N	4	FT
Turning Radius : Wheels	N	3	FT
: Body Corner	N	4	FT
Speed : Maximum	N	2	MI/HR
: Maximum Operating	N	2	MI/HR
Acceleration : Nominal	N	3	MI/HR/SEC
: Maximum	N	3	MI/HR/SEC
: Minimum	N	3	MI/HR/SEC
Deceleration : Minimum	N	3	MI/HR/SEC
: Maximum	N	3	MI/HR/SEC
: Nominal	N	3	MI/HR/SEC
: Emergency	N	3	MI/HR/SEC
Jerk Rate, Nominal	N	3	MI/HR/SEC^2
Weight : Empty	N	5	LB
: Seated Load	N	5	LB
: Normal Standing Load	N	6	LB
: Crush Load	N	6	LB

Figure A-5 Reference data transit vehicle specification information.

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	-
Fleet ID	A/N	4	-
Subfleet ID	A	1	-
Number of Buses	N	3	BUSES
Bus Manufacturer	A	16	-
Doors: Front; Manufacturer	A	16	-
: Rear; Manufacturer	A	16	-
Air Comfort; Heating;			
: : Manufacturer	A	16	
: Ventilation: No. of Blowers	N	1	BLOWERS
: : Manufacturer	A	16	
: : Capacity, Total	N	3	CFM
: : Fresh Air Make-Up	N	2	%
: Air Conditioning : Capacity	N	2	TONS
: : Manufacturer	A	16	
Electrical : Generator : Type	A	4	-
: : Cold Output	N	3	AMPS
: : Cold Output	N	3	VOLTS
: Starter : Type	A	4	
: : No-Load Voltage	N	2	VOLTS
: : Manufacturer	A	16	
Engine : Model	N	6	
: Displacement	N	3	CU. IN.
: Manufacturer	A	16	
Brakes: Front : Type	A	12	
: : Manufacturer	A	16	
: Rear: Type	A	12	
: : Manufacturer	A	16	
Suspension, Steering, Tires:			
Front Axle, Type	A	12	
Manufacturer	A	16	
Rear Axle, Type	A	12	
Differential Lubricant Capacity	N	2	PINTS
Manufacturer	A	16	
Steering Gear Transfer Box, Type	A	12	
Manufacturer	A	16	
Power Steering Gear, Type	A	12	
Manufacturer	A	16	
Wheels, Type	A	8	
Manufacturer	A	16	
Tires, Type	A	8	
Manufacturer	A	16	
Transmission : Type	A	12	
: Manufacturer	A	16	
: Driveshaft Type	A	12	
: Manufacturer	A	16	

Figure A-6 Reference data transit vehicle configuration information.

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Fuel Supply : Tank, Capacity	N	3	GALLONS
: Fuel Filter, Primary, Type	A	12	
: , Manufacturer	A	16	
: , Secondary, Type	A	12	
: , Manufacturer	A	16	

Figure A-6 Reference data transit vehicle configuration information (concluded).

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	
Fleet ID	A/N	4	
Part Nomenclature	A/N	40	
Manufacturer	A	16	
Manufacturer's Part Number	A/N	24	
Property Number : Part	A/N	16	
: Stock	A/N	16	
: MIS Code	A/N	16	
Quantity in Service	N	6	PARTS
Failure Rate : Nom. Spec.	N	6	MMBF
: Last Reported	N	6	MMBF
Next Higher Assy. P/N	A/N	24	
Cost Per Part: OEM	N	5	$
: Latest	N	5	$
Physical Characteristics: L x W x H	N	12	IN
: Weight	N	5	LB
Performance: Capacity/Rating, Nominal & Units	A/N	10	
: Capacity/Rating, Overload & Units	A/N	10	
Number in Service	N	6	PARTS

Figure A-7 Reference data hardware specification information.

APPENDIX B

DYNAMIC DATA FORMATS

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	-
Fleet ID	A/N	4	-
Bus Number	N	5	
Date, Reporting	N	6	MO/DY/YR
Period Reported: From (Date)	N	6	MO/DY/YR
: To (Date)	N	6	MO/DY/YR
Mileage: Period	N	6	MI
: Cumulative	N	7	MI
Operating Hours[1] : Period	N	4	HR'S
: Cumulative	N	5	HR'S

[1]If Mileage not Required.

