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TRANSIT RELIABILITY INFORMATION PROGRAM (TRIP)

PHASE I REPORT

Stanley B. Limpert
Carol L. Schweiger
Phillip J. Silvia

DYNAMICS RESEARCH CORPORATION
SYSTEMS DIVISION
60 Concord Street
Wilmington MA 01887

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16. Abstract

The Transit Reliability Information Program (TRIP) is a government initiated program to assist the transit industry in satisfying its need for transit reliability information. TRIP provides this assistance through the operation of a national reliability Data Bank. This Data Bank collects, stores, and analyzes data that is generated by transit operators during the course of revenue service operation and equipment maintenance. The results of the periodic analyses of the stored data are distributed to TRIP participants and users.

This document is a summary of the accomplishments of TRIP Phase I, along with the results achieved and conclusions reached during the initial phase of TRIP. It summarizes the design development and subsequent operation of the Experimental Data Bank (EDB), that was implemented for the purpose of evaluating and refining the design concepts of the (full-scale) TRIP Data Bank. TRIP has been designed as a 3-phase program. Phase I consists of: 1) definition and scoping of the functional and operational requirements of the TRIP Data Bank; 2) design, implementation, operation, and enhancement of a rail rapid vehicle EDB for the purpose of evaluating the design concepts of the (full-scale) TRIP Data Bank on a prototype scale; and 3) design, implementation, operation, and enhancement of an EDB for buses. Phase II will merge the two EDBs into a single data bank and expand the scope of the data bank to include all aspects of the vehicles involved. Phase III will expand the TRIP Data Bank to include other classes of equipment.

17. Key Words		18. Distribution Statement
TRIP Data Bank	EDB	**Available to the public through the National Technical Information Service Springfield, Virginia 22161**
Generic Mapping	Vehicles	
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National Reliability Data Bank	Buses	
Equipment Maintenance	Rapid Rail	

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PREFACE

The Transit Reliability Information Program (TRIP) is a government-initiated program to assist the transit industry in satisfying its need for transit reliability information. TRIP provides this assistance through the operation of a national reliability Data Bank. This Data Bank collects, stores, and analyzes data which is being generated by transit operators in the course of revenue service operation and equipment maintenance. The results of periodic analyses of the stored data are distributed to TRIP participants and users.

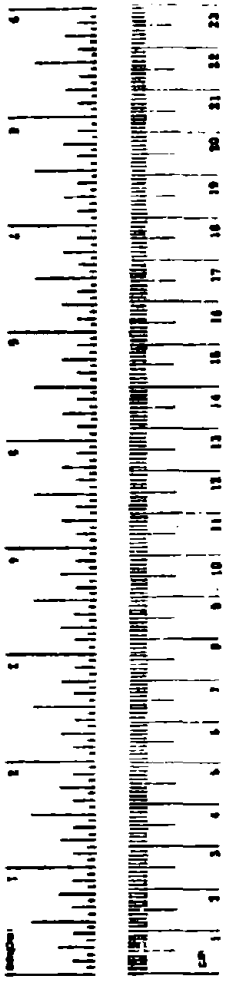
TRIP has been designed as a three-phased program. Phase I consists of defining the functional and operational requirements of the TRIP Data Bank, and designing, implementing, and operating an Experimental Data Bank for the purpose of evaluating the design concepts of the (full-scale) Data Bank on a prototype scale. Phase II consists of merging the two EDBs into a single data bank and expanding the scope of the data bank to include all aspects of vehicles involved. Phase III will be the expansion of the TRIP Data Bank to include other classes of equipment.

This report contains a summary of the results achieved and conclusions reached during initial phase of the Transit Reliability Information Program. This "Phase I Report" has been prepared by the Dynamics Research Corporation (DRC), Wilmington, Massachusetts, under Contract Number DOT-TSC-1559, issued by the U.S. Department of Transportation (DOT), Transportation Systems Center (TSC), on behalf of the Office of Safety and Product Qualification of the Urban Mass Transportation Administration (UMTA), Office of Technology Development and Deployment, U.S. DOT.

The authors would like to acknowledge with gratitude the assistance provided by Roberta Gosselin in the preparation and production of this report.

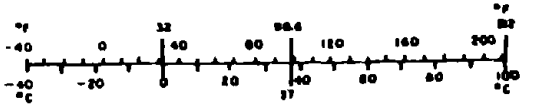
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.96	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. EXECUTIVE SUMMARY

This report contains a summary of the results achieved and conclusions reached during the initial phase of the Transit Reliability Information Program (TRIP). This "Phase I Report" has been prepared by the Dynamics Research Corporation (DRC), Wilmington, Massachusetts, under Contract Number DOT-TSC-1559, issued by the U.S. Department of Transportation (DOT), Transportation Systems Center (TSC), on behalf of the Office of Safety and Product Qualification of the Urban Mass Transportation Administration (UMTA), Office of Technology Development and Deployment, U.S. DOT.

TRIP is a government-initiated program to assist the transit industry in satisfying its need for transit reliability information. TRIP provides this assistance through the operation of a national reliability Data Bank. This Data Bank collects, stores, and analyzes data which is being generated by transit operators in the course of revenue service operation and equipment maintenance. The results of periodic analyses of the stored data are distributed to TRIP participants and users.

TRIP has been designed as a three-phased program. Phase I consists of:

- Definition and scoping of the functional and operational requirements of the TRIP Data Bank;
- Design, implementation, operation, and enhancement of a Rail Rapid Vehicle (RRV) Experimental Data Bank (EDB) for the purpose of evaluating the design concepts of the (full-scale) TRIP Data Bank on a prototype scale;
- Design, implementation, operation, and enhancement of an EDB for Buses.

Phase II consists of merging the two EDBs into a single data bank and expanding the scope of the data bank to include all aspects of the vehicles involved. Phase III will be the expansion of the TRIP Data Bank to include other classes of equipment.

TRIP is currently in Phase I. The purpose of this report is to present a summary of the accomplishments and recommendations resulting from the design, development, and implementation of the RRV EDB under Contract Number DOT-TSC-1559. Prior to the TRIP Critical Design Review (CDR) on March 31, 1980, "Phase I" of Contract Number DOT-TSC-1559 and "Phase I" of the TSC TRIP Implementation Plan were concurrent events. The net effect of the CDR was to extend the duration of Phase I of the Implementation Plan, postponing the commencement of Phase II by

15 - 21 months.

The original purpose of Phase II of the contract was to provide transition support for the lead-in to Phase II of the TSC TRIP Implementation Plan. Because of the CDR outcome, however, the objective of Phase II of the contract was redirected from a posture of maintaining EBD operation until the full-scale Data Bank was established, to maintaining EDB operation until a "continuation contract" could be issued to continue EDB operation, refinement, and expansion as recommended by the CDR Committee. Even though Phase I of the contract "expired" in September 1980, the work of Phase I has continued to the present. Therefore, the period covered by this report is from September 1978, when the contract was awarded, through March 1981. The activities conducted during the remainder of Contract Number DOT-TSC-1559 will be summarized in the "Final Technical Report" to be produced at the conclusion of the contract.

1.1 CONCLUSIONS AND RECOMMENDATIONS

The following is a summary of the conclusions and recommendations presented in the main body of this Phase I Report:

- The national Data Bank concept has been proven to be both possible and practical through the operation of the TRIP Experimantal Data Bank (EDB).

- The active participation and interest in TRIP by the APTA TRIP Liaison Board membership during Phase I on the program indicate that TRIP has been demonstrated as a viable central source of transit reliability information which:

  - is flexible and responsive in meeting the needs of its users;
  - provides maximum information at minimum cost to the user.

- Expansion and operation of the full-scale Data Bank requires:

  - knowledgeable personnel;
  - dedicated resources;
  - a systematic expansion approach;
  - orderly operation.

Specific conclusions of Phase I, based upon the comments of the Critical Design Review (CDR) Committee expressed during the first CDR of TRIP, are as follows:

- The full benefit of TRIP has yet to be realized -- the major benefits will be derived from long-term operation of the Data Bank;

- Dynamics Research Corporation (DRC) should continue to operate the TRIP Experimental Data Bank for an additional year in order to allow more time to:

  - explore the full potential of the system;
  - develop output reports;
  - refine system operation;
  - develop more confidence in the system;

- A second CDR should take place one year hence to again consider the timing of EDB expansion into a full-scale system.

These conclusions form the basis of recommendations for the implementation, expansion, and operation of the full-scale Data Bank. Generally, recommendations can be made in the areas of alternative approaches to TRIP operation, maintenance, and expansion (O,M&E), expansion of the Data Bank from its experimental to full-scale configuration, and long-term operation of the Data Bank. Specifically, these recommendations can be summarized as follows:

- Recommendations for Data Bank expansion:

  - Systematic approach to expansion:

    - o Completion of EDB Generic Parts Lists;
    - o Other vehicle types at EDB properties;
    - o Vehicle types at other transit properties;
    - o Other classes of equipment;

  - Maintain consistency during expansion:

    - o Generic Parts List development;
    - o Data handling procedures;
    - o Data Bank operation;

  - Technical support for expansion:

    - o Increased labor force;
    - o Training/familiarization;

- Recommendations for Data Base operation:

  - Knowledgeable personnel:

    - o Data quality preservation;
    - o Accuracy and validity of output reports;
    - o Transit property interface;

- Dedicated resources (personnel and automated data processing equipment):

  - o Timeliness of output reports;
  - o Input data volume;

- Engineering support:

  - o Responding to "special requests";
  - o Resolving data anomalies.

1.2 INTRODUCTION AND SUMMARY

This document is a summary of the accomplishments of TRIP Phase I along with the results achieved and conclusions reached during Phase I of Contract Number DOT-TSC-1559. Phase I consisted of two major activities covering the planning, designing, and testing of a small-scale (experimental) data bank. The first activity was to define and document TRIP functional and operational requirements necessary to satisfy program requirements. The second activity was to develop, establish, and operate an Experimental Data Bank (EDB), as a prototype of the full-scale TRIP Data Bank, for the purpose of evaluating the proposed methodology.

An overview of the Transit Reliability Information Program (TRIP) is presented in Section 2. This background material covers the goals of the program, a description of the three phases of the program, and the historical development of Phase I of the program. Also, a list of documents produced under this contract is presented for reference purposes.

Section 3 presents an evaluation of Phase I activities. This evaluation is based, first, on an assessment of TRIP concepts set forth at the beginning of the program. Second, the evaluation addresses an assessment of the experience gained through and conclusions of the Experimental Data Bank operation. Third, projections of the full-scale TRIP Data Bank are presented based upon the EDB experience. Fourth, a summary of the results and conclusions of the first Critical Design Review (CDR) Committee is presented.

Section 4 provides a summary of characteristics and requirements which must be considered in the design, implementation, and operation of a full-scale TRIP Data Bank. This summary is based upon the experience gained through the design, implementation, and operation of the TRIP EDB for Rail Rapid Vehicles (RRV), and on the feedback received from representatives of the operating transit properties who have actively participated in the program.

Recommendations for the implementation, expansion, and operation of the full-scale TRIP Data Bank are presented in Section 5. Alternative approaches to the implementation of the full-scale Data Bank are discussed in this section, as well as considerations for the expansion of the Data Bank from its experimantal to full-scale configuration and subsequent long-term operation.

A summary of the results and conclusions reached during each of the twelve tasks of Contract Number DOT-TSC-1559 is presented in Section 6. Each task is discussed in terms of its activities, the approach used to perform the task, and the results and conclusions reached.

2. BACKGROUND

This section presents an overview of the Transit Reliability Information Program (TRIP). This background material covers the goals of the program, a description of the three phases of the program, and the historical development of Phase I of the program. A list of documents produced under the Phase I support contract (DOT-TSC-1559) is also provided.

2.1 OVERVIEW

The Transit Reliability Information Program (TRIP) is a government initiated response to an acknowledged need to collect and analyze rail transit equipment reliability data on a national level. The goals of TRIP are to:

- Amalgamate current reliability efforts within the transit industry, and provide a focal point for a consolidated reliability effort;
- Promote uniform reliability related definitions for the transit industry;
- Provide a central repository for voluntary submittal of transit industry field failure data;
- Provide uniform processing and analysis of reliability data;
- Provide means for periodic distribution of reliability data to potential users;
- Provide data for factual comparison of reliability between related equipments;
- Provide substantive data for specifying new equipment procurements, and justifying product improvement projects and supporting system analysis programs.

TRIP has been designed as a three-phased program. Phase I consists of:

- Definition and scoping of the functional and operational requirements of the TRIP Data Bank;
- Design, implementation, operation, and enhancement of a Rail Rapid Vehicle (RRV) Experimental Data Bank (EDB) for the purpose of evaluating the design concepts of the

(full-scale) TRIP Data Bank on a prototype scale;

- Design, implementation, operation, and enhancement of an EDB for Buses.

Phase II consists of merging the two EDBs into a single data bank and expanding the scope of the data bank to include all aspects of vehicles involved. Phase III will be the expansion of the TRIP Data Bank to include other classes of transit equipment.

TRIP is currently in Phase I. The initial TRIP support contract was issued to the Dynamics Research Corporation in September, 1978, by the U.S. Department of Transportation (DOT), Transportation Systems Center (TSC) for the purpose of planning and establishing a program to collect and evaluate reliability information on new and existing transit vehicles. This contract focused on TRIP for Rail Rapid Vehicles (RRV-TRIP) and included the definition and scoping of the full-scale TRIP Data Bank.

The American Public Transit Association (APTA), under separate contract to TSC, established the TRIP Liaison Board consisting of representatives from U.S. rail transit authorities and transit equipment manufacturers. The Liaison Board has provided continuous guidance for the development of TRIP and the EDB through a series of periodic meetings. From the Liaison Board membership, six transit authorities volunteered at the contract "kick-off meeting" to participate in the development of TRIP by supplying data to the EDB. The six properties are:

BART - Bay Area Rapid Transit District;
CTA - Chicago Transit Authority;
GCRTA - Greater Cleveland Regional Transit Authority;
NYCTA - New York City Transit Authority;
PATCO - Port Authority Transit Corporation;
WMATA - Washington Metropolitan Area Transit Authority.

2.2 PROGRAM CHRONOLOGY

The development of the TRIP Data Bank began with an investigation of existing reliability data banks and an analysis of the data collection and reporting approaches being used in the transit industry. Particular emphasis was placed upon the six EDB properties. The results of these investigations were used to formulate a functional definition of the TRIP Data Bank. Each of the required TRIP Data Bank functions was further defined into modular "elements" which were then translated into preliminary design requirements and specifications.

Part of the TRIP Data Bank design included the development of a uniform system of transit vehicle component identification. This parallel activity resulted in the formulation of the "Generic Part Number" (GPN), a code by which equipment of similar function is classified and grouped according to that function. The purpose of the GPN is to provide a common numbering system to which the individual part numbering systems used at the various transit properties can be cross-referenced. The GPN is the major "key" by which component data is stored in the TRIP Data Bank and, because of its orientation toward equipment function, provides a means for efficient data retrieval in support of analytical comparison of functionally similar equipment. Procedures were subsequently developed for preparing the "Generic Parts List" (GPL), the cross-reference table of transit property part numbers versus Generic Part Numbers.

The design and implementation of the Experimental Data Bank began early in 1979. The purpose of the EDB was to provide a model or prototype of the TRIP Data Bank so that the various aspects of the emerging Data Bank design could be tested and refined prior to full-scale implementation. The TRIP Liaison Board recommended three rail vehicle subsystems (doors and door controls, propulsion, and friction brakes) for use as "pilot equipment" in the EDB.

Following the successful completion of the Software Acceptance Test, the TRIP Experimental Data Bank began operation on August 6, 1979, with the input of July data from BART and WMATA. EDB refinement and expansion have been on-going activities since the initiation of operation. Expansion of the "input side" of the EDB continued with the inclusion of CTA and PATCO in November, 1979, and NYCTA in February, 1980. (GCRTA will be brought on-line during in 1981). The EDB currently contains data going back to August 1, 1979, for CTA and PATCO, and July 1, 1979, for BART, NYCTA, and WMATA.

The first EDB Output Report was published in September 1979, and contained the July data for BART and WMATA. The TRIP Liaison Board reviewed the report and recommended several modifications to format and content. EDB Output Reports were subsequently published in November, 1979 (August and September data), March, 1980 (November 1979 data), and July, 1980 (March data).

It is on the "output side" of the EDB where emphasis on the word "experimental" has occurred. Each of these EDB Output Reports has been a major revision of the previous report in terms of both format and content. Methods of presenting the data, level of detail, accuracy and validity, statistical significance . . . . All of these, and more, are of concern to the Liaison Board members, and their concern is reflected in the high level of interest being expressed in the presentation of information from the EDB.

A Critical Design Review (CDR) of TRIP was held in April 1980. The CDR Committee, consisting of the TRIP Liaison Board representatives from the six participating properties and representatives from APTA, UMTA, and TSC, reviewed the preceding 24 months of TRIP activity; assessed TRIP benefits; listened to each participant's position on TRIP; and concluded that TRIP should be continued. It was further concluded that TRIP cannot be properly evaluated without 12 to 18 months of additional EDB experience.

