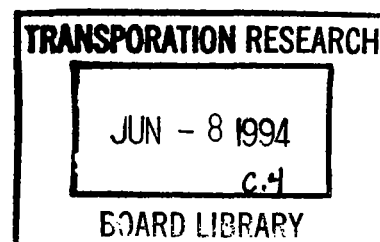


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SHRP-P-679

Long-Term Pavement Performance Information Management System Five-Year Report



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Indiana Department of Transportation

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M. Lee Powell, III
Ballenger Paving Company, Inc.

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Federal Highway Administration

Henry A. Thomason, Jr.
Texas Department of Transportation

Stanley I. Warshaw
National Institute of Standards and Technology

Roger L. Yarbrough
Apcon Corporation

Key SHRP Staff

Damian J. Kulash
Executive Director

Guy W. Hager
Implementation Manager

Edward T. Harrigan
Asphalt Program Manager

Kathryn Harrington-Hughes
Communications Director

Don M. Harriott
*Concrete & Structures/Highway
Operations Program Manager*

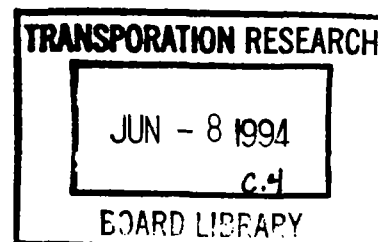
Neil F. Hawks
*Long-Term Pavement Performance
Program Manager*

Harry Jones
Finance & Administration Director

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SHRP-P-679

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Dr. William O. Hadley
Mr. Charlie Copeland
Hadley and Associates
Austin, Texas



Strategic Highway Research Program
National Research Council
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Project Manager: *A. Robert Raab*
Production Editor: *Marsha Barrett*
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Strategic Highway Research Program
National Academy of Sciences
2101 Constitution Avenue N.W.
Washington, DC 20418

(202) 334-3774

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SHRP-LTPP INFORMATION MANAGEMENT SYSTEM (IMS)

BACKGROUND

A major impediment to past pavement research efforts has been the lack of availability and access to comprehensive, diverse, yet consistent traffic, materials, structural, and climatic data for different pavement types. There is no doubt that data sets containing variable and inconsistent data make it extremely risky to develop inferential conclusions. Because of historic problems with data comprehensiveness, quality, and consistency, it is of strategic importance to develop a national database which can overcome these shortcomings and allow researchers to pursue long-term pavement performance studies with confidence.

The principal goal of the Strategic Highway Research Program's Long-Term Pavement Performance (SHRP-LTPP) study was the design of an approach for the collection of information and development of analysis procedures capable of providing short, intermediate, and long-term findings for improving overall pavement performance. Minimal improvements in highway performance will far exceed the entire cost of the SHRP-LTPP program.

As a consequence, a major activity of SHRP-LTPP was the establishment of a National Pavement Performance Database (NPPDB) to support the goals, objectives, and needs of LTPP program.

The SHRP-LTPP Overview Report should be consulted if the reader desires additional information concerning the overall LTPP program (Ref 1).

LTPP - INFORMATION MANAGEMENT SYSTEMS

From the outset, one of the basic objectives of the Strategic Highway Research Program (SHRP) was to establish a National Pavement Performance Database (NPPDB) to store all of the data collected and/or generated under the Long-Term Pavement Performance (LTPP) Program (Ref 2). The type of data collected in the LTPP program and stored in the National Pavement Performance Database (NPPDB) include the following:

- Inventory (as built)
- Materials Characterization
- Longitudinal Profile
- Deflection (FWD)
- Cross Profile
- Distress
- Friction
- Maintenance
- Rehabilitation
- Climate
- Traffic

An Information Management System (IMS) was developed in the SHRP-LTPP program to service the NPPDB within the LTPP program and is composed

of four regional systems (RIMS) and a central system (NIMS). The National Information Management System (NIMS) is the central system (Ref 3), which is comprised of the hardware and software systems that were assembled to house the NPPDB. This system is administered by and resides at the Transportation Research Board (TRB). The four regional systems are designated as Regional Information Management Systems (RIMS). LTPP data was generally received, checked, and entered at the RIMS by the four Regional Coordination Office Contractor (RCOC) personnel under the direction of a SHRP Regional Engineer (SRE). Periodic uploads were made from the RIMS to the NIMS.