Figure B-1 Dynamic data transit vehicle utilization.

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	-
Fleet ID	A/N	4	-
Bus Number	N	5	
Date, Reporting	N	6	MO/DY/YR
Period Reported: From	N	6	MO/DY/YR
: To	N	6	MO/DY/YR
Fuel Consumed	N	6	GALLONS
Vendor	A	5	-
Oil Consumed	N	4	QTS
Vendor	A	5	-
Coolant Consumed	N	4	GALLONS
Vendor	A	5	-
Tires	N	2	TIRES
Vendor	A	5	-

Figure B-2 Dynamic data transit vehicle consumption information.

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	-
Fleet ID	A/N	4	-
Bus Number	N	5	-
Date, Report	N	6	MO/DY/YR
Mileage, Cumulative	N	7	MI
Operating Hours, Cumulative[1]	N	6	HR'S
Report Number, Reference	A/N	8	-
Road Call/Incident: Date	N	6	MO/DY/YR
: Time	N	4	HR/MIN
When Discovered	A/N	2	(CODE)
Where Discovered	A/N	8	-
Trouble Symptom	A/N	4	(CODE)
Consequence to Vehicle or Coach	A/N	2	(CODE)
Related Report Number	A/N	8	-
Affected Hardware	A/N	8	(CODE)
Incident Narrative	A/N	120	-

[1] If Mileage not Reported.

Figure B-3 Dynamic data transit vehicle road call/incident information.

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	-
Fleet ID	A/N	4	-
Bus Number	N	5	-
Date, Report	N	6	MO/DY/YR
Mileage, Cumulative	N	7	MI
Operating Hours, Cumulative[1]	N	6	HR'S
Report Number, Reference	A/N	8	-
Inspection: Date	N	6	MO/DY/YR
: Time	N	4	HR/MIN
: Maintenance Shop	A/N	4	(CODE)
Inspection Type	A/N	4	(CODE)
"Expendable" Supplies	-	-	-
Part: Number	A/N	16	-
: Name	A/N	24	-
: Vendor	A	16	-
Location on Car	A/N	8	-
Quantity	N	2	-
Unit of Measure	A	4	-
Repairs	-	-	-
Part: Number	A/N	16	-
: Name	A/N	24	-
: Vendor	A	16	-
Location on Car	A/N	8	-
Failure/Defect Code	A/N	4	(CODE)
Maint./Repair Code	A/N	4	(CODE)
Quantity Replaced	N	2	
Elapsed Time	N	5	HR'S
Labor Hours	N	5	LBR HR'S

[1]If Mileage Not Reported.

Figure B-4 Dynamic data transit vehicle scheduled maintenance information.

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	-
Fleet ID	A/N	4	-
Bus Number	N	5	-
Date, Report	N	6	MO/DY/YR
Mileage, Cumulative	N	7	MI
Operating Hours, Cumulative[1]	N	6	HR'S
Report Number, Reference	A/N	8	-
Maintenance : Date	N	6	MO/DY/YR
: Location (Shop)	A/N	4	(CODE)
Part: Number	A/N	16	-
: Name	A/N	24	-
: Vendor	A	16	-
: Location on Car	A/N	8	-
Failure/Defect Code	A/N	4	(CODE)
Primary/Secondary Failure Code	A/N	1	(CODE)
Maint./Repair Code	A/N	4	(CODE)
Serial Number: Removed	N	16	-
: Replaced	N	2	-
Quantity Replaced	N	2	-
Replacement Part Condition (New/Used/Second)	A	1	(N/U/R)
Inspection Code	A/N	4	(CODE)
Elapsed Time	N	5	HR'S
Labor Hours	N	5	LBR HRS

[1] If Mileage not Reported.

Figure B-5 Dynamic data transit vehicle repair information.