The CDR recommendation impacted Phase I of the TSC TRIP Implementation Plan as follows:

- The operation and refinement of the RRV-EDB by DRC with three major assemblies from 6 series of vehicles will be continued for an additional 21 months (15-month EDB operation and refinement with an additional 6-month EDB operation and merge transition period).

- The establishment and operation by TSC of an EDB for buses will begin during Phase I by monitoring a sample of assemblies from a limited number of buses. Participation and interest in, as well as potential benefits from Phase I indicate that TRIP EDB users (operating properties, consultants, Federal Government, and suppliers) want factual information from TRIP and are relying on TRIP's large quantity of readily available maintenance data to provide timely reports of equipment replacement experience.

Pending a favorable decision from the final Phase I CDR, Phase II will start a full-scale merged RRV and Bus TRIP Data Bank. It will be established and put on line starting with the transfer of data from the RRV and Bus EDB's. The number of equipments initially monitored will be small, but as the capability expands, additional equipments will be monitored until failure data on all vehicle components are contained in the data bank.

A CDR of Phase II can then be performed to determine if Phase II accomplished its goals and if Phase III is justified. Phase III is envisioned as the expansion of the Data Bank and GPL's to cover UMTA responsibilities in Fare Collection, ATO/ATC, and track and structures. As other transportation equipments are incorporated, the TRIP Data Bank will become the UMTA National TRIP.

2.3 REFERENCES

The following reports, issued by the Dynamics Research Corporation (DRC), collectively describe the development of the TRIP Experimental Data Bank. Except for references (6) and (7), below, these are "draft" reports which document the progressive development of the EDB. In some cases, the specific information contained in these reports has become obsolete. For the most part, however, the concepts remained valid as the EDB evolved and have been incorporated into one or more of the "final" reports, references (11) through (14), below.

(1) Report No. E-4852U - TRIP Task 1 Draft Report (Data Bank/Source Investigation), December 18, 1978.

(2) Report No. E-4894U - TRIP Task 2 Draft Report "TRIP Data Bank Scope and Definition", January 18, 1979.

(3) Report No. E-4895U - TRIP Task 3 Draft Report "Transit Vehicle Equipment Lists", January 18, 1979.

(4) Report No. E-4896U - TRIP Task 3 Draft Report "Reliability Equipment List Operating Procedures", January 18, 1979.

(5) Report No. E-4998U - TRIP Task 4 Interim Report "Rapid Rail Transit Vehicles Guidelines for the Operation and Use of the TRIP Data Bank", April 16, 1979.

(6) Report No. R-284U - "TRIP Experimental Data Bank Acceptance Test Plan-Final", July 9, 1979.

(7) Report No. R-285U - "TRIP Experimental Data Bank Acceptance Test Procedures-Final", July 9, 1979.

(8) Report No. E-5234U - "TRIP Experimental Data Bank Program Maintenance Manual - Preliminary", October 19, 1979.

(9) Report NO. E-5235U - "TRIP Experimental Data Bank User's Manual - Draft", October 19, 1979.

(10) Report No. E-5361U - "TRIP Generic Maintenance Action Codes", February 5, 1980.

The following reports, also issued by DRC, are companion documents to the "TRIP Phase I Final Report". Collectively, these reports document the configuration, operation, use, applications, and development of the TRIP experimental Data Bank.

(11) Report No. R-337U - "TRIP Experimental Data Bank Program Maintenance Manual", September 1980.

(12) Report No. R-338U - "TRIP Experimental Data Bank Operating Procedures Manual", March 1981.

(13) Report No. R-339U - "TRIP Participants Guidelines" September 1980.

(14) Report No. R-340U - "TRIP Reliability Demonstration Plan for Rapid Rail Vehicles", March 1981.

3. PHASE I EVALUATION

The purpose of this section is to present an evaluation of the results obtained and conclusions reached during Phase I of Contract Number DOT-TSC-1559. Phase I consisted of two major activities, covering the planning, designing, and testing of a small (experimental) data bank:

- Define and document TRIP functional and operational requirements necessary to satisfy the TRIP Program requirements;

- Develop, establish, and operate an Experimental Data Bank (EDB) as a prototype of the full-scale TRIP Data Bank for the purpose of evaluating the proposed methodology.

This evaluation is based on DRC's close monitoring of the complete operation of the EDB, especially critical recognition of operational bottlenecks, contradictory procedures, unanticipated situations, and costs per unit input. This careful scrutiny has addressed the three major areas of TRIP:

- TRIP Data Bank Concept - to ensure that the design of the system is responsive to the stated objectives of TRIP;

- EDB Operation - to ensure that TRIP:

  - is a cost-effective solution to satisfying the reliability information requirements of the transit industry;

  - provides a maximum amount of information while imposing a minimum burden upon TRIP users;

- Transit Industry Feedback - to ensure that TRIP is responsive to the ultimate end-users of the Data Bank.

This evaluation of the TRIP concept and Data Bank configuration and operation should provide an accurate appraisal of the potential contribution of TRIP to improve transit equipment reliability.

3.1 TRIP CONCEPT ASSESSMENT

When the objectives of TRIP were stated at the kick-off meeting (November 8, 1978), there was a high degree of skepticism about successfully undertaking such a project. It was expressed that it was impossible to collect data from a number of independent sources, put it into a common data bank and produce commonly formatted outputs.

One and one-half years later, at the first Critical Design Review of TRIP, the skepticism turned to statements of strong support of the concept and recommendations to continue the program based on its success to date. Representatives of the the six rail properties that are participating in the operation of the TRIP Experimental Data Bank (EDB) expressed their favorable support for continuing the EDB in order to further refine the system.

Even though the long-term benefits were not apparent at that point in the program (and will not be apparent until some unknown point in the future), the participants felt that the foundation and concepts upon which TRIP is built were proven. These "proven" concepts can be stated as follows:

- Consolidate transit industry reliability efforts;
- Provide reliability information presented in a transit industry context;
- Provide maximum information output while minimizing burden on data sources;
- Provide a comprehensive data source for:
  - equipment reliability comparison;
  - new equipment procurement;
  - product improvement programs;
  - system analysis efforts.

Since that first CDR, when it became apparent that TRIP concepts have been proven through EDB operation, the emphasis has been to continually refine the system based on the participants' interface. This emphasis has covered the following areas of refinement:

- EDB Software Enhancements, including;
  - additional aids for hard-copy data entry;
  - development of new output reports;
- EDB Data Validation, including;
  - increased input and output auditing capability;
  - output data averaging over prescribed intervals;
- EDB Expansion, including;
  - one additional property;
  - one additional vehicle system.

3.2 EXPERIMENTAL DATA BANK ASSESSMENT

The Experimental Data Bank (EDB) is a scaled-down data bank which reflects the full-scale system as nearly as possible. The EDB was established in order to detect, modify, and improve imperfections in the operating guidelines before the full-scale system goes on-line. The experimental aspects of data collection, screening, processing and reporting are being conducted with the intention of upgrading procedures and periodically conducting reviews of the system (CDR's).

Significant progress was made in Phase I during which six rapid rail properties, BART, CTA, GCRTA, NYCTA, PATCO, and WMATA, were solicited and agreed to participate in the TRIP EDB. Their participation consisted of selecting one series of vehicles from their property for monitoring by the EDB and having a representative of their property on the APTA TRIP Liaison Board. Members met to review and make recommendations on the establishment of Generic Pars Lists (GPLs), the Regional TRIP familiarization meetings, EDB implementation status, use of the TRIP Data Bank, and any other ongoing TRIP activities.

The TRIP EDB, currently being operated by DRC, collects utilization, repair, and maintenance data on the door, friction brake, and propulsion systems of 1300 rapid rail vehicles at five properties; analyzes the data; and generates reports. The EDB serves as an intermediate step toward the efficient development and implementation of the full-scale TRIP Data Bank in Phase II.

Based on the first CDR (March 31, 1980), it was concluded that the EDB operation should be continued from one to two years in order to properly evaluate TRIP. This additional EDB experience will include bringing the sixth participating property (GCRTA) on-line, and adding an additional vehicle system to the three systems currently monitored by the EDB.

3.3 FULL-SCALE TRIP DATA BANK PROJECTION

Pending a favorable decision from the final Phase I CDR, Phase II will start a full-scale merged RRV and Bus TRIP Data Bank. It will be established and put on line starting with the transfer of data from the RRV and Bus EDBs. The number of equipments initially monitored will be small, but as the capability expands, additional equipment will be monitored until failure data on all vehicle components are contained in the Data Bank. A projection of the number of vehicles that will be monitored by the Data Bank is given in Table 3-1.

Based on this projection, and by collecting data on all systems of some 10,000 bus and rail vehicles, the full-scale TRIP

Table 3-1. DATA BANK PROJECTED GROWTH

VEHICLE MONITORING ASSUMPTION

Year End	No. of Vehicles		Yearly Average		Vehicle Years
	Rail	Bus	Rail	Bus	
0	1500	0	–	–	–
1	2500	1500	2000	750	2750
2	3500	3000	3000	2250	5250
3	4500	4500	4000	3750	7750
4	4500	4500	4500	4500	9000
					24,750

Data Bank could grow at an annual input rate of 1.6 million dynamic data records. Table 3-2 shows an estimate of records input and processed, based on the number of monitored vehicles shown in Table 3-1, assuming that 0.5 records/vehicle/day are generated. Considerations for handling this volume of data are discussed in Section 4.

An estimate of the personnel required to operate and maintain the full-scale TRIP Data Bank is shown in Table 3-3. The functions to be performed by each type of personnel can be described as follows:

- Manager: Oversee every aspect of the TRIP system.
- Engineer:
  - Perform data validation;
  - Perform comparative reliability assesment;
  - Perform "other" engineering analyses.
- Programmer:
  - Provide software support directed by engineering personnel and operations supervisors;
  - Provide support for special data requests.
- Data Entry: Enter data submitted to TRIP by participating properties.
- Output Generation: Generate output reports to be distributed to participating properties;
- Operations Supervisor: Oversee entire Data Bank operation, including;
  - Data Entry;
  - Output Generation;
  - Engineering Analysis;
  - Programming Support.

3.4 CRITICAL DESIGN REVIEW SUMMARY

The first Critical Design Review (CDR) was held at APTA Headquarters in Washington, DC, on March 31, 1980. The CDR committee, consisting of the TRIP Liaison Board representatives from the six participating properties and representatives from APTA, UMTA, and TSC, reviewed the preceeding 24 months of TRIP activity; assessed TRIP benefits; listened to each participant's position on TRIP; and concluded that TRIP cannot be properly evaluated without 12 to 24 months of additional EDB experience.

Table 3-2. DATA BANK SIZE

DATA PROCESSING & STORAGE ESTIMATE

(Records Expressed in Thousands)

Year	No. of Input Records		Annual No. of Records Processed	No. of Records in Active, On-Line Storage
	Rail	Bus		
1	350	150	500	1,600
2	550	400	950	1,600
3	750	700	1450	1,600
4	800	800	1600	1,600
			4500	

(100 Characters Per Record, Average)

Table 3-3. DATA BANK STAFFING ESTIMATE

Number of People by Category

Year	Manager	Eng'r	Prog'r	Data Entry	Output Generation	Operations Supervisor	Yearly Total
1	1	2	3	5	2	2	15
2	2	3	2	7	3	2	19
3	2	3	1	9	3	2	20
4	2	3	1	10	3	2	21

Generally, the results of the CDR can be summarized as follows:

- National Data Bank concept proven through EDB operation;
- TRIP has been demonstrated as:
  - Central source of transit information;
  - Flexible and responsive to meeting user needs;
  - Provides maximum information at minimum cost to user;
- Expansion and operation of full-scale Data Bank requires;
  - Knowledgeable personnel;
  - Dedicated resources;
  - Systematic expansion approach;
  - Orderly operation.

Specific comments of the CDR Committee concerning the near-term future of TRIP are highlighted below:

- The full benefit of TRIP has yet to be realized -- the major benefits will be derived from long-term operation of the Data Bank;
- Dynamics Research Corporation (DRC) should continue to operate the TRIP Experimental Data Bank for an additional year in order to allow more time to:
  - Explore the full potential of the system;
  - Develop additional output reports;
  - Refine system operation;
  - expand the prototype system;
  - Develop more confidence in the system;
- A second CDR should take place one year hence to again consider the timing of EDB expansion into a full-scale system.

The CDR recommendations impacted Phase I of the TRIP Implementation Plan as follows:

- The operation and refinement of the RRV-EDB by DRC will be continued for an additional 21 months (15-month EDB operation and refinement with an additional 6-month EDB operation and merge transition period);
- The EDB will be expanded from three vehicle systems at five properties to four vehicle systems at six properties;

- The establishment and operation by TSC of an EDB for buses will begin during Phase I by monitoring a sample of assemblies from a limited number of buses.

4. FULL-SCALE TRIP DATA BANK CONSIDERATIONS

The primary purpose of the TRIP Data Bank is to provide a system for the collection, analysis, and reporting of reliability information on transit systems and equipment on a nationwide basis. In order to serve this purpose, TRIP Data Bank development has focused on the following objectives:

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

The purpose of this section is to provide a summary of characteristics and requirements which must be considered in the design, implementation, and operation of a full-scale TRIP Data Bank. This section is based upon the experience gained through the design, implementation, and operation of the TRIP Experimental Data Bank and the continuous dialog that has been maintained between DRC and representatives of the operating transit properties who have actively participated in the program both as sources of input data for the EDB and members of the TRIP Liaison Board.

4.1 GENERAL CONSIDERATIONS

The subject of the TRIP Data Bank is transit equipment and systems. The purpose of TRIP is to collect, analyze, and report reliability information on this equipment. The TRIP Data Bank is therefore, primarily an engineering data bank and should be organized as such, with emphasis upon the equipment which it monitors.

4.1.1 Expansion Capability

Although the emphasis to date has been on rapid rail vehicles, the number and types of equipment to be monitored by TRIP will rapidly, at first, and continuously increase. The TRIP

Data Bank must, therefore, be capable of rapid, yet orderly expansion.

4.1.2 Data Types

Two basic types of data must be collected by TRIP: "dynamic data", or data which is continuously produced as the result of operating and maintaining the equipment; and "static data", or reference data which describes the attributes and operating environment of the equipment. Reliability statistics are generated from the dynamic data, whereas the static (reference) data is used to interpret the reliability statistics. Static data is entered only once and changes infrequently. Dynamic data, on the other hand, is added continuously to the data base and constitutes the bulk of the data that is stored and processed.

4.1.3 Record Formats

The two basic types of data can be subdivided into specific kinds of data. Dynamic data, for example, includes utilization data, scheduled maintenance (inspection and preventative maintenance) data, and unscheduled maintenance (repair) data. Static data includes such subcategories as operating environment data, configuration data, and specification data.

Separate data base record formats should be provided to address the specific type of data to be stored. Data storage and retrieval efficiency can be maximized if each type of record can be readily identified in the data base. The number of record formats should be limited, however, to prevent the data base from becoming an organizational maze.

4.1.4 Data Volume

By collecting data on only three (of eleven) systems on fewer than 1300 rapid rail vehicles, the EDB is growing at an average annual rate of 72,000 records (dynamic data only). By collecting data on all systems of some 10,000 bus and rail vehicles, the full-scale TRIP Data Bank could grow at an estimated annual rate of 1.6 million dynamic data records (see Section 3.3). The TRIP Data Bank, therefore, must be capable of high-volume data processing. On-line data storage should be limited to a finite calendar period, such as one year, in order to minimize storage costs.

4.1.5 Output Reporting

Routine periodic reports should be published at least quarterly. These reports should contain both high-level summaries stressing graphics to provide easy industry comparison, and detailed reports for the data sources on their own equipment. Trend analysis should be an integral part of routine reports.

The TRIP Data Bank must also have the capability to respond to requests for special analyses and reports. This capability requires engineering access to the data base. Special request reports will probably become the dominant output requirement for the TRIP Data Bank. The organization and staffing of the Data Bank should be oriented toward a demand for engineering support from the industry.

4.2 OPERATING CONSIDERATIONS

The TRIP Data Bank must be capable of accepting data from participating transit properties in its organic format. This requires that the TRIP Data Bank must be highly flexible in its ability to assimilate data.

The data input subsystem should be capable of accepting data from both computer-readable (e.g., magnetic tape) and hard-copy media. The initial stages of input processing require customized software and algorithms to address the specific attributes of the data being supplied. Standard formatting, however, should be achieved at the earliest possible point in the input software subsystem to minimize the number and size of custom software modules.

Because of the varied types and formats of data to be stored in the TRIP Data Bank, a "dictionary-driven" software system should be given preferential consideration. A data base dictionary would provide single-point definition and control for all data base update and data access functions. New record types could be easily introduced by modifying only the dictionary without the necessity of extensive software modifications.

The safety and safeguarding of data files within the TRIP Data Bank should be included as routine procedures. Software design should incorporate procedures for recovery from system or software failure. Input data modules should be protected for restart in the event of system failure. Automated back-up to tape of the TRIP Data Base should be included as a routine procedure following a data base update. Input data files used in data base update should likewise be protected to prevent the loss of data due to system failure.