A critical function of the IMS is the verification and validation of the accuracy and correctness of the data, received and stored within the national pavement performance database (NPPDB).

The NPPDB data must pass a number of IMS based Quality Assurance (QA) checks before being released to the public for review, compilation, analysis, and research. These checks verify the presence, reasonableness, accuracy, and validity of the data. The procedures for data checks, as well as, data uploads to the NIMS are critical elements in the SHRP-LTPP IMS.

SHRP-LTPP REGIONS

Regional offices were established to coordinate SHRP-LTPP related activities across the United States and Canada. Each region includes a number of states and/or provinces, with test sections located throughout

the defined boundaries. The regional centers operate as regional data collection and validation centers for pavement test section data.

The four SHRP regions were selected primarily based on climatic considerations (Ref 4). The regions, however, were adjusted to correspond to state boundaries as illustrated in Figure 1 (Ref 5). The North Atlantic region corresponds generally to a wet-freeze AASHTO classification, while the Southern region is situated primarily in a wet-nonfreeze zone. The North Central region is predominately wet-freeze, while the Western region contains both dry-freeze and dry-nonfreeze.

It should be noted that the climatic zone designations do not necessarily represent the environmental conditions at a specific location within that region. For example, a wet no-freeze region (e.g., west coast states) could in fact contain wet-freeze areas at higher elevations.

The IMS functions performed at the regions involved primarily data collection, data validation, and data entry. These are essential IMS elements since the regional staff have a working relationship with all of the data providers and the technical expertise to judge data quality.

Inventory, maintenance, rehabilitation, and traffic data are collected at the state level and forwarded to the appropriate regional center. The regional centers are responsible for the collection of test and monitoring data on the pavement sections. All data collected are entered in the RIMS through a menu-driven system or are loaded by programs