DATA ELEMENT	DATA TYPE	FIELD LENGTH	UNITS
Transit Property ID	A	2	-
Fleet ID	A/N	4	-
Bus Number, Removed From	N	5	-
Date, Report	N	6	MO/DY/YR
Report Number, Reference	A/N	8	-
Part (Repaired): Number	A/N	16	-
: Name	A/N	24	-
: Vendor	A	16	-
: Location on Car	A/N	8	-
: Serial No.	A/N	16	-
Maintenance : Date	N	6	MO/DY/YR
: Location (Shop)	A/N	4	(CODE)
: Type (Unit/Batch)	A	1	(U/B)
Part Removal : Report No., Reference	A/N	8	-
: Failure/Defect Code			
Part Repair	-	-	-
: Failure/Defect Code	A/N	4	(CODE)
: Part : Number	A/N	16	-
: Name	A/N	24	-
: Vendor	A	16	-
: Quantity	N	2	-
: Maint./Repair Code	A/N	4	(CODE)
Elapsed Time	N	5	HR'S
Labor Hours	N	5	LBR HR'S

Figure B-6 Dynamic data transit vehicle component repair.

APPENDIX C

PROPOSED REPORT FORMATS

Report Type: BMU 01
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

PROPERTY: xxxxx

BUS NUMBER	FLEET-ID (MANUF-MODEL)	CUMULATIVE MILES	MILES THIS PERIOD	MILES LAST PERIOD	MILES LAST YEAR
101	GMC-T8H203	100,000	5,000	7,000	65,000
102	GMC-T8H203	300,000	2,000	3,000	15,000
103	GMC-T8H203	50,000	1,000	900	0
ALL	GMC-T8H203	450,000	8,000	10,900	70,000
201	FLX-5310281	150,000	5,000	5,000	60,000
202	FLX-5310281	400,000	6,000	4,000	50,000
ALL	FLX-5310281	550,000	11,000	9,000	110,000
301	AMG-SG220	50,000	5,000	4,000	0
ALL	AMG-SG220	50,000	5,000	4,000	0

Figure C-1 Transit reliability information program transit bus monthly utilization.

Report Type: BMU 02
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

PROPERTY: xxxxx

FLEET ID (MANUF-MODEL)	ACTIVE BUSES	TOTAL CUM MILES	CUM MILES/BUS	MILES THIS PERIOD	MILES/BUS THIS PERIOD	MILES LAST PERIOD	MILES/BUS LAST RECORD
GMC-T8H203	100	2,500,000	25,000	210,000	2,100	300,000	3,000
AMG-SG220	20	100,000	5,000	10,000	500	8,000	400
ALL	120	2,600,000	21,667	220,000	18,33	308,000	2,567

Figure C-2 Transit reliability information program transit bus monthly utilization.

Report Type: BMU 03
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

ALL PROPERTIES

PROPERTY	FLEET-ID (MANUF-MODEL)	ACTIVE BUSES	TOTAL CUM MILES	CUM MILES/ BUS	MILES THIS PERIOD	MILES/BUS THIS PERIOD	MILES LAST PERIOD	MILES/BUS LAST PERIOD
00001	GMC-T8H203	100	2,500,000	25,000	210,000	2,100	300,000	3,000
00002	GMC-T8H203	75	1,200,000	16,000	100,000	1,333	100,000	1,333
00003	FLX-5310281	150	3,000,000	20,000	250,000	1,666	300,000	2,000
ALL		325	4,700,000	14,462	560,000	1,723	700,000	2,154

Figure C-3 Transit reliability information program transit bus monthly utilization.

Report Type: BMC 01
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

PROPERTY: xxxxx

BUS NUMBER	FLEET-ID (MANUF-MODEL)	MILES THIS PERIOD	TOTAL FUEL (GAL)	MILES/ GAL	MPG LAST PERIOD	TOTAL OIL (QT)	MILES/ QUART	MPQ LAST PERIOD	TOTAL COOLANT	MILES/ QUART	MPQ LAST PERIOD	TIRES REPLACED
101	GMC-78H203	16,000	4,100	3.66	3.60	30	500	480	7.6	2,000	1,600	1
102	GMC-T8H203	20,000	5,000	4.00	4.50	33	600	610	5.0	4,000	4,060	0
ALL	GMC-78H203	36,000	9,100	3.86	4.00	63	556	545	12.6	2,800	2,776	1
203	AMG SG220	30,000	10,000	3.00	3.00	63	476	476	6.0	5,000	5,000	3
ALL	AMG SG220	30,000	10,000	3.00	3.00	63	476	476	6.0	5,000	5,000	3

Figure C-4 Transit reliability information program transit bus monthly consumption.