4.2.1 Data Submission

Transit properties follow their own independent schedules for data submission. Although some semblance of regularity is achieved, it can be generally expected that data will arrive "when it gets there and not any sooner". For this reason, data submissions must be carefully monitored and catalogued to ensure that output reports can be produced in a timely manner and that data is not lost. At NYCTA, for example, the computer file from which utilization data is derived contains 62 days (2 months) of cumulative mileage for each vehicle. The daily mileage "cells" in this file are overwritten at the end of each day. Therefore, no more than six weeks should be allowed to pass beyond the end of a month before contacting NYCTA and inquiring about a "late" data tape.

In general, data can be expected to arrive at the TRIP Data Bank facility 2 - 4 weeks following the close of the period being reported. For properties which submit data (magnetic tape or hard-copy) on a monthly or 4-week cycle, 3 - 4 weeks has been the average delay experienced by the Experimental Data Bank. A 2 - 3 week delay has been typical for weekly or biweekly submission of hard-copy data.

Properties submitting hard-copy data should be encouraged to submit expendable (from their perspective) copies of the data since they will be retained by the Data Bank. If non-expendable copies are submitted, the Data Bank must provide the xerographic service. Similarly, data submitted on magnetic tapes should be transcribed onto Data Bank tapes so that the original can be returned to the source for recycling thus minimizing the cost of participation to the property.

4.2.2 Input Data Preparation & Processing

TRIP Data Bank personnel must become intimately familiar with the format and content of the data being submitted by each source. A thorough understanding of the coding schemes used to identify the equipment itself, the equipment condition or disposition, and maintenance actions performed on the equipment is required in order to properly design the algorithms and software necessary to convert the property's data into the standard Data Bank format.

The operations staff must also be knowledgeable of code definitions and usage at the property to be able to resolve anomalies encountered during the input processing of the data. Familiarity with the equipment for which the data is being reported and the vocabulary used by the property to describe both the equipment and the maintenance performed on it is necessary in order to resolve, from narrative, data errors which have been

in the encoding and/or entry of the data.

Some data errors simply cannot be resolved by reading the narrative data or referring to code books. It is important, therefore, that a liaison be maintained between the TRIP Data Bank staff and the transit property personnel.

Data errors, regardless of the source, will be encountered. The TRIP Data Bank, therefore, must have the capability to deal with these errors both procedurally and operationally. The Data Bank software must include "error files" to hold data which fails input editing, "error correction" programs for accessing and correcting erroneous data records, and "automatic retry" of corrected records by the input software.

4.2.3 Data Organization & Storage

As previously stated, the TRIP Data Bank is primarily an engineering data bank whose function is to collect, store, and analyze data on transit equipment and systems for the purpose of reporting reliability information. Although data is submitted to TRIP by individual transit properties, the primary objective of the TRIP Data Bank is not to report that data back to the source. Rather, the objective of TRIP is to gather data on functionally equivalent components from many sources, analyze that data, and report back to the industry the comparative reliability achieved or experienced.

The organization of the data within the data base will have the greatest impact on the ease with which data can be retrieved. Having too few major "keys" by which data is stored results in too large a block of data being retrieved for a particular set of search criteria. Having too many "keys" results in excessive retrieval costs because each key must be searched and tested for a proper match with the specified criteria.

Data records should consist of two "parts", label and data, for ease of access. The record label should have at least the following key fields:

- Part Number -- to identify the component to which the record pertains;
- Source/Location -- the transit property and car (or coach) number in which the component is in service;
- Record Type -- to identify the type of data contained in the record (e.g., repair, inspection, mileage, specification, etc.);

- Date -- the origin date of the record (e.g., date of inspection or repair completion, date on which mileage was recorded; etc.);

- Subdate -- an index number to differentiate between multiple records for the same label, but different data.

4.2.4 Data Retrieval & Analysis

The TRIP Data Bank should include the capability to access any data element within a record and, on the basis of that data element, retrieve the record either wholly or in part. The primary method of data access and retrieval, however, should be via the "key label" of a (two-part) data base record, as described in the preceeding subsection.

"Bulk" data extraction via the record key is an efficient method of subsetting the data contained in a large data base. Routine report production, for example, requires only a three-month subset of the data base to produce a "monthly" report. Subsetting of the data base, therefore, can be accomplished via the "Date" key field.

Search, sort, and other statistical and analytical routines also operate more efficiently if the number of the data elements being processed is kept reasonably small. Two-stage data retrieval - "bulk" subset; then detailed search - has been successfully employed in the Experimental Data Bank and has proven to be the most cost-effective method of accessing data.

The TRIP Data Bank must be capable of performing trend analysis as well as incremental (i.e., monthly) analysis. To eliminate the necessity of reprocessing monthly segments of data, the monthly statistics should be stored in summary form for use in performing trend analyses. The summary statistics should span a minimum of thirteen (13) months in order to display seasonal fluctuations.

4.2.5 Data Reporting

The major consideration for the reporting of data from the TRIP Data Bank is that the information reported must accurately represent the data provided as input by the properties. The accurate processing of data from input through to output is an absolute requirement of the TRIP Data Bank.

Beyond accuracy, however, is the requirement that the information presented in the output reports of the TRIP Data Bank be valid. Intermediate processing of data for validity should be

integrated into all subsystems and modules of the TRIP Data Bank software. The validity, or "reasonableness", of the data, however, requires more than just automated data processing to ascertain. The TRIP Data Bank personnel should possess familiarity with the vehicles and equipment, transit properties, and industry which TRIP has been designed to support.

4.3 FUNCTIONAL CONSIDERATIONS

Functional requirements of the TRIP Data Bank (TDB) are shown in Figure 4.1. From a practical perspective, the objective of the TDB is to produce information in the form of periodic and special output reports. The data from which this information is derived is generated within the operation and maintenance environments of transit authorities.

Output reports are generally limited in number, type, and format; yet the variety and content of input data formats is limited only by the number of transit authorities that are supplying the data. It is incumbent upon the Data Bank, therefore, to provide the following functional capabilities:

- STANDARD FORMATTING -- to prepare and transform the otherwise diverse data into a format which can be processed by "standard" software using "standard" techniques and algorithms;

- DATA EDITING AND VERIFICATION -- to ensure the accuracy and validity of the data being processed for Data Bank input;

- DATA ORGANIZATION AND STORAGE -- to provide maximum retrieval efficiency of voluminous data;

- DATA RETRIEVAL AND REPORTING -- to provide for the production of routine reports, reference information reports, and special reports necessary for assisting and supporting the activities and needs of TRIP users.

4.3.1 Data Submission

A liaison must be established and maintained between the TRIP Data Bank and each participating transit property. Preferably, all communications with a transit property are channeled through a single individual at the property. Multiple paths of communication, which can lead to duplication of effort, should be avoided.

All inquiries regarding "late" data submissions and data

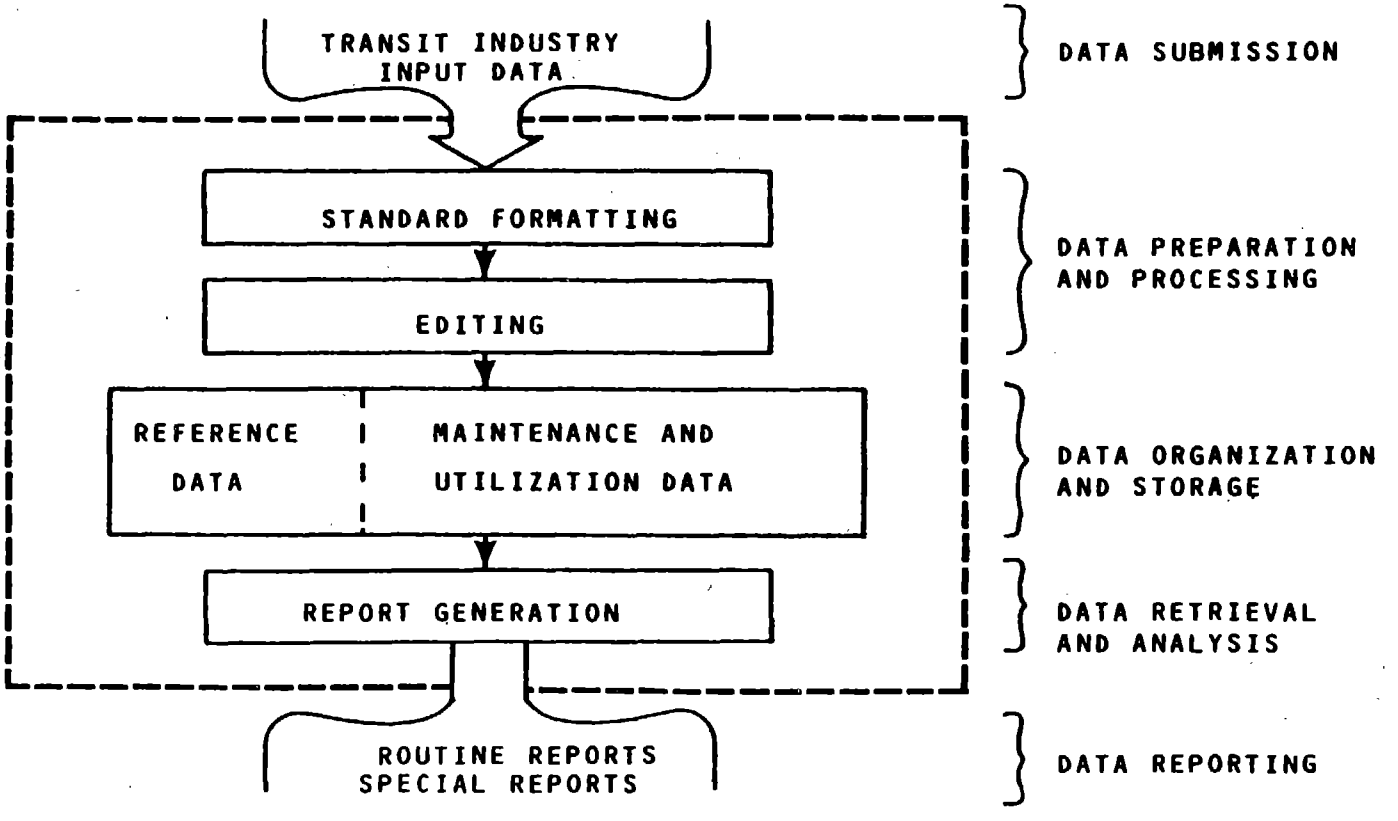

Figure 4-1 TRIP DATA BANK FUNCTIONAL REQUIREMENTS

anomalies should be directed to this individual. The property should be encouraged to appoint someone to this position who is knowledgeable of the data being submitted to TRIP. The liaison should be familiar (or, at least, know who to ask at the property) with the vehicles and equipment being monitored by TRIP, its operation and maintenance, and the generation, flow, and use of data at the property.

Data submission also involves obvious logistics considerations. The receiving of incoming data and shipping of processed tapes are routine functions of TRIP Data Bank operation. All receipts and shipments must be monitored and catalogued to ensure that no data is lost.

4.3.2 Input Data Preparation & Processing

The various transit authorities employ different methods of collecting and processing the data that they may generate during the course of operating and maintaining their equipment. In order to accommodate this diverse data in the TRIP Data Bank, the design of the Data Bank software must include functional modules for converting the incoming data from the unique, property-specific format to the standard format of the Data Bank. These functions include:

- HARD-COPY DATA ENTRY -- direct entry of data through a video display computer terminal from hard-copy form;
- MAGNETIC TAPE DATA EXTRACTION -- selection of TRIP-related data from computer-generated magnetic tapes of transit property data;
- STANDARD (GENERIC) DATA FORMATTING -- conversion of the data record from the transit property format into the standard TRIP Data Base input record format;
- GENERIC MAPPING -- cross-referencing of selected data elements to standardized (generic) equivalents;
- DATA EDITING -- comparison of data elements with property-specific definitions, value ranges, etc.;
- ERROR CORRECTION -- determining and implementing corrections to data elements which failed data editing.

Data editing should be integrated into all functional elements of input data preparation and processing. "Editing" includes checking both content (values versus definitions) and syntax (position, number of characters, alpha versus numeric characters, etc.). "Range testing" is a typical editing technique applied to content for screening data.

Another form of editing is the automated validation of selected data elements of the input data records. The "generic mapping" function (see 4.3.2.2, below) is by its nature the major form of data validation. Data cross-referencing from property-specific values to generic (standard) values is most easily accomplished via table look-up routines. In order for a data element to be "mapped", the property value must appear literally in the cross-reference table.

The table look-up approach to date validation could be applied to:

- Cross-referencing of:
  - Property acronym (or name) to a numeric code;
  - Property part numbers to "generic" part numbers;
  - Property maintenance codes to "generic" maintenance codes;
- Vehicle (i.e., car/coach body) number appearance on the property roster.

Automated data validation may also be applied to the combination of certain data elements such as part numbers versus maintenance codes. For example, a "defect" code defined as "wheel flat - 2-inch" can apply only to the steel wheels of a transit car.

The ability to correct data errors must be provided along with the ability to detect them. Records containing errors should be corrected prior to entry onto the Data Base. Error correction requires the following, as a minimum:

- Error detection and identification;
- Manual correction determination (e.g., substitutionary data), including transit property interface (if required);
- Manual correction implementation:
  - Accessing the "bad" data record; and
  - Substituting the "correct" data for the "bad" data element; or
  - Deleting the entire "bad" record, if appropriate;
- Automatic "retry" of corrected records.

Standard formatting is a two-stage process. The first step is to convert the data from the property format to a standard, intermediate format. This function should be accomplished by the data entry/extraction software (see 4.3.2.1, below) so that

"standard" software can be used for all other Data Bank functions. The second step is to cross-reference selected data elements of the standardized property data record to "generic" values, append these values to the property data, and reformat the data elements into the standard, generic record format (see 4.3.2.2, below) for subsequent entry onto the TRIP Data Base (see 4.3.3).

4.3.2.1 Data Entry

The data received from the transit properties generally does not contain any reference to the transit property except for the return address on the package. The property ID, therefore, must be added to the data records during the data entry process.

The major objective of the data entry function is to convert the property-specific data into a standard format for subsequent processing by standard software. The TRIP Data Bank must be capable of accepting data from both hard-copy forms and computer-readable media (e.g., magnetic tapes).

For hard-copy data, procedures must be established for the handling, sorting, processing, and archival storage of the data forms. Hard-copy data entry should be via video display terminals driven by interactive software. Although this software may reside on the Data Bank host computer, off-line data entry is preferred since "intelligent terminals" and/or "desk top computers" provide both lower per-record input costs and easily expandable, multi-station data entry capability. Tape cassettes of diskettes could be used as the off-line bulk storage media. The data from the cassetts or diskettes can then be batch-loaded into the host computer for the next stage in input processing.

Hard-copy data entry software should include the following functional capabilities:

- Direct data entry (no keypunching);
- Multiple screen formats for data input including "look-alike" formats for each source and type of hard-copy data;
- "Menu" selection of screen formats to accomodate the addition of new formats as required;
- Automatic fill-in of repetitive data elements (e.g., date, property acronym, etc.);
- Immediate syntax checking (e.g., required data elements, numeric versus alphabetic characters, etc.);
- Data element reformatting/reordering.

The input processing of computer-readable data is similar to that of hard-copy data except that the human factor is replaced by automated algorithms. Magnetic tape data entry requires "customized" software for each transit property due to the unique format and content of the tapes from each source. Some tapes may be directly readable by the Data Bank host computer. Other tapes, however, may require code set and/or format conversion before the logical processing of the data can be performed.

Magnetic tape data extraction programs may require any or all of the following functional capabilities:

- Record sorting, screening, and selection based upon one or more data elements (e.g., part number, record type, etc.);
- Record merging (e.g., when the data pertaining to a single maintenance event is distributed among multiple records);
- Data element extraction and reordering;
- Date record formatting into multiple standard record types;
- Processing "restart" in the event of output file overflow.

4.3.2.2 Generic Mapping

The purpose of the "generic mapping" function is to cross-reference selected data elements of the property input record to equivalent generic (common) values. Generic data elements form the basis for comparative reliability assessment and data reporting. Part numbers, maintenance codes (repair or test), and equipment condition codes (symptom or defect) should be cross-referenced to a common (generic)set of codes based upon equivalent definitions. Generic codes should be appended to the property data during the input processing of data and stored as an integral part of the data record.

The generic mapping process could be accomplished by a series of table look-up routines. The first step would be to construct a "Generic Serial Number" (GSN) for the data record to identify the source of the data (i.e., the transit property), vehicle number to which the data pertains, and the vehicle series to which the vehicle belongs. The vehicle number contained in the data record can be used as a search key to determine the vehicle series from "Fleet Tables" which are identified by property ID.

The next step in the generic mapping process would be to

cross-reference the transit property part number contained in the data to a "Generic Part Number" (GPN). A table of transit property part numbers versus GPNs should be prepared for each type or series of vehicles for which the transit property is submitting data. A vehicle series is defined as a grouping of vehicles based upon the following:

- Single or multiple-unit (e.g., married pairs) vehicles purchased under a specific contract (e.g., NYCTA's R-44 cars);
- Single vehicles whose configuration differs from another "type" of vehicle purchased under the same contract (e.g., BART's "A" versus "B" cars);
- Both of the above (e.g., PATCO's single cars versus their older married pairs).

Each table of part numbers should be compiled into a "Generic Parts List" (GPL). Since each type or series of vehicle is unique, a separate GPL should be prepared for each vehicle series and contain the property part numbers and corresponding GPNs which pertain to that vehicle type. Each GPL should be identified by property ID and vehicle series ID. The generic mapping of the property part number contained in the data record can be accomplished by using the property ID and vehicle series ID elements of the GSN created in the first step of the generic mapping process to select the appropriate GPL, and then using the property part number from the data record to search the GPL for the corresponding GPN.

The final step in the generic mapping process is to cross-reference the transit property maintenance action codes to Generic Maintenance Action Codes. Maintenance action codes describe the four basic steps in the maintenance process:

- SYMPTOM CODES -- describe operational problems usually experienced by the vehicle operator;
- DEFECT CODES -- describe reasons behind the observed symptom which are usually discovered during trouble-shooting, inspection, testing, or maintenance activities;
- REPAIR CODES -- describe actions taken to correct known defects or to treat observed symptoms;
- TEST CODES -- describe actions taken to disclose a defect or to validate a repair.

A Maintenance Code Table is a cross-reference table of transit property maintenance action codes versus Generic Maintenance Action Codes. A Codes Table should be prepared for each property that is supplying data to the Data Bank. The

property ID element of the GSN should be used to identify and select the appropriate Maintenance Codes Table. The transit property maintenance action codes from the data record can then be used to search the Codes Table for the corresponding generic codes.

If the table look-up routines are successful in assigning generic values, the record is reformatted into a "generic transaction" which combines the data elements of the property record, or "non-generic transaction", with the generic values. If the mapping process fails a table look-up routine (e.g., car number, property part number, or property maintenance code cannot be found on the table), the entire "non-generic transaction" should be written to an error file for examination and correction by the operations personnel. The TRIP Data Bank must include software for correcting these records so that they can be re-processed during the next execution of the generic mapping function.

After an entire "batch" of new and corrected records have been mapped and reformatted into "generic transactions" consisting of key fields (GPN, GSN, date (from the data record), subdate, and record type) and data fields (property and generic data elements), the records should be sorted, character-by-character, into a working file. Each record should be compared with the next record in the sorted sequence. If two or more records are exact duplicates, the first record should be retained and the duplicate records "dropped". Such duplications should be treated as multiple submissions by the property; therefore, only the first submission is to be retained as valid data.

If the key fields of two or more records are duplicate, yet the succeeding data fields differ by at least one field, the subdate key field should be incremented by one (i.e., reset from "0" to "1", "2", etc.) to establish a unique "key label" for each data record. After all records have been processed from the sorted work file, they should be written to tape for subsequent input to the data base. This off-line media for data storage serves as the input media for the data base management software and provides the ability for restart if a system or software failure occurs during data base update.

It should be noted that primary control for the generic mapping process is derived from the various cross-reference files that are used in the table look-up routines. Once established, the contents of these files are reletively stable. Some changes do occur, however, as vehicles are retired from service due to accident or vandalism, maintenance codes are redefined, or new equipment is introduced. The TRIP Data Bank software, therefore, must include programs for maintaining the cross-reference tables.

4.3.2.3 Data Organization & Storage

The TRIP Data Bank must be capable of accepting a wide variety of data on the operation, maintenance, specification, configuration, and operating environment of transit equipment and systems. The organization of this data in the data base will have major effects on the operation of the TRIP Data Bank, including: efficiency of adding to and updating the information contained in the data base; expediency of producing routine reports and outputs; flexibility of data retrieval to produce special reports and analyses; and cost of operation.

A number of possible data bank storage formats could be utilized for TRIP. One would be a sequential chronological format based on the order in which the data is received. Another would provide for storage of input data in multiple locations or files based upon the types of retrievals which may be required. Sequential data storage would provide a simple format for data input by the addition of new data to the last data previously stored. Sequential storage, however, would require time-consuming searches of stored data to locate each data item required for routine or special outputs. Multiple storage locations would be advantageous for routine data retrieval by having data already collected and organized for these outputs. Multiple storage, however, would require more time to input data to the several locations and more space to store it in. Lengthy retrieval searches would also be required to produce special outputs since the data would have to be reassembled from its various locations.

A third, and more efficient, data base storage concept, which provides both flexibility of data retrieval and efficient use of storage space, is an "integrated data base". The characteristics of this storage approach include:

- Storage of all data in one central location, thereby permitting efficient access to any data element or groups of elements;
- Entry/storage of each unique data element once and only once to minimize storage space requirements;
- Organization of all data types based upon the logical relation of "index keys" assigned to data records;
- Storage of different types of data based upon the same "index key" arrangement to maximize retrieval efficiency.

The use of an "intregrated data base" organizational approach for the TRIP Data Bank could utilize the Generic Part Number as the unifying primary "index key" for data identification. Data could be efficiently stored based upon a single data base entry of each new data element, data storage

space would be minimized, and retrievals and outputs could be readily generated based upon the ordering of the stored data by GPN, GSN, date associated with this data, and the type of data being stored.

The data base management portion of the TRIP Data Bank must provide the following minimum functions:

- Input editing;
- Error correction;
- Data base update;
- Data access/retrieval.

Two basic types of editing are required on all data base transactions. The first is to ensure that the transaction is an allowable function, namely: add, modify, delete, or access/retrieve. All four of these functions may be "allowable" with respect to an entire record, but not to an individual data element within the record. Modification of the record type key field, for example, should not be allowed since this field defines the format and content of the data record.

The second type of editing is to check the incoming transaction for syntax (order of elements, left/right justification of data fields, alpha versus numeric characters, etc.) and content (range/tolerance, specific value, etc.). Data base transactions which fail either type of editing should be written to an error file for examination and correction by the operations personnel. The data base management software, therefore, must also contain the functions necessary for correcting these records.

Control of the editing process could be accomplished through the use of a data base "Dictionary". The Dictionary itself is the master format or description file for data being input, stored, or retrieved from the data base. To provide this master format control capability, the data base Dictionary contains:

- Complete descriptions of all data base input record types, including:
  - Data elements within each record type;
  - Sequence of data elements within each record type;
  - Field length of all data elements;
- Complete listing of all valid Generic Part Numbers being accepted into the Data Bank (i.e., a "Master" Generic Parts List);
- Tolerance tables containing the range of allowable values for critical data items;

- Complete descriptions of all record types as they appear on the data base.

A second level of editing should be provided by the software that performs the actual data base update function. Once the input data has been checked for proper format and content, the "key" elements (GPN, GSN, date, subdate, and record type) should be compared to data already stored on the data base in order to avoid duplicate entries. If a duplicate key is found on the data base, the individual data elements of the record already on the data base should also be compared with the "new" record. If they, too, are duplicate, the "new" record should be "dropped" as a duplicate submission. If the individual data elements of the "new" record differ by at least one field from those in the record already on the data base, the "new" record should be written to an error file for examination by the operations personnel. If the record is determined to be a valid transaction, then the "subdate" key field should be incremented and the record re-processed.

The data base update function should also include the capability to:

- Modify data already on the data base (individual and/or global):
  - Modify selected key elements;
  - Modify data elements;
  - Check for existence of data elements;
- Retire/delete from the data base (entire records only):
  - Individual records;
  - Record groups, where the "groups" are defined by a single or combination of key elements (GPN, GSN, date, or record type).

Some special investigations may require access to the entire TRIP data base. The organization and structure of the data base and design of the data base management software, therefore, should allow access to the stored records, in whole or in part, on the basis of one or more discrete data elements of the record.

Most analyses, however, will require only a subset of the data. The primary method of retrieving data, therefore, will be via range or discrete value testing of one or more key elements of the data records. The objective of subsetting the data base is to reduce the amount of data to be processed to a manageable volume and thereby minimize processing costs.

4.3.2.4 Data Reporting

The primary objective of the TRIP Data Bank is to provide information on the reliability and associated utilization of transit equipment and systems. This objective will be met through the production and distribution of reports which present the results of analyses of vehicle and equipment operating and maintenance data which has been collected and stored in the Data Bank. Reports will also be produced which present reference information on transit properties, vehicle types, and associated equipment. These reference data reports will be used for the interpretation and comparison of the reliability and utilization reports.

Outputs and reports to be generated by TRIP will be of both routine and special types. Output capabilities of the system should provide for the prompt and efficient production of periodic reports on fleet, vehicle, and component reliability and performance. Output capabilities must also have the flexibility to format and produce reports for special data retrievals and analyses. Routine report generation capabilities should likewise retain the flexibility to be modified in a timely and efficient manner based upon changes in reporting requirements.

The generation of routine reports will require handling large quantities of vehicle operation, maintenance, and failure data from a number of sources. This data must be input into TRIP, converted into a common format so that comparison is possible, and analyzed and summarized to produce these reports. Typical functions required for the production of routine output reports include:

- Tabular summaries of data:
  - System (Vehicle, Power & Way, etc.);
  - Property;
  - Industry;
- Arithmetic computations:
  - Sums;
  - Averages;
  - Percentages;
- Statistical calculations:
  - Mean;
  - Standard deviation;
  - Curve fitting;
- Plotting:
  - Trend plots;

- Bar charts;
- Histograms.

The generation of special reports requires that the TRIP Data Bank have the capability to store and retrieve data on transit equipment down to the "Lowest Replaceable Unit" (LRU) level of detail. In order to support component tracking and prototype performance analysis, each LRU must be traceable by serial number. Reference (specification, configuration, and operating environment) data will also play a major role in special analyses by providing the background information necessary for comparative analysis. The TRIP Data Bank, therefore, must be capable of simultaneous retrieval of different types of data.

Although a primary goal of TRIP is to provide a central repository containing all collected transit equipment failure and reliability information, the usefulness of this data will also depend upon the promptness and flexibility with which this stored information can be retrieved, and the methods which are available for analysis and reporting.

5. TRIP DATA BANK RECOMMENDATIONS

Detailed functional and operating considerations which should be addressed for the implementation of the full-scale TRIP Data Bank have been previously described in Section 4. Of equal importance are the recommendations and factors which should also be considered as part of the implementation, expansion, and operation of the full-scale Data Bank. This section, therefore, addresses the following program issues related to the management of TRIP:

- Alternative approaches for the implementation of the full-scale Data Bank;
- Considerations for the expansion of the Data Bank from the experimental to full-scale configuration;
- Considerations for the long-term operation of the TRIP Data Bank.

5.1 DATA BANK IMPLEMENTATION ALTERNATIVES

Due to the anticipated size and operating cost of the full-scale Data Bank, careful consideration should be given to the selection of the group or organization which will provide the long-term operating capabilities. Further, organizational alternatives for the implementation of the full-scale Data Bank should be evaluated with respect to the cost, effort, time, and possible risks associated with each alternative.

The organizational alternatives for Data Bank implementation include:

Alternative 1: Continued sponsorship by the U.S. DOT; continued operation by the current (EDB) contractor.

Alternative 2: Continued sponsorship by the U.S. DOT; operation by a new contractor.

Alternative 3: Installation at an existing U.S. DOT data processing facility; use of UMTA-developed software.

Alternative 4: Organization of a new UMTA data processing facility; use of UMTA-developed software.

An overview comparison of the factors for each of these alternatives is shown in Figure 5-1. As might be expected, Alternative 1, continued operation by the present EDB contractor, presents the fewest potential additional requirements which would have to be addressed for implementation, expansion, and operation of the full-scale Data Bank. The only considerations to be

	ALTERNATIVE 1 – U.S. DOT SPONSORED; OPERATED BY EDB CONTRACTOR	ALTERNATIVE 2 – U.S. DOT SPONSORED; OPERATED BY NEW CONTRACTOR	ALTERNATIVE 3 – EXISTING U.S. DOT COMPUTER FACILITY; UMTA SOFTWARE	ALTERNATIVE 4 – NEW UMTA COMPUTER FACILITY; UMTA SOFTWARE
OPERATION				
– EXPANSION FOR NEW TRANSIT PROPERTIES	●	●	●	●
– TRANSFER TRANSIT PROPERTY LIAISON	●	●	●	
– DEVELOP NEW TRANSIT PROPERTY LIAISON	●	●	●	
– MODIFY DATA SUBMITTAL PROCEDURES	●	●	●	
TRAINING				
– NEW STAFF	●	●	●	
– EXPANDED STAFF	●	●	●	●
COMPUTER SOFTWARE				
– MACHINE COMPATIBILITY STUDY	●	●	●	
– SOFTWARE TRANSFER CONVERSION, OR DEVELOPMENT	●	●	●	
– SOFTWARE VALIDATION	●	●	●	
– PARALLEL EDB OPERATION	●	●	●	
COMPUTER HARDWARE				
– COMPUTER SPECIFICATION/PROCUREMENT	●			
– COMPUTER FACILITY ESTABLISHMENT	●			
– COMPUTER FACILITY STAFFING	●			

FIGURE 5-1
FULL–SCALE TRIP DATA BANK
ALTERNATIVES IMPLEMENTATION REQUIREMENTS

addressed would be the continuation of the expansion of the Data Bank coverage begun during the EDB implementation, and the addition of staff to handle the expanded work load.

Alternative 2, transfer of the operation of the Data Bank to a new contractor, raises a series of issues which would have to be addressed. First, a completely new staff organization would have to be familiarized and trained in the operation of the Data Bank. Second, all interface procedures with the participating transit properties would have to be re-established, including liaison with the property and Data Bank representatives, and modification of data transmission procedures. Third and finally, the Data Base itself, along with its operating software, would have to be transferred to the new Data Bank operator. This transfer process would include: conversion and transfer of software developed for TRIP; development and/or tailoring of software for the storage of the data itself; implementation and testing of the complete software system prior to transfer of the data contained in the (experimental) Data Bank; and parallel operation of the Data Bank at the EDB and new contractor facilities until the new software is in place and operationally proven to prevent a major gap in historical data already contained in the Data Bank through the operation of the EDB.

Alternative 3, operation by the Government at an existing Government data processing facility, would require addressing the same set of issues raised by Alternative 2, above. Alternative 4, operation by the Government at a new data processing facility established by the Government specifically for TRIP, would add to the concerns of Alternative 3 those considerations and requirements of purchasing and installing the new computer hardware itself. These hardware considerations, of course, have to be evaluated in parallel with the considerations for transition of the Data Bank software.

General considerations which should be addressed in the evaluation and selection of implementation alternatives include:

- Does the new operations staff have adequate transit property and equipment knowledge and experience to validate input and output data and interface with property personnel?

- Has a realistic and supportive estimate been supplied as to the labor, cost, and time required to transfer, develop/tailor, and validate new operating software, if required?

- Has an adequate acceptance testing and transition plan been provided to determine the time and cost for the transfer of the Data Bank operation?

- How do the costs and time required for transfer compare to the program benefits?

5.2 DATA BASE EXPANSION

Regardless of which implementation alternative is selected, the Data Bank operations staff will have to develop a thorough and comprehensive approach for the expansion of the coverage of the Data Bank. This expansion approach should include:

- Progressive expansion of the equipment and properties monitored by the Data Bank, and especially the expansion of the Generic Parts Lists;
- Maintenance of systematic procedures during the expansion process to insure data handling and operating procedures consistency;
- Technical support in the form of additional experienced staff to assist in the expansion effort.

After evaluation of the EDB implementation experience, DRC has concluded that the expansion of the monitoring coverage for equipment and properties should be conducted in the following sequence of steps:

1. Complete coverage (i.e., Generic Parts Lists) of all equipment on the vehicles currently being monitored by the EDB.
2. Expand coverage to include new vehicle types at the EDB properties.
3. Expand coverage to include other vehicle types at properties which are new TRIP participants.
4. Finally, expand coverage to include other types of equipment beyond the vehicle itself (e.g., wayside train control equipment, electrification equipment, track and structures, etc.).

These proposed steps in the expansion of the TRIP Data Bank coverage provide a controlled approach to add to the Generic Parts Lists, augment data input and handling procedures, and add to the operations staff to deal with the increasing work load. While no rate of coverage expansion has been suggested, the goal of TRIP to support new vehicle acquisition points toward a more rapid expansion in order to support the information needs of the industry regarding the current influx of new vehicles.

Throughout the expansion process, the operations staff must insure that all procedures for operation are continuing to be systematically applied. Of primary importance is the strict control of the development of the Generic Parts Lists (GPLs). The GPLs, as the index, dictionary, and cross-reference to the data stored in the data base, must be completely accurate and

consistent. Each addition to the GPLs must strictly follow procedures for development and implementation that have been used throughout the program.

An important further consideration in the expansion of the Data Bank coverage is the availability of technical personnel to support this activity. This added technical staff will be initially required for the development of new GPLs. Subsequently, this same staff will be required for the expansion of the associated data collection, data entry, and data handling procedures. Finally, this staff will support the expansion of the output reporting coverage to include the new equipment, vehicle types, and properties being monitored.