Report Type: BMC 02
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

PROPERTY: xxxxx

FLEET-ID (MANUF-MODEL)	ACTIVE BUSES	MILES THIS PERIOD	TOTAL FUEL (GAL)	MILES/ GAL	MPG LAST PERIOD	TOTAL OIL (QT)	MILES/ QT	MPQ LAST PERIOD	TOTAL COOLANT	MILES/ QT	MPQ LAST PERIOD	TIRES REPLACED
GMC-78H203	100	1,760,000	456,000	3.85	4.00	3,150	556	546	625	2,800	2,775	50
AMG-SG220	30	900,000	300,000	3.00	3.00	1,890	475	475	180	5,000	5,000	45
ALL	130	2,650,000	755,000	3.51	3.77	5,040	528	529	805	3,292	3,288	95

Figure C-5 Transit reliability information program transit bus monthly consumption.

Report Type: BMC 03
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

ALL PROPERTIES

PROPERTY	FLEET ID (MANUF-MODEL)	ACTIVE BUSES	MILES THIS PERIOD	TOTAL FUEL (GAL)	MILES/ GAL	TOTAL OIL (QT)	MILES/ QT	TOTAL COOLANT	MILES/ QT	TIRES REPLACED
0001	GMC-78H203	100	1,750,000	455,000	3.85	3,150	556	625	2,800	50
0002	FLX-5310281	50	1,000,000	250,000	4.00	1,667	600	625	1,600	30
ALL		150	2,750,000	705,000	3.90	4,817	571	1,250	2,200	80

Figure C-6 Transit reliability information program transit bus monthly consumption.

Report Type: BMIR 01
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

PROPERTY: xxxxx

BUS NUMBER	FLEET-ID (MANUF-MODEL)	MILES THIS PERIOD	TOTAL INSPECTIONS	INSPECTION TYPES/SYSTEMS	MILES/ INSP	TOTAL ROAD CALLS	SYSTEM INVOLVED	MILES/ROAD CALL	NO. OUT-OF-SERVICE ROAD CALLS
101	GMC-T8H203	15,000	5	A—Brakes B—Safety	3,000	0			
102	GMC-T8H203	10,000	2	C—24K F—Torque Converter	5,000	1	Xmission	10,000	1
All	GMC T8H203	25,000	7		3,571	1		25,000	1

Figure C-7 Transit reliability information program transit bus monthly inspections and road calls.

Report Type: BMIR 02
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

PROPERTY: xxxxx

FLEET–ID (MANUF-MODEL	ACTIVE BUSES	TOTAL MILES	TOTAL INSPECTIONS	MILES/ INSP	TOTAL ROAD CALLS	MILES/ ROAD CALL	NO. OUT-OF-SERVICE ROAD CALLS
GMC-T8H203	100	1,250,000	350	3,571	50	25,000	30
FLX-6310281	50	1,000,000	250	4,000	200	5,000	150
All	150	2,250,000	600	3,750	250	9,000	180

Figure C-8 Transit reliability information program transit bus monthly inspections and road calls.

Report Type: BMIR 03
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

ALL PROPERTIES

PROPERTY	FLEET-ID (MANUF-MODEL)	ACTIVE BUSES	MILES THIS PERIOD	TOTAL INSPECTIONS	MILES/ INSP	TOTAL ROAD CALLS	MILES/ ROAD CALL	NO. OUT-OF SERVICE ROAD CALLS
0001	GMC-T8H203	200	583,333	118	4,944	195	2,991	70
0002	AMG-SG220	100	350,000	100	3,500	50	7,000	10
All		300	933,333	218	4,281	245	3,810	80

Figure C-9 Transit reliability information program transit bus monthly inspections and road calls.

Report Type: BMIR 04
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

SYSTEM: ENGINE

PROPERTY	FLEET ID (MANUF MODEL)	ACTIVE BUSES	MILES THIS PERIOD	TOTAL INSPECTIONS	INSPECTION TYPE	MILES/BUS/ INSP	TOTAL ROAD CALLS
0001	GMC T8H203	160	438,000	100	A-60 B-25 C-25	4,380	106
0002	GMC-T8H203	100	350,000	75	A-25 B-10 C-15 D-25	4,667	75
All		260	788,000	175	A-75 B-35 C-40 D-25	4,503	181

Figure C-10 Transit reliability information program transit bus monthly inspections and road calls.