This added technical staff must have experience with both transit properties and equipment. Equipment knowledge will be vital for proper and timely development of GPLs. Property experience will be useful for the development of data collection and validation procedures required for each new data source. Property experience will also be imperative for the continued refinement and improvement of Data Bank output information and reports to make them as useful to the participants as possible.

5.3 DATA BASE OPERATION

In order to support both the expansion and long-term operation of the full-scale TRIP Data Bank, certain resources will be required. These resources include:

- Knowledgeable staff -- who are experienced in both data processing and transit equipment;
- Dedicated personnel and hardware -- to insure that top priority is given to the operation of the system and the production of outputs;
- Engineering support -- to insure the validity of analyses and respond to requests for special data retrievals and analyses.

The success of the TRIP effort is based upon the quality and dedication of the staff provided for the operation of the Data Bank. This staff has, as a program responsibility, the task of insuring the quality of the data contained in the data base. This data quality control depends upon the staff's capabilities to detect and correct data anomalies and errors based upon its knowledge and experience with transit equipment and its functional characteristics. In the same way, the operations staff must also insure the reasonableness and accuracy of output reports produced from the system. Finally, the participants themselves must provide a knowledgeable interface to address users' needs, answer questions, and provide information.

In order to provide for the consistent and effective operation of the Data Bank, both dedicated personnel and automated data processing hardware are required. Dedicated staff is imperative to insure that all operations tasks, especially data entry, are dealt with promptly, and that personnel are not diverted to other activities. Dedicated data processing equipment will insure that the data quality and integrity is maintained as well as remains under the control of the operations staff.

Finally, it is important that long-term engineering support be provided as an integral part of the operation of the full-scale Data Bank. The success of TRIP would potentially be brought into question if the operation of the Data Bank becomes merely a "data processing" operation. The value and usefulness of the program is predicated on its ability to address equipment-related engineering questions, investigations, and analyses. To meet this continuing objective, ongoing engineering support is required. This engineering capability will be used to: continue to evaluate, refine, and improve the output products of the Data Bank; resolve more complex data anomalies; define and conduct engineering analyses and the preparation of reports in response to special requests from users of the TRIP Data Bank.

6. CONTRACT TASK SUMMARY

The purpose of this section is to present a summary of the results achieved and conclusions reached during each of the twelve tasks of Contract Number DOT-TSC-1559. The approach taken by the Dynamics Research Corporation (DRC) for this contract is illustrated in Figure 6-1.

On September 18, 1978, Dynamics Research Corporation (DRC) began work on Contract Number DOT-TSC-1559 to define, develop, and establish the Transit Reliability Information Program (TRIP). The objective of this effort is to develop a comprehensive coordinated approach to transit vehicle reliability assessment by satisfying the following program requirements:

- Consolidated data system to provide a central source of reliability information for all transit vehicles which will collect, screen, and store the necessary data;
- Reliability data analysis including determination of the type and quantity of data to be collected, methods for analyzing and summarizing input data, and analytical approaches for detailed reliability investigations;
- Reliability assessment support to assist participants and other groups in reliability research and analysis by providing prompt, timely outputs and reports, and by providing the capability for special data searches and analyses.

The major aspects of the technical approach proposed by DRC for TRIP were to:

- Define and document TRIP functional and operational requirements necessary to satisfy the aforementioned program requirements;
- Develop, establish, and operate an Experimental Data Bank (EDB) as a prototype of the full-scale TRIP Data Bank for the purpose of evaluating the proposed methodology;
- Establish the (full-scale) TRIP Data Bank.

The first two activities comprise Phase I of the contract effort and cover the planning, designing, and testing of a small scale (experimental) data bank. The purpose of the Experimental Data Bank (EDB) is to provide a working "model" which can be used to evaluate the concepts of the full-scale TRIP Data Bank developed during the first major activity above, and to refine procedures for the acquisition, storage, retrieval, and application of the output reports. The results of this evaluation will by used to formulate recommendations for continuing the operation of the Data Bank and expansion into a

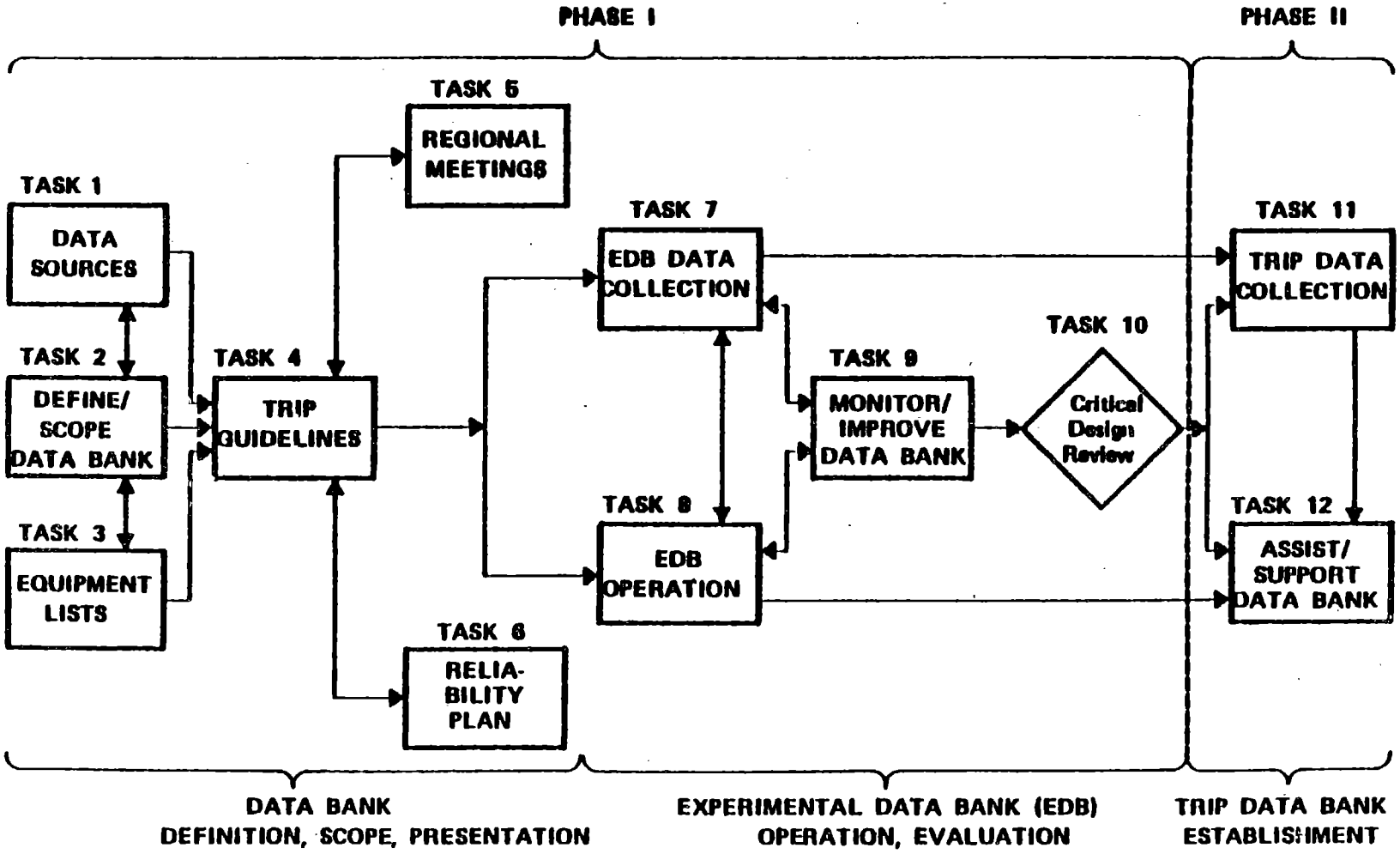

FIGURE 6-1. TRIP CONTRACT APPROACH

full-scale system during Phase II.

The implementation and subsequent operation of the EDB was based upon the voluntary participation of six operating transit properties who are supplying data to TRIP. Because of unexpected and changing circumstances at four of these properties, TRIP experienced delays in the initiation of EDB operation due to slower-than-expected accumulation of background information necessary for executing the design of the system as well as the transit vehicle data itself which is the input data for the system. The insufficiency of data resulted in the inability to adequately exercise the Data Bank concept within the time period originally specified for the contract.

A modification to Contract Number DOT-TSC-1559 was subsequently issued which increased the period of performance of Phase I (specifically, Tasks 7 - 9) by nine months. This extended period of EDB operation and refinement produced the following results:

- Provided a more thorough evaluation of TRIP Data Bank design concepts;
- Provided a more comprehensive assessment of the operational requirements for the full-scale TRIP Data Bank;
- Provided a better opportunity for the APTA TRIP Liaison Board to participate in the continued development and refinement of TRIP output reports;
- Provided more complete and detailed information for the EDB evaluation presented at the Critical Design Review (CDR).

Prior to the CDR, "Phase I" of Contract Number DOT-TSC-1559 and "Phase I" of the TSC TRIP Implementation Plan had been concurrent events. The net effect of the CDR was to extend the duration of Phase I of the Implementation Plan, postponing implementation of Phase II for 15 - 21 months.

The original purpose of Phase II of the contract was to provide transition support for the lead-in to Phase II of the TSC Implementation Plan. Data preparation assistance from Task 7 was to be continued in Task 11, and EDB operation from Task 8 was to be continued in Task 12, while a separately contracted effort was to be initiated to establish a full-scale TRIP Data Bank.

Because of the CDR outcome, however, the objective of Phase II of the contract was redirected from a posture of maintaining EDB operation until the full-scale Data Bank was established, to maintaining EDB operation until a "continuation contract" could be issued to continue EDB operation, refinement, and expansion as recommended by the CDR committee.

In keeping with this shift in emphasis, the contract task summary presented in the following subsections considers Tasks 11 & 12 to be post-CDR contiguous extensions of Tasks 7 & 8, respectively.

6.1 TASK 1 -- EVALUATE/ASSESS DATA BANKS/ POOLS

The activities of Task 1 are illustrated in Figure 6-2. The purpose of Task 1 was to:

- Characterize the types, formats, and quantities of available transit vehicle operating, maintenance, and failure data to be used for the development of the TRIP Data Bank input and output procedures;
- Define transit vehicle hardware configurations, through parts breakdowns, as the basis for the development of both Reliability Equipment Lists in Task 3 and the Data Bank storage structure in Task 2;
- Scope transit property and vehicle reference, or background, information to be used to interpret reliability information to be produced by the TRIP Data Bank;
- Evaluate the configuration and operating methods of existing reliability data banks to assess the applicability of these approaches to the design of the TRIP Data Bank.

The approach used for the Task 1 investigations was to visit transit properties to collect the designated information and to visit an existing reliability data bank and review the document and outputs of a number of other existing data banks.

The transit properties which were visited were those selected as a cross-section sample for participation in the TRIP Experimental Data Bank. These properties are:

BART	Bay Area Rapid Transit District;
CTA	Chicago Transit Authority;
GCRTA	Greater Cleveland Regional Transit Authority;
NYCTA	New York City Transit Authority;
PATCO	Port Authority Transit Corporation;
WMATA	Washington Metropolitan Area Transit Authority.

Existing reliability data banks which were investigated included: the Government - Industry Data Exchange Program (GIDEP); Reliability Analysis Center (RAC); two U.S. Military Maintenance data systems; and the DRC Technical Integrated Data

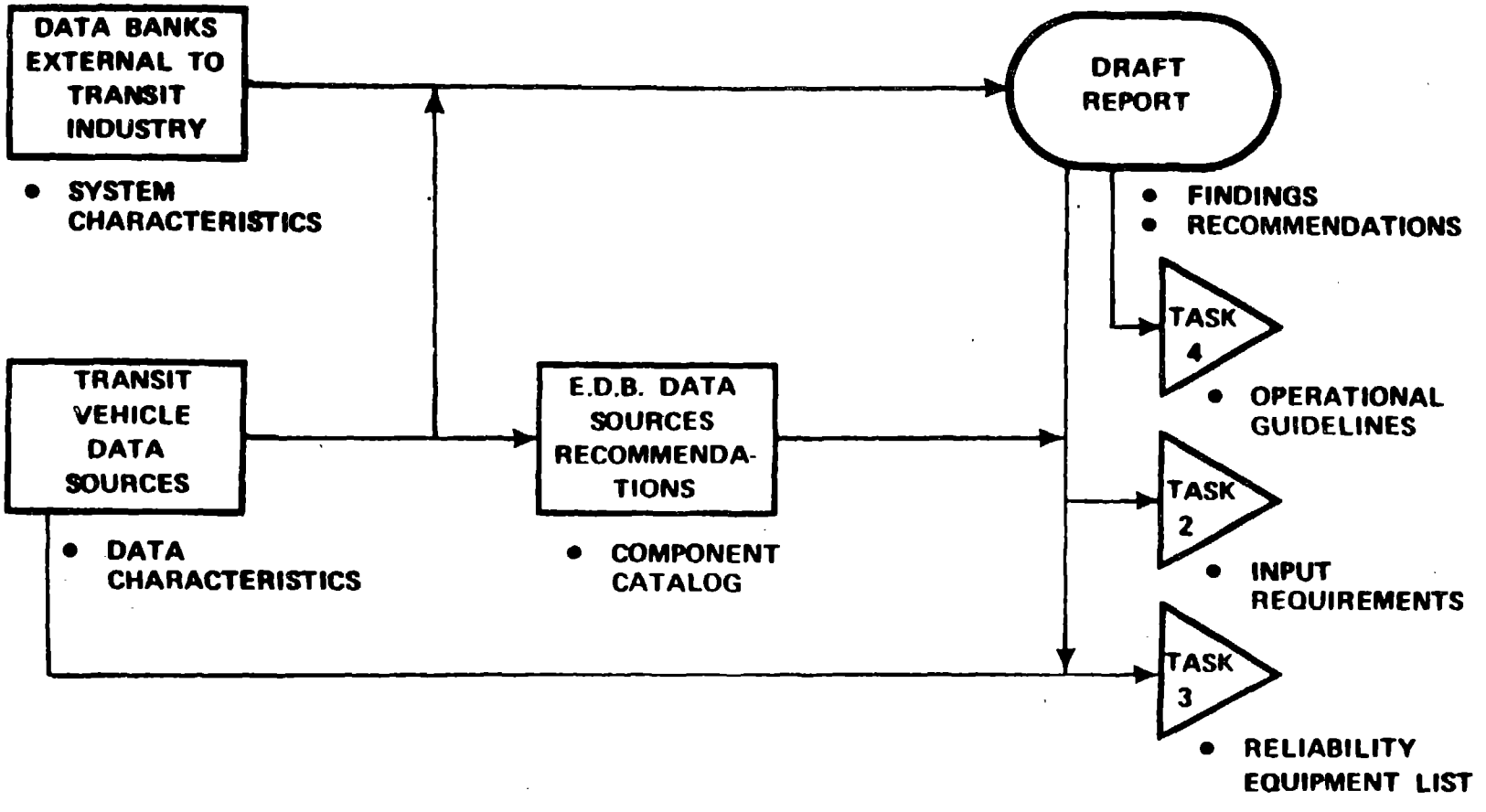

FIGURE 6-2. LOCATE & ASSESS EXISTING DATA BANKS & SOURCES (TASK 1)

System (TIDS).

The Task I effort was completed in December 1978. The following conclusions were reached based on the investigation of data banks external to the transit industry:

- No publicly available data bank exists for transit-specific components;
- Existing reliability data systems (eg: GIDEP, RAC, AFM 66-1, USN 3M) do not differentiate between primary and secondary failures and therefore provide "practical" rather than "classical" reliability information from their data;
- The Government - Industry Data Exchange Program (GIDEP) offers the potential of becoming the point of distribution for the outputs from the TRIP Data Bank;
- The publications of the Reliability Analysis Center, Rome Air Development Center (RAC/RADC), provide a good example for the presentation of reliability information and offer suggested analyses for reliability assessment which are suitable for inclusion in TRIP;
- U.S. Military Maintenance Data Systems, particularly the Air Force AFM 66-1 and Navy 3M systems, provide good examples of "generic" approaches to equipment hierarchical descriptions and failure/repair coding which directly correspond to the intended approach for the TRIP Data Bank;
- DRC's Technical Integrated Data System (TIDS) provides a basis for the development of the TRIP Data Bank through its modular approach to system design;

The investigation of existing sources of reliability information on transit vehicle equipment and, in particular, the survey of the six transit properties that are participating in the development of the TRIP Data Bank have yielded the following observations and conclusions:

- The total extent of data that would normally be collected to support the classical, detailed reliability analysis of transit equipment is not available unilaterally;
- Tracking of serialized equipment is done for only a few major (high cost) assemblies;
- No differentiation is made between primary and secondary failures;
- Failure data is recorded to different levels of equipment detail at different properties (e.g., only to subsystem

level versus to the component level);

- Transit properties are most interested in tracking the latest vehicle or hardware types;
- Vehicle configuration data, while available, must be correlated from several sources at each property to produce cross-reference lists of property and manufacturer's part numbers;
- Transit property reference data (e.g., maintenance activity codes, failure codes, etc.) must be correlated into "generic" cross-reference lists for comparison between properties;
- The majority of the properties (5/6) use mileage as the basis for preventative maintenance and failure rate determination;
- Only that maintenance data which pertains to what was done to and on the vehicle itself (primary maintenance) can be correlated to a vehicle failure event (except at BART);
- Secondary (bench) maintenance of components removed from a vehicle cannot be traced to a vehicle failure event through existing data forms (except at BART);
- Where a choice existed, the transit properties selected their most recently purchased vehicles for inclusion in the TRIP EDB.