Report Type: BMR 01
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

PROPERTY: xxxxx

BUS NUMBER	FLEET-ID (MANUF-MODEL)	MILES THIS PERIOD	TOTAL REPAIRS	NO. PM REPAIRS	SYSTEMS REPAIRED	MILES/NON PM REPAIR	TOTAL REPLACEMENTS	MILES/ REPLACEMENT
101	FLX-6310281	2,100	4	1	1–Body 3–Engine	700	2	1,050
102	FLX-6310281	3,000	2	2	2–A/C	–	4	750
103	FLX-6310281	2,500	4	0	2–Brakes 2–Body	625	3	833
All	FLX-6310281	7,600	10	3	3–Body 2–Brakes 2–A/C 3–Engine	1,086	9	844
201	AMG-SG220	4,000	4	2	1–Brakes 2–Engine 1–A/C	2,000	5	800
All	AMG-SG220	4,000	4	2	1–Brakes 2–Engine 1–A/C	2,000	5	800

Figure C-11 Transit reliability information program transit bus monthly repair information.

Report Type: BMR 02
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

PROPERTY: xxxxx

FLEET—ID (MANUF MODEL)	ACTIVE BUSES	MILES THIS PERIOD	TOTAL REPAIRS	NO. PM REPAIRS	MILES/NON-PM REPAIR	TOTAL REPLACEMENTS	MILES/REPL
FLX-6310281	50	160,000	170	51	1,281	163	980
GMC-T8H203	100	200,000	200	50	1,333	100	2,000
AMG-SG220	25	100,000	76	30	2,222	40	2,500
All	175	450,000	446	131	1,433	293	1,536

Figure C-12 Transit reliability information program transit bus monthly repair information.

Report Type: BMR 03
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page NO: 01

ALL PROPERTIES

PROPERTY	FLEET-ID (MANUF-MODEL)	ACTIVE BUSES	MILES THIS PERIOD	TOTAL REPAIRS	NO. PM REPAIRS	MILES/NON-PM REPAIR	TOTAL REPLACEMENTS	MILES/ REPLACEMENT
0001	GMC-T8H203	100	300,000	150	75	4,000	100	3,000
0003	All	176	460,000	445	131	1,433	293	1,536
All		276	760,000	595	206	1,928	393	1,908

Figure C-13 Transit reliability information program transit bus monthly repair information.

Report Type: BMR 04
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
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SYSTEM. DOORS AND DOOR CONTROLS

PROPERTY	FLEET ID (MANUF MODEL)	ACTIVE BUSES	MILES THIS PERIOD	TOTAL REPAIRS	NO. PM REPAIRS	TOTAL REPLACEMENTS
0001	GMC-T8H203	100	300,000	20	10	10
0002	GMC-T8H203	150	500,000	50	10	5
0003	GMC-T8H203	25	60,000	10	2	5
All	GMC-T8H203	275	860,000	80	22	20

Figure C-14 Transit reliability information program transit bus monthly repair information.

Report Type: BQRM 01
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

PROPERTY: xxxxx

BUS NUMBER	FLEET-ID (MANUF MODEL)	MILES THIS PERIOD	NO. MAINT. ACTS	MEAN MILES BETWEEN M. A.IRES	NO. MAINT ACTS/ YEAR	MMBMA OVER BUS LIFE
101	AMG SG220	2,000	2	1,000	5	5,000
102	AMG SG220	3,000	1	3,000	8	4,500
All	AMG-SG220	5,000	3	1,667	13	4,682

Figure C-15 Transit reliability information program transit bus quarterly maintenance actions.

Report Type: BORM 04
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

SYSTEM: BRAKES

PROPERTY	FLEET ID (MANUF MODEL)	ACTIVE BUSES	MILES THIS PERIOD	NO. OF MAINT. ACTS	MMBMA	NO. M. A./BES/ YEAR	M. A./BES/ MILE	TOTAL REPAIR TIME	MEAN TIME TO REPAIR
0001	AMG SG220	50	100,000	5	20,000	20	0.000017	800	40
0002	AMG SG220	25	100,000	7	14,286	24	0.000020	1200	60
All	AMG SG220	75	200,000	12	16,667	44	0.000018	2000	45

Figure C-16 Transit reliability information program transit bus quarterly maintenance actions.

Report Type: RR 01
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
Page No: 01

PROPERTY ID	TOTAL ROUTE MILES	TOTAL FLEET	AVG SPEED (MPH)	AVG HEADWAY (MIN)	AVG STOP SPACING (FT)	AVG TRIP TIME	AVG PAX/ HOUR	MAXIMUM GRADE (°)
001	50	25	20	10	25	15	75	10
002	200	100	25	10	1000	30	100	10
003	100	50	20	25	1500	25	30	5
All	350	175	22	15	842	23	68	8

Figure C-17 Transit reliability information program transit bus transit property reference information.

Report Type: RR 02
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
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FLEET ID (MANUF MODEL)	ACTIVE BUSES	YEAR IN SERVICE	DIMENSIONS LENGTH	HEIGHT	WIDTH	WHEELBASE	MAX SPEED (MPH)	NOM. ACCEL (MPHPS)	NOM DECEL (MPHPS)	WEIGHT EMPTY	FULL
FLX 5310281	140	1974	40'-0	8'-0	9'-0	286"	60	3.0	6.0	20,600	26,600
GMC-T8H203	100	1976	40'-½"	8'-½"	9'-0	284½"	60	3.0	6.0	23,000	29,000

Figure C-18 Transit reliability information program transit bus fleet reference information.

Report Type: RR 03
Reporting Period:
From: MM/DD/YY
To: MM/DD/YY

Report No: 001
Report Date: MM/DD/YY
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PART NUMBER	PART NAME	NEXT HIGHER ASSY.	SYSTEM	TOTAL QTY
	Battery Assy.	Low Voltage Power Storage	Electrical	3

FLEET ID (MANUF-MODEL)	TOTAL QTY IN SERVICE	VENDOR CODE	MFGR PART NO.	DIMENSIONS			WEIGHT (LB)	RATING		LATEST ($) COST/UNIT
				LENGTH	WIDTH	HEIGHT		NOM	MAX	
GMC-T8H203	50	02	123AB66	34	16	10	20	24v	40v	150
FLX-5310281	25	05	5412AB	35	15	12	21	28v	40v	200
AMG-SG220	100	71	5513AB	40	18	12	25	30v	45v	350

Figure C-19 Transit reliability information program transit bus equipment reference information.

Report Type: SR 01

Reporting Period:

From: MM/DD/YY

To: MM/DD/YY

Report No: 001

Report Date: MM/DD/YY

Page No: 01

COMPONENT: BRAKE DRUM

VENDOR	PART NUMBER	PROPERTY	FLEET-ID	ACTIVE BUSES	MILES THIS PERIOD	NO. MAINT. ACTS	MAINT. ACTS/ MILE	MEAN MILES BETWEEN MAINT. ACTS
01	A2B3XYZ	001	GMC-78H203	50	125,000	5	.00004	25,000
02	CDEF3520	005	FLX-5310281	20	60,000	10	.00017	6,000

Figure C-20 Transit reliability information program transit bus special report vendor maintenance actions.

Report Type: SR 02

Reporting Period:

From: MM/DD/YY

To: MM/DD/YY

Report No: 001

Report Date: MM/DD/YY

Page No: 01

VENDOR: xxxxx

COMPONENT	PART NO.	PROPERTY	FLEET-ID	ACTIVE BUSES	MILES THIS PERIOD	NO. MAINT ACT	MEAN MILES BETWEEN MAINT ACT
Brake Lining	AG5370X	002	GMC-T8H203	25	75,000	3	25,000
Brake Shoe	AP6580Y	002	AMG-SG220	10	35,000	1	35,000

Figure C-21 Transit reliability information program transit bus special report vendor maintenance actions.