Based upon the conclusions of the investigations of this task, the following recommendations were made and integrated into subsequent tasks:

- Further discussions should be conducted with GIDEP for setting up a separate data bank for TRIP information when it becomes available;
- Careful consideration should be given to the use of TIDS as the basis for the design of the TRIP Data Bank;
- A generic coding scheme should be developed for failure, maintenance, and other codes and information recorded by individual transit properties;
- Consideration should be given to the storage of maintenance narrative data as well as parts cost, labor types, and repair times, as correlative information;
- Selection of components to be tracked in the EDB should be made in light of results which can be produced in 6-8 months. This may involve the consideration of components

based primarily on their failure rates;

- Components to be tracked in the EDB should include the most recent technology (e.g., chopper versus cam propulsion control) which have generated significant industry interest;

- Procedures should be developed to process hard-copy maintenance data, where that is the only format in which the data is available, including the coding of narrative information concerning affected hardware, failure type, and action taken.

A detailed discussion of the results, conclusions, and recommendations of the Task 1 activities is contained in DRC Report Number E-4852U.

6.2 TASK 2 -- DEFINE/SCOPE TRIP DATA BANK

The activities of Task 2 are illustrated in Figure 6-3. The major areas addressed in Task 2 were:

- Definition and scope of the full-scale TRIP Data Bank configuration;

- Definition and scope of the Experimental Data Bank (EDB) configuration as the intermediate step toward the efficient development of the full-scale Data Bank;

- Characterization of rail transit vehicle operating, maintenance, repair, and reference data to be used as input for the Data Bank;

- Definition of potential outputs and reports to be produced by the Data Bank;

- Scoping of operating requirements for the full-scale Data Bank, including: operating methods and procedures, estimated Data Bank size, and projected Data Bank staffing;

- Scoping of cost factors for the full-scale Data Bank, including: operating costs, program sponsorship, etc.;

- Scoping of projected benefits to be derived from the full-scale TRIP Data Bank and associated cost justification.

Significant input to the definition and scoping effort of Task 2 was provided by work which was simultaneously conducted on Tasks 1 and 3. Information provided by the Task 1 investigation

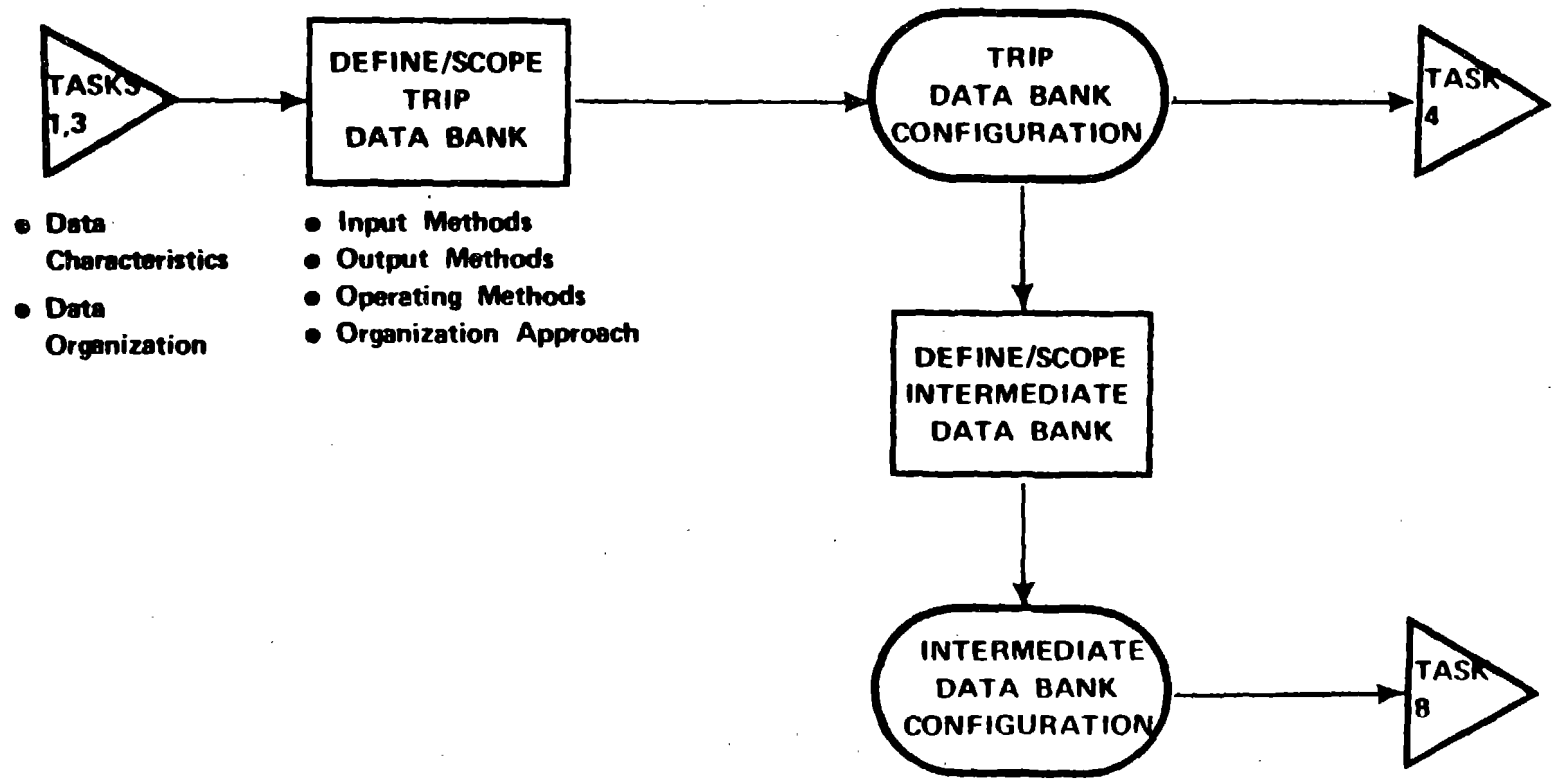

FIGURE 6-3. DEFINE/SCOPE TRIP RELIABILITY DATA BANK (TASK 2)

and assessment of existing reliability data banks and rail transit vehicle data sources included:

- Format, content, and estimated quantity of utilization, maintenance, and repair data for rail transit vehicles available from transit properties to be used for Data Bank input;

- Format, content, and availability of reference data covering transit property, rail transit vehicle, and vehicle hardware characteristics and operating policies to be stored in the Data Bank;

- Examples of reliability information and reports being currently generated by individual transit properties to be used for the definition of TRIP outputs;

- Operating procedures and methods of existing reliability data banks, including output generation, and reporting, input data processing, and information distribution, to be used for the development of the TRIP Data Bank operating approach.

Information provided by the Task 3 development of Reliability Equipment Lists which was used in the Data Bank definition and scoping effort included:

- Classification of rail transit vehicle equipment using a function-oriented Generic Part Numbering approach as the basis for the organization of the Data Bank data storage approach;

- Rail transit vehicle equipment Generic Part Numbering as the basis for the development of common formatting of data from several sources;

- Operating procedures for adding, deleting, or modifying equipment to be tracked as one facet of the Data Bank operation.

A major effort in the definition and scoping of the TRIP Data Bank configuration and requirements was to characterize the available rapid rail transit vehicle operating, maintenance, and inspection data which would be used as input for TRIP. The characteristics of the available data, including format, content, and commonality between sources, provided the major input to the development of Data Bank configuration and operating requirements for processing and storing input data. This information also provided a basis for defining the initial format of output reports to be produced by TRIP.

It should be noted that the development of many automated data processing systems begins with the definition of the outputs to be produced. Based upon this definition, input data

requirements are established along with data processing requirements to convert the input data into output reports.

The specific approach taken for TRIP differed from this general design approach in that the input data for TRIP was predefined as being the data produced by the transit properties. The "basic philosophy" of TRIP is that data be accepted in its organic form, and no additional data collection or reporting requirements are to be imposed upon the data sources. The design of the initial output reports for TRIP, therefore, was significantly influenced by the data definitions acquired in Task 1.

The Task 2 activities were completed in January 1979. A detailed presentation of the initial TRIP Data Bank scope and definition is contained in DRC Report Number E-4894U.

6.3 TASK 3 -- ESTABLISH/PRIORITIZE RAPID RAIL EQUIPMENT LISTS

The activities of Task 3 are illustrated in Figure 6-4. The objectives of the Task 3 effort were to:

- Establish a uniform system of rail transit vehicle component identification that can be used for the merging of data on these components into the TRIP Data Bank;
- Identify pilot rail transit equipment to be monitored by the TRIP Experimental Data Bank;
- Develop operating procedures for modifying the list of components being monitored by the TRIP Data Bank;
- Establish a system of cross-referencing components by parameters which describe the characteristics, performance, and reliability of the components.

The work conducted in Task 3 was based upon inputs from the completed Task 1 effort and upon the concurrent work conducted for Task 2 . The approach used for the Task 3 effort was to:

- Define the types of information that would be needed to identify transit vehicle components and to acquire same;
- Define the types and content of equipment lists that would be needed to establish and operate the TRIP Data Bank;
- Develop and demonstrate a coding scheme to support component identification and integration into a common data bank;

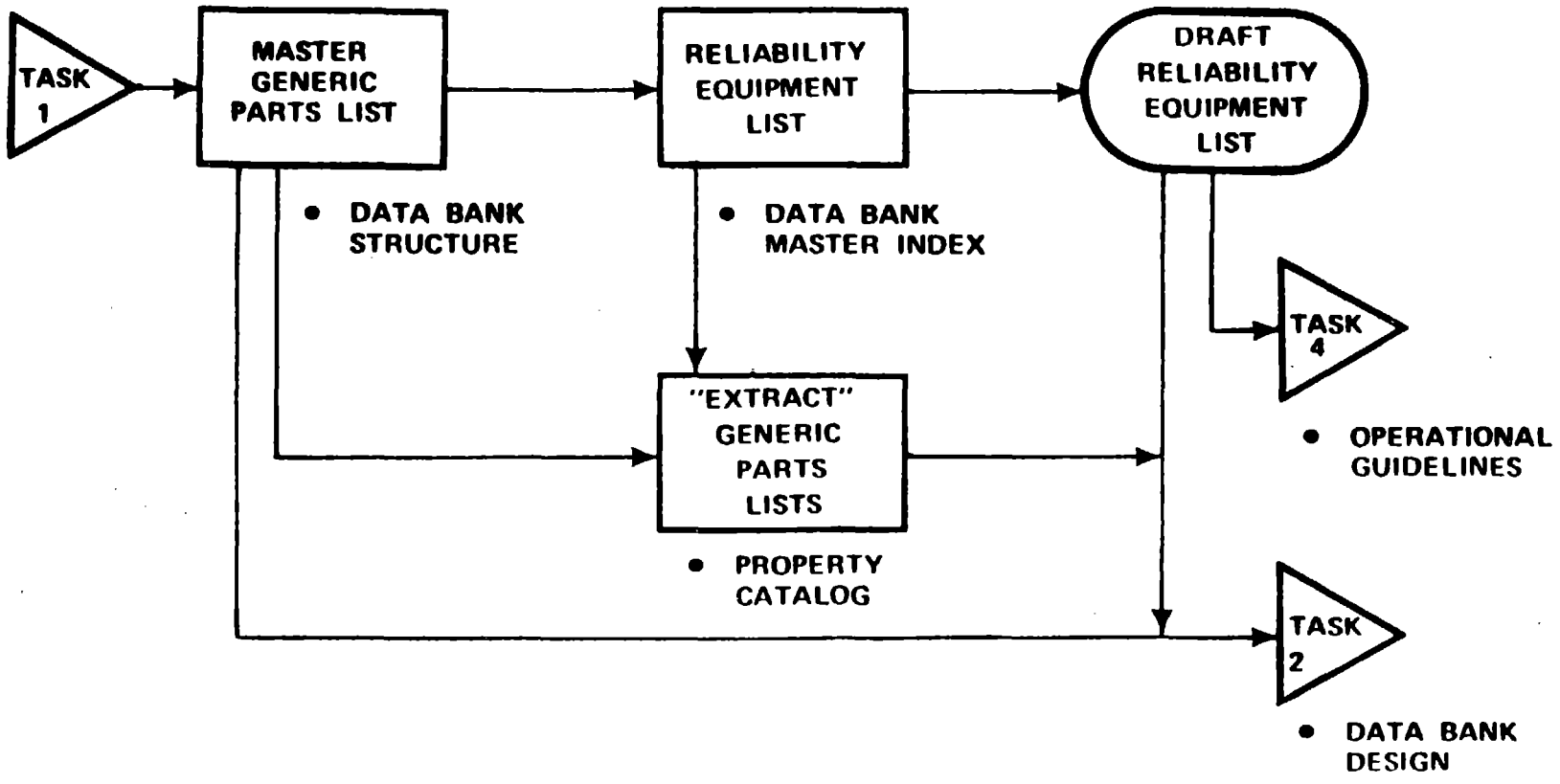

FIGURE 6-4. DEVELOP RELIABILITY EQUIPMENT LIST (TASK 3)

- Define the types of cross-referencing information that would be needed to supplement the reliability information of the data bank output reports and provide a perspective for interpreting this reliability information.

The Task 3 effort resulted in the definition of the following elements of the TRIP Data Bank:

- Generic Serial Number (GSN);
- Generic Part Number (GPN);
- Generic Parts List (GPL);
- Master Generic Parts List (MGPL);
- Reliability Equipment List (REL);
- Master Reliability Equipment List (MREL);
- Parametric Characteristics List (PCL).

The preliminary definitions of these elements are contained in DRC Report Number E-4895U.

The Task 3 effort also resulted in the development of the methodologies necessary to define the basic structure of the TRIP Data Bank through transit vehicle equipment lists. The first draft of the operating procedures for developing and modifying these equipment lists is contained in DRC Report Number E-4896U.

Development of the operating procedures was completed in January 1979. This methodology was then applied to the preparation of Generic Parts Lists for the first five participants in the Experimental Data Bank. The GPLs for BART and WMATA were completed in June 1979; for PATCO and CTA in September 1979; and for NYCTA in January 1980.

6.4 TASK 4 -- DEFINE/RECOMMEND/PREPARE TRIP GUIDLINES

The activities of Task 4 are illustrated in Figure 6-5. The objective of Task 4 was to produce a guidelines document for participants in TRIP describing the operation, capabilities, and use of the TRIP Data Bank.

An interim report (DRC Report Number E-4998U) was published in April 1979 which was based upon the preliminary definition of the TRIP Data Bank that emerged from the efforts of Tasks 1 - 3. This document provided TRIP participants with an overview of the (then emerging) Data Bank design and operation. Procedures for submitting data and a description of the output reports to be

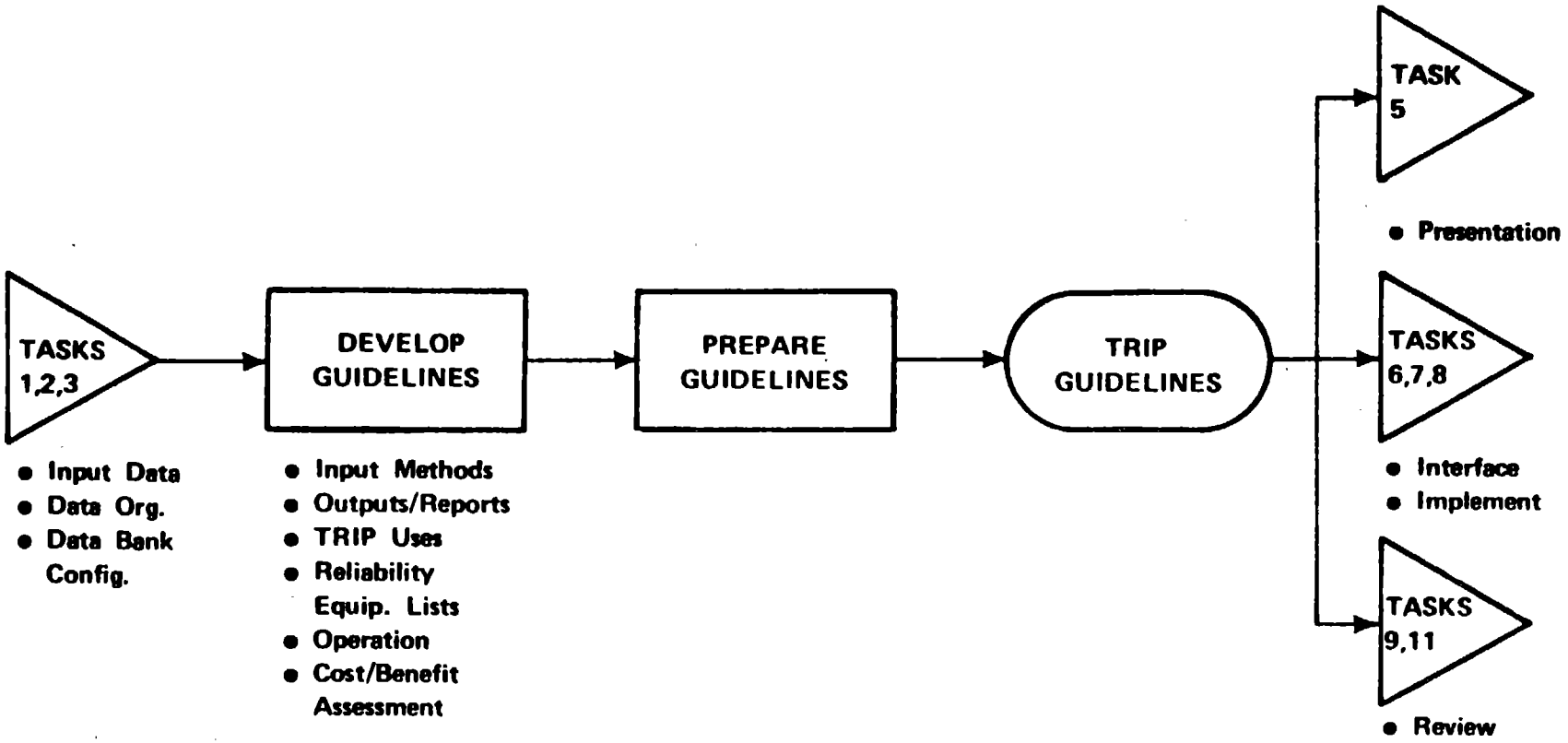

FIGURE 6-5. DEFINE/RECOMMEND/PREPARE GUIDELINES (TASK 4)

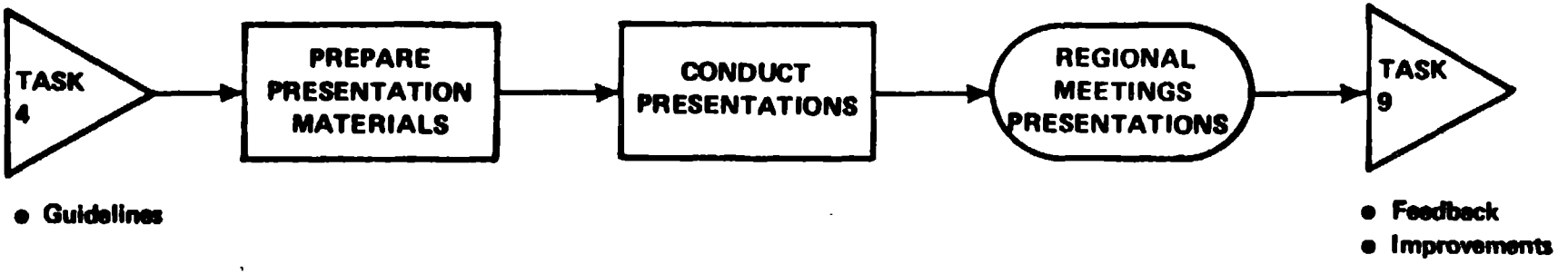

FIGURE 6-6. PREPARE/CONDUCT REGIONAL MEETING PRESENTATIONS (TASK 5)

produced were also included in the interim guidelines document.

The Task 4 effort focused the results of Tasks 1 - 3 into a concise definition of the TRIP Data Bank. It was from this definition that the operation of and data submission to the Experimental Data Bank (EDB) were implemented in Tasks 7 & 8. The guidelines that emerged from Task 4 also formed the basis of the activities performed in Tasks 5 & 6.

The Task 4 guidelines document was subsequently revised to incorporate the many enhancements and changes that occurred during the development, operation, and refinement of the TRIP EDB during Tasks 7 - 9. The revised Task 4 document was published in January 1981 as "TRIP Participants Guidelines", DRC Final Report Number R-339U.

6.5 TASK 5 -- PREPARE/CONDUCT REGIONAL MEETING PRESENTATIONS

The activities of Task 5 are illustrated in Figure 6-6. The purpose of Task 5 was to conduct regional meetings designed to familiarize the transit properties with the operation and use of TRIP. These meetings were held at PATCO, WMATA, CTA, GCRTA, and NYCTA. The meetings consisted of presentations by the Government Technical Monitor for TRIP, Mr. Richard H. Robichaud, and the DRC TRIP Program Manager, Mr. Stanley B. Limpert. The TRIP presentations were given in two parts; (1) A morning executive session providing a broad overview of the program's operation and potential uses; (2) An afternoon detailed session explaining the mechanics of data entry, storage, and extraction. Each session was followed by a question and answer period. The questions received dealt primarily with the influence TRIP will have on:

- Specifications for new rail equipment;
- Upgrading data reporting at a given property;
- Warranty assurance;
- Production and use of special reports.

The regional meetings also provided a forum for discussing data collection and submission procedures that were to be implemented for TRIP at each of the properties visited.

6.6 TASK 6 -- RAILCAR STANDARDIZATION RELIABILITY PLAN

The activities of Task 6 are illustrated in Figure 6-7. The objective of the Task 6 effort was to produce a Reliability

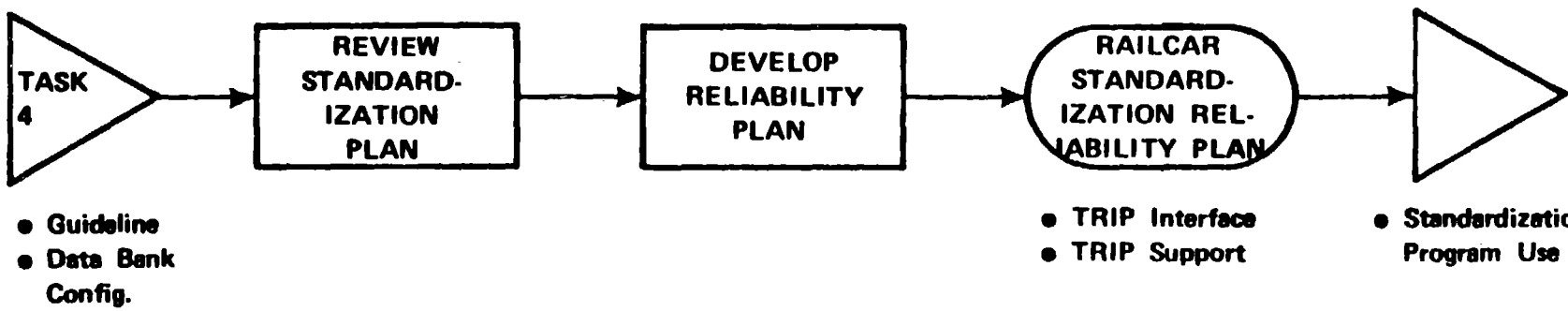

FIGURE 6-7. RAILCAR STANDARDIZATION RELIABILITY PLAN (TASK 6)

Verification Demonstration Plan for Rapid Rail Vehicles. The purpose of the plan was to provide an interface between TRIP and the Railcar Standardization Program.

The Reliability Verification Demonstration (RVD) Plan was first published as a draft report (DRC Report Number E-5150U) in August 1979. The purpose of the document was to familiarize potential users of TRIP with the Data Bank capabilities and data requirements as they pertain to the conduct of a Reliability Verification Demonstration Program. A second draft was produced in October 1979 which, in contrast to the first draft, placed more emphasis on the RVD Plan itself.

These two drafts were integrated into a single final report (DRC Report Number R-340U) and published in April 1980 as "TRIP Reliability Verification Demonstration Plan for Rapid Rail Vehicles". This document was prepared as an applications manual for the TRIP Data Bank. It provides the user with both an overview of TRIP and the TRIP Data Bank, and guidelines for planning and conducting a Reliability Verification Demonstration Program using the TRIP Data Bank to collect and process the data collected during the program.

6.7 TASKS 7 & 11 -- TRIP EDB DATA PREPARATION ASSISTANCE

The activities of Task 7 are illustrated in Figure 6-8. There were three major objectives to Task 7:

- Establish and maintain a liaison with each transit property supplying data to the TRIP Experimental Data Bank (EDB);
- Assist each property with developing and implementing procedures for submitting data to the EDB;
- Assist each property as required with data submission.

Task 7 was performed concurrently with Tasks 8 & 9. The primary liaisons with each transit property were established early in the program through the American Public Transit Association (APTA) TRIP Liaison Board. Working relationships were established with the representatives and other personnel of the transit properties during the performance of earlier tasks in the program.

Routine data submission was begun with the initial five participating properties (BART, WMATA, PATCO, CTA, and NYCTA, in that order) as the EDB was implemented to accept and process their data.

A major philosophy of TRIP is that data would be accepted

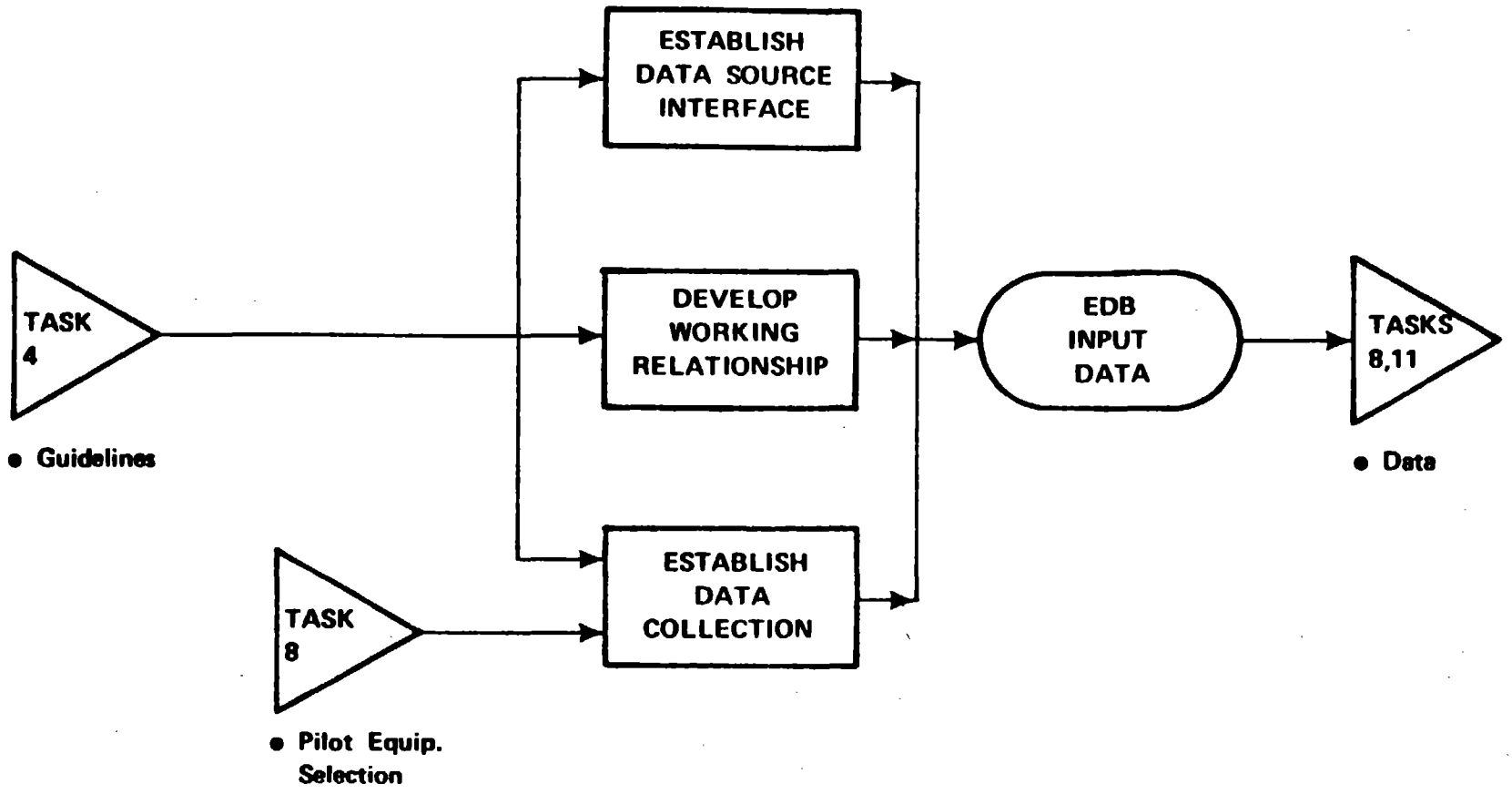

FIGURE 6-8. EXPERIMENTAL DATA BANK (EDB) DATA PREPARATION ASSISTANCE (TASK 7)

from transit properties in its organic form. "Data preparation assistance" was subsequently incorporated into the very design of the EDB in the form of interactive programs to enter data from hard-copy forms generated by the properties, with the data entry labor being provided by TRIP under Task 7. Similarly for magnetic tape data submission, procedures and programs were set up to copy the data from the property tapes onto DRC tapes so that the property tapes could be returned for recycling. The cost of the magnetic tape itself was thus eliminated from the cost to the property of TRIP participation.

A unique case was encountered at PATCO where input data was in the form of punched cards. In order to facilitate handling, data preparation assistance to PATCO consisted of subcontracting with a local (to PATCO) computer service bureau to load the data from the cards onto a magnetic tape. The magnetic tape was thus used as the input media to the EDB with the program assuming the cost of media conversion.

When the period of performance for Task 7 expired in September 1980, data preparation assistance transferred to Task 11 of the contract.

6.8 TASKS 8 & 12 -- ESTABLISH/OPERATE EXPERIMENTAL DATA BANK

The activities of Task 8 are illustrated in Figure 6-9. The objective of Task 8 was to establish and operate an Experimental Data Bank (EDB) as a prototype or model of the TRIP Data Bank for the purpose of validating and refining the Data Bank definition and operating guidelines developed in Task 4.

The design and implementation of the EDB began early in 1979. The APTA TRIP Liaison Board recommended three vehicle subsystems (doors and door controls, propulsion, and friction brakes) as the "pilot equipment" to be monitored by the EDB. Using the procedures and definitions developed during Task 3, Generic Parts Lists for these three systems were developed for BART and WMATA. (Changing circumstances at CTA, NYCTA, and PATCO forced a postponement in the development of their GPLs.) Software development for the EDB proceeded during the first half of 1979, and by the end of July, the EDB was ready for testing.

Software acceptance tests were successfully conducted from July 30 to August 3, 1979. On August 6, 1979, the TRIP Experimental Data Bank began operation with the input of July data from BART and WMATA. EDB refinement and expansion began on August 7th and have been on-going activities ever since.

Expansion of the "input side" of the EDB included the initiation of data entry for CTA and PATCO in November 1979, and for NYCTA in February 1980. In spite of the later dates for the

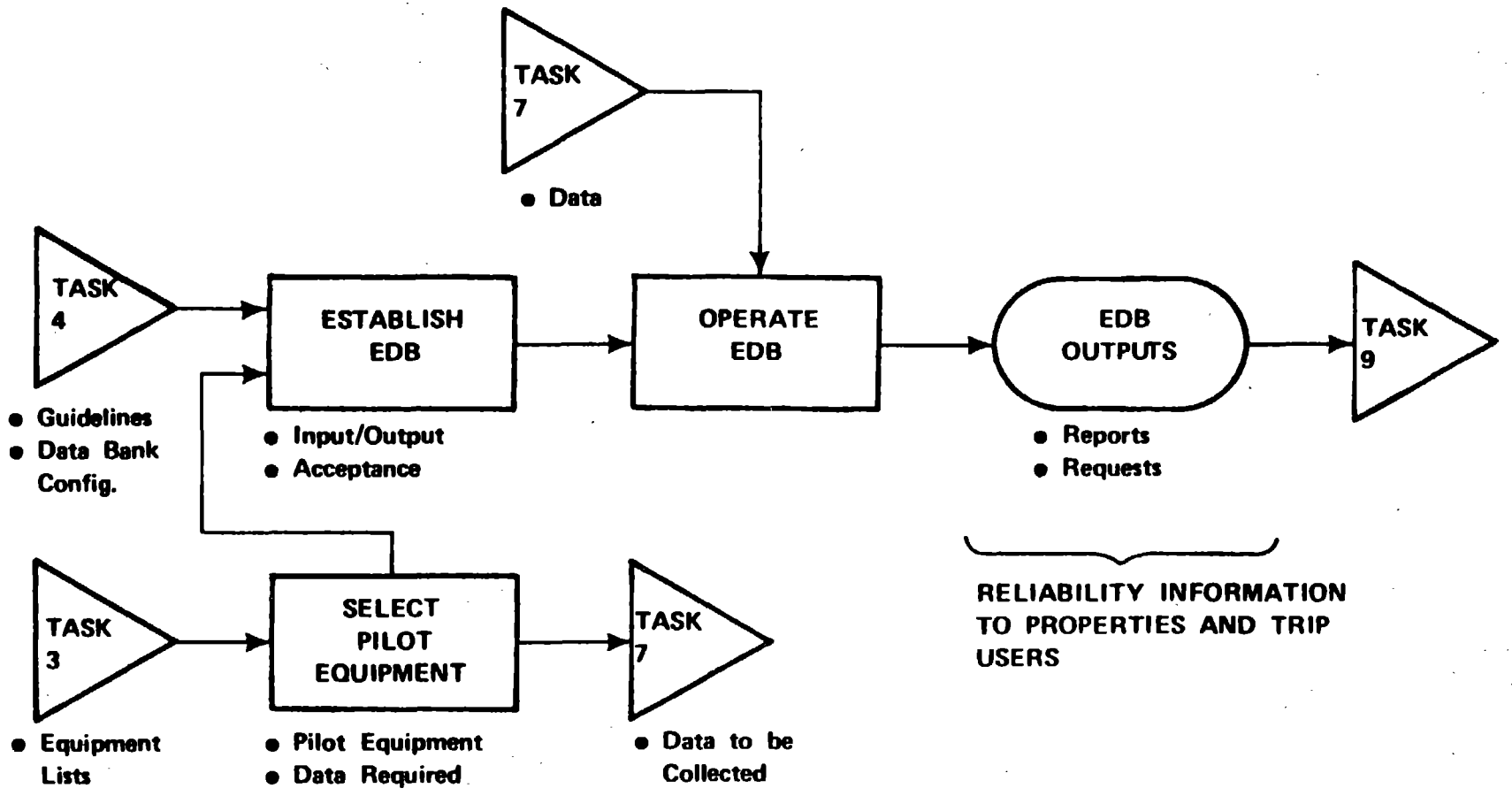

FIGURE 6-9. ESTABLISH/OPERATE EXPERIMENTAL DATA BANK (TASK 8)

initiation of data entry, these properties also submitted historical data so that the EDB contains data going back to July 1, 1979, for BART, NYCTA, AND WMATA, and August 1, 1979, for CTA and PATCO.