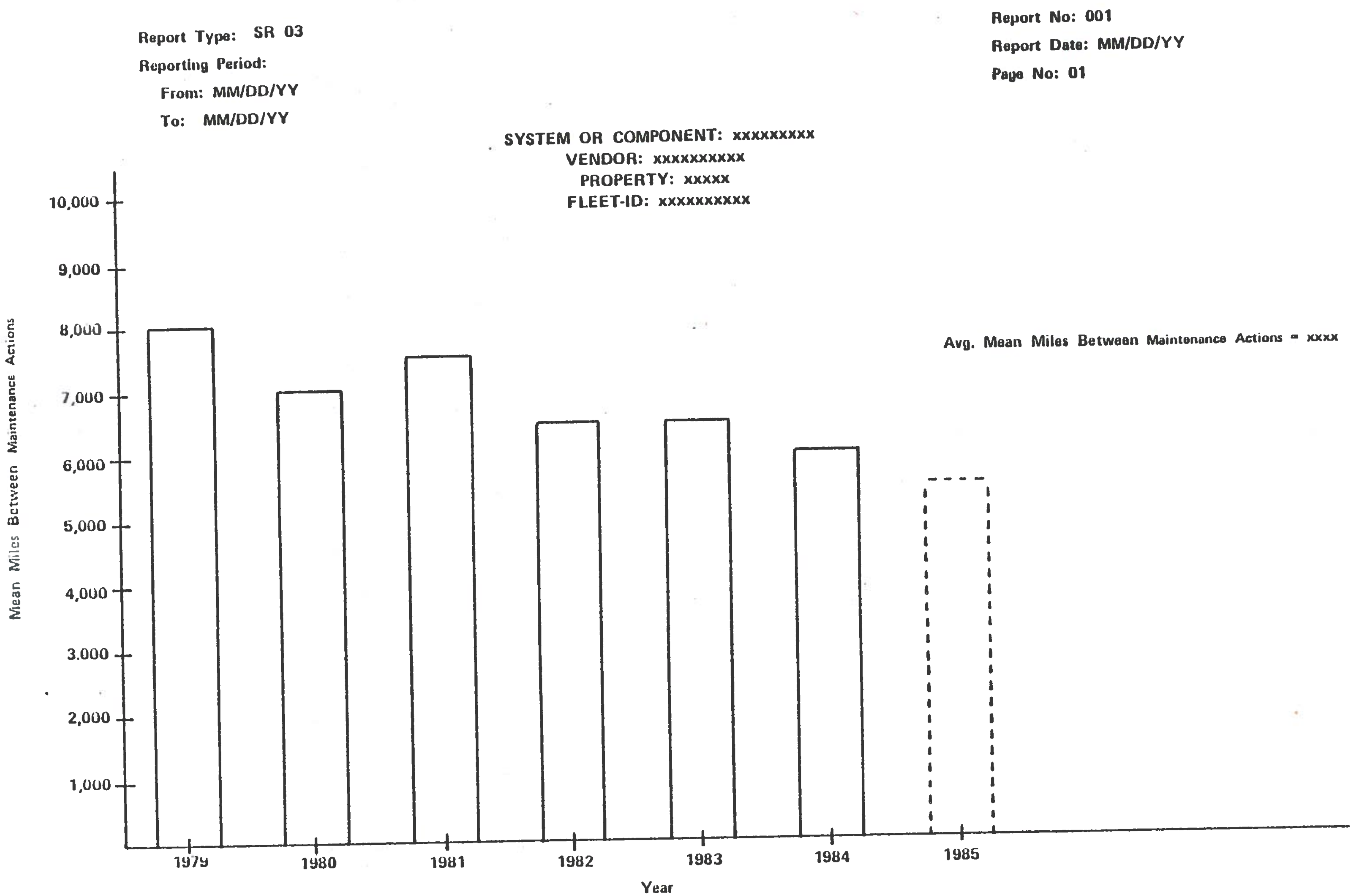

Figure C-22 Transit reliability information program transit bus special report maintenance actions trends.

Report Type: SR 04

Reporting Period:

From: MM/DD/YY

To: MM/DD/YY

Report No: 001

Report Date: MM/DD/YY

Page No: 01

PROPERTY	FLEET-ID (MANUF-MODEL)	SYSTEM MODIFY/RETROFIT	NARRATIVE-MODIFICATION/RETROFIT
001	GMC-T8H203	A/C	Moved compressor to top rear of bus and added engine thermostat to keep temperature high enough
003	FLX-5310281	Brake	Developed new brake lining composed of substance 105.

Figure C-23 Transit reliability information program transit bus equipment modification/retrofit.