The first EDB Output Report was published in September, 1979, and contained the July data from BART and WMATA. The TRIP Liaison Board reviewed the report and recommended several modifications to format and content. EDB Output Reports were subsequently published during Task 8 in November, 1979 (August and September data), March, 1980 (November, 1979, data) and July 1980 (March data).

It was on the "output side" of the EDB where emphasis on the "experimental" nature of the data bank occurred. Each EDB Output Report was a major revision of the previous report in terms of both format and content. Methods of presenting the data, level of detail, accuracy and validity, statistical significance, all of these, and more, were of concern to the Liaison Board members, and their concern was reflected in the high level of interest expressed in the presentation of information from the EDB.

At the 8th meeting of the TRIP Liaison Board (July 1980), the EDB Output Report format was changed from one volume having seven sections to seven separate volumes, one for the industry, and one for each of the six participating properties. This format has remained in effect ever since.

The first "Special Reports" were also presented to the Liaison Board at their 8th meeting. Three reports were produced for this meeting. The first report contained a detailed (by Generic Part Number) inventory of data records contained in the TRIP Data Base for the period January 1 - March 31, 1980. The second Special Report contained a recapitulation of the detailed Data Base inventory showing the results aggregated to the 3rd, 4th, and 5th (of 8) levels of indenture in the Generic Part Number. This report was incorporated into the monthly Output Report by the Liaison Board at that meeting. The Third Special Report displayed, in a matrix format, the data elements being provided by each property in each of the four dynamic data record types.

When the period of performance for Task 8 expired in September 1980, EDB operation transferred to Task 12 of the contract.

6.9 TASK 9 -- MODIFY/IMPROVE TRIP OPERATING PROCEDURES

The activities of Task 9 are illustrated in Figure 6-10. The major objective of Task 9 was to monitor the operation of the Experimental Data Bank for the purpose of identifying areas in

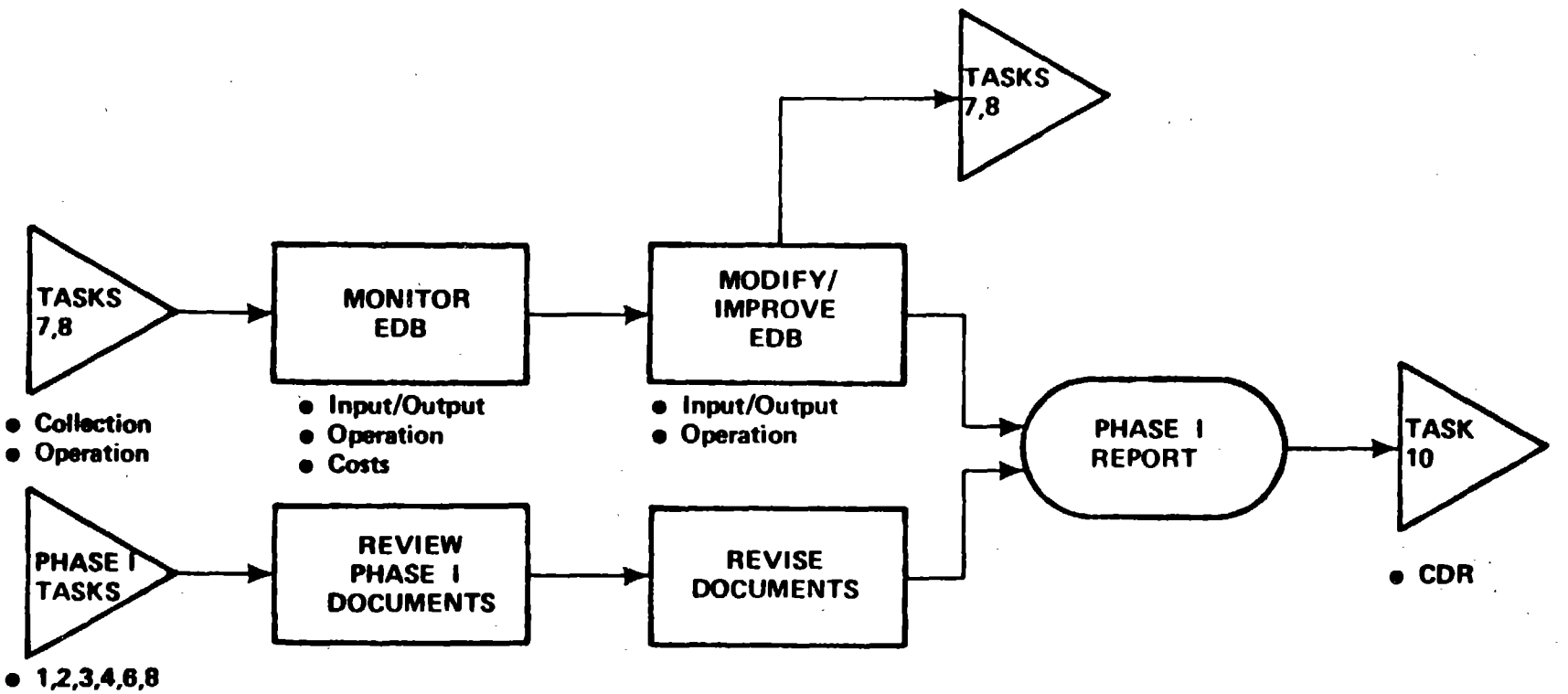

FIGURE 6-10. MODIFY/IMPROVE TRIP OPERATING PROCEDURES (TASK 9)

which improvement could be made.

The TRIP Data Bank definition that emerged from Tasks 1 - 4 was used as the cornerstone for EDB implementation in Tasks 7 & 8. Many of the operating procedures defined in the earlier stages of the program were quite speculative in nature since there was no previous industry experience with a data bank of the size and scope of that being developed for TRIP. Similarly, data definitions were provided in vacuo by each property without consideration of subtle variances within the industry. These subtleties were not exposed until after EDB operation had commenced and the first Output Report published.

Publication of Output Reports from the EDB has thus been a major source of input for system modifications. The Liaison Board had been unable to reach agreement within itself during the early design stages of the TRIP Data Bank regarding the format and content of output reports. A "first cut" was subsequently made by DRC and presented to the Liaison Board in the EDB Output Report for the Month of July 1979, DRC Report Number E-5206U.

The 5th TRIP Liaison Board meeting, which was held in September 1979, marked a turning point in the program. With the July Output Report in hand, the Liaison Board was stimulated into thinking in more concrete terms about the reporting capability of TRIP. The emphasis on Output Report refinement has remained ever since.

In addition to improvements inspired by "external" stimuli, many changes were also made to make the EDB software more cost-effective to operate. Various software "modules" were linked into logical jobstreams to eliminate stop/restart delays. "Permanent files", which formerly had been used to pass data from one software module to another, were converted to "temporary files" which exist only while the jobstream is being executed thus reducing system storage costs on the computer.

On-line storage of the Data Base file itself became the cost high-driver after only a few months of EDB operation. Storage costs were significantly reduced by convertng to magnetic tape as the bulk storage media for the Data Base and Data Base Dicitonary. This change had only a minimal impact on system operation since all of the software modules and jobstreams used to manipulate the Data Base were "batch jobs" which do not require on-line access to the Data Base.

Although the period of performance for Task 9 contractually expired in September 1980, the spirit of Task 9 remained as EDB operation transitioned into Tasks 11 & 12 (Contract Phase II). Funding allocations for Tasks 11 & 12 were sufficient to maintain a nominal level of EDB refinement and enhancement, and most of this effort has gone into accomodating the desires of the Liaison Board with regard to Output Report modification.

In spite of a major snafu in the mileage data supplied by CTA in July 1980, the EDB Output Report for the month of June 1980 was published in October. This report marked the beginning of "monthly" Output Report production. At their 9th meeting in October 1980, the Liaison Board expressed their desire that DRC publish "monthly" (as determined by scope and content) EDB Output Reports for each calendar month as all of the data (including corrections) for a given month is made available by the properties. This approach to routine report production recognized the logistics problems inherent in a voluntary program and thus refrained from imposing a fixed schedule.

EDB enhancement has continued throughout the remainder of Contract Number DOT-TSC-1559. Most of the recent refinements have been confined to Output Report revisions and streamlining of the report production process. Other areas of possible improvement have been identified and catalogued. Due to limited resources in the second phase of the contract, however, implementation of these improvements has been postponed.

6.10 TASK 10 -- CRITICAL DESIGN REVIEW PRESENTATION

The activities of Task 10 are illustrated in Figure 6-11. In the TSC Implementation Plan, TRIP consists of three phases: Phase I covers the planning, designing, and testing of a small-scale transit reliability data bank for a select group of rail and bus vehicle components; Phase II is the establishment and operation of a full-scale reliability data bank; Phase III is the expansion of Phase II to include other classes of transit equipment.

The purpose of the Critical Design Review (CDR) was to review Phase I activities and accomplishments, and to assess whether or not the time was appropriate to commence with Phase II of the TRIP Implementation Plan. The CDR of TRIP was held at APTA Headquarters in Washington, DC, on March 31, 1980. The CDR Committee, consisting of the TRIP Liaison Board representatives from the six properties participating in the EDB operation and representataives from APTA, UMTA, TSC, and DRC reviewed the preceeding 24 months of TRIP activity. The transit property representatives had previously been requested to submit their individual property's recommendations and comments concerning the development and operation of the EDB and future expansion of the EDB into a full-scale TRIP Data Bank.

The general concensus of the EDB property representatives was that TRIP is a worthwhile program and should be continued. Specific comments concerning the near-term future of TRIP are highlighted below:

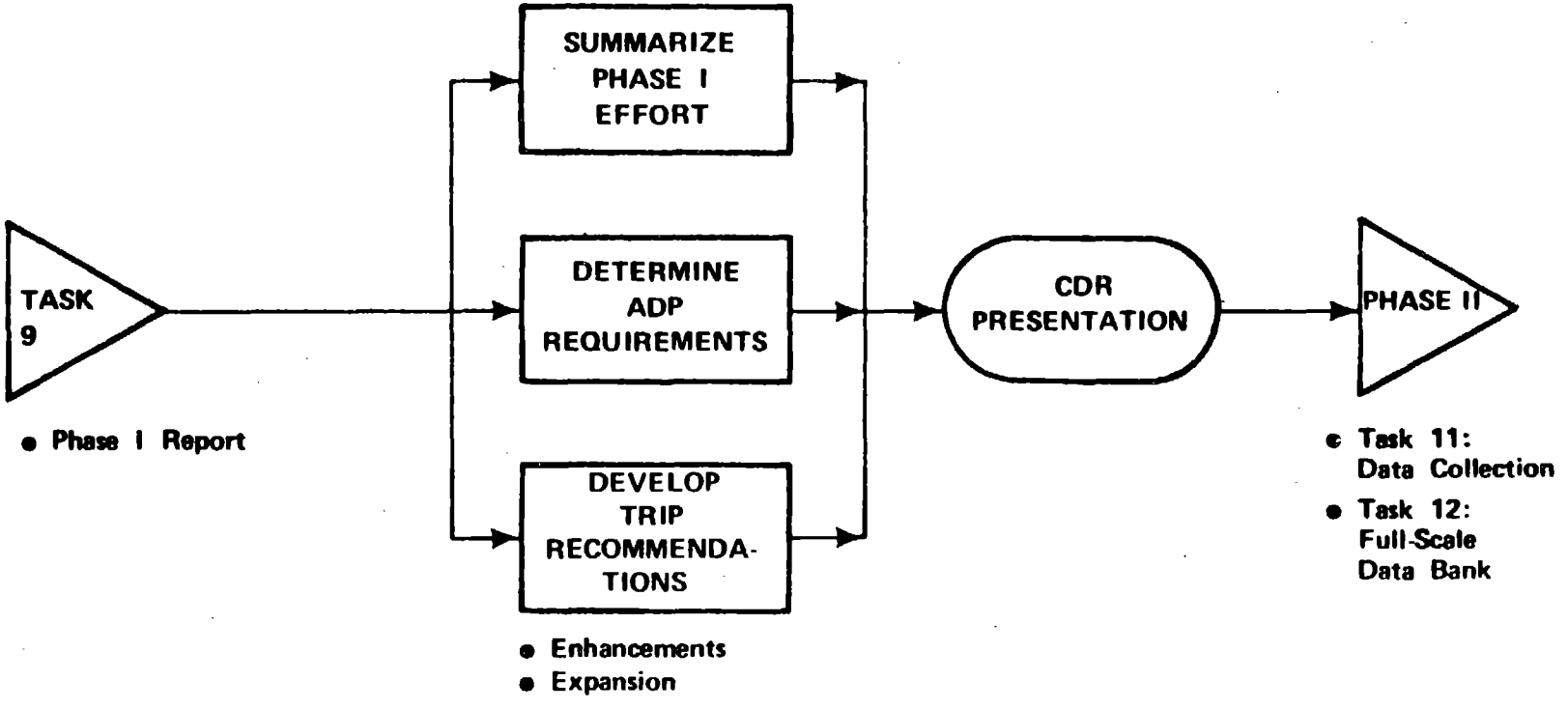

FIGURE 6-11. CRITICAL DESIGN REVIEW (CDR) PRESENTATION (TASK 10)

- The full benefit of TRIP has yet to be realized -- the major benefits will be derived from long-term operation of the Data Bank;

- Dynamics Research Corporation (DRC) should continue to operate the TRIP Experimental Data Bank for an additional year in order to allow more time to:

  - explore the full potential of the system;
  - develop output reports;
  - refine system operation;
  - develop more confidence in the system;

- A second CDR should take place one year hence to again consider the timing of EDB expansion into a full-scale system.

A full transcript of the proceedings from the technical discussions of the TRIP CDR is contained in DRC Report Number E-5505U.

Participation and interest in, as well as potential benefits from, Phase I indicate that TRIP EDB users (operating properties, consultants, Federal Government, and suppliers) want factual information from TRIP and are relying on TRIP's large quantity of readily available maintenance data to provide timely reports of equipment replacement experience.

Pending a favorable decision from the final Phase I CDR, Phase II will start a full-scale merged RRV and Bus TRIP Data Bank. It will be established and put on-line starting with the transfer of data from the RRV and Bus EDBs. The number of equipments initially monitored will be small, but as the capability expands, additional equipments will be monitored until failure data on all vehicle components are contained in the Data Bank.

A CDR of Phase II can then be performed to determine if Phase II accomplished its goals and if Phase III is justified. Phase III is envisioned as the expansion of the Data Bank and equipment monitored to cover UMTA responsibilities in Fare Collection, ATO/ATC, and track and structures. As other transportation equipments are incorporated, the TRIP Data Bank will become the UMTA National TRIP.

APPENDIX

REPORT OF NEW TECHNOLOGY

A significant amount of rail transit equipment reliability data was collected which aided in the establishment of a national transit reliability Data Bank. The Data Bank will promote the amalgamation of current reliability efforts within the transit industry; provide a focal point for a consolidated reliability effort; and assist the transit industry in creating, developing, and improving revenue service operations.