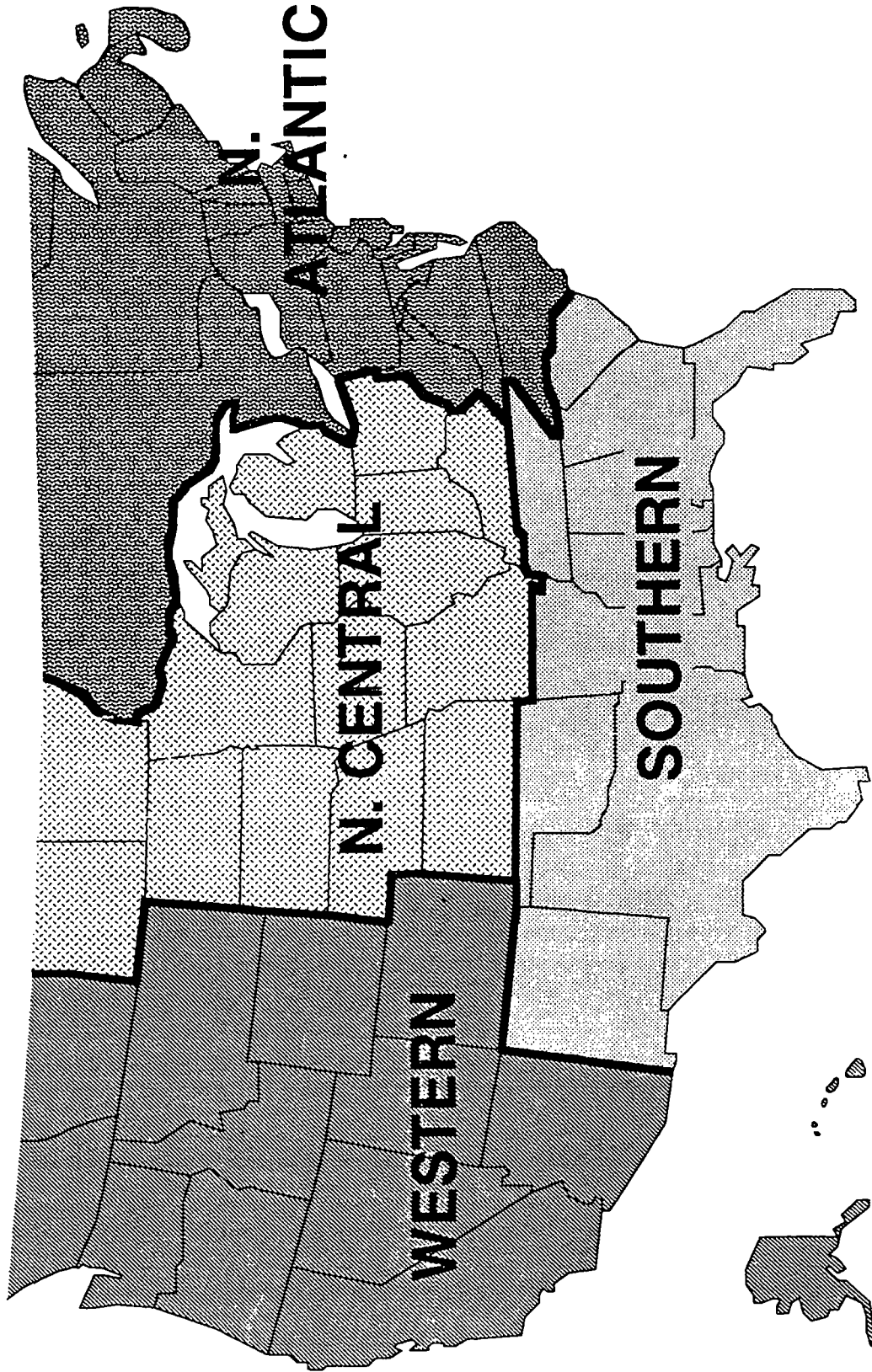


FIGURE 1
SHRP-LTPP Regional Boundaries

which read the data from machine-readable media. Quality checks are incorporated into all update programs, and reports are designed to provide additional checks. Pavement data are transferred to the NIMS after validation at the regional level.

DATA/INFORMATION SOURCES

INTRODUCTION

Several informational sources describe in detail the data housed within the LTPP database and how it was collected for the NPPDB. The SHRP LTPP Data Collection Guide (Ref 5) is the main source of data collection instruction and data sheets for the LTPP program. Detailed data collection guides have been developed for the materials characterization and sampling program and for most of the activities defined within the pavement monitoring program.

An IMS SCHEMA report describes the data structure as it is implemented in the ORACLE Relational Database Management System (DBMS) and illustrates the data tables (logical groups of data) and the fields (or data elements) contained within those tables. The schema also identifies the key (index) fields, and the data types associated with each field.

The IMS Data Dictionary report provides a more thorough description of each of the fields (or data elements) and contains various items of interest about each of the fields. The Data Dictionary includes two ranges of values, absolute and expected, which are used in the IMS process. The Absolute Range is defined by the maximum and minimum values that can be entered in a given field. Data values less than or greater than these values cannot be entered, hence the name "Absolute Range." The "Expected Range" in data values is the range an experienced pavement

researchers "expect" based on engineering knowledge and judgment. Data outside this expected range triggers a warning upon data entry and will not pass the QA/QC range checks.

The IMS Schema and Data Dictionary reports are updated as the IMS develops and evolves and are provided on disk to researchers requesting SHRP data. The current versions of the reports are normally included in the latest version of the Database Structure Reference Manual (Ref 6) of the LTPP IMS Manuals.

DATA COLLECTION GUIDE

The primary purpose of the Data Collection Guide (DCG) is to provide a uniform basis for data collection during long-term monitoring of the performance of pavement test sections under the LTPP study. Data items considered to be of high priority in achieving the goals of LTPP are identified, but other data items that are desirable for inclusion in the NPPDB for other purposes are also included. The guide recognizes that modifications and additions will be necessary as technical advances are made and other research needs become better defined. To insure that critical data will be available for the future development of pavement performance models, emphasis is particularly placed on collection of those data items considered essential to long-term pavement performance.

The DCG was initially developed for use with the General Pavement Study (GPS) sections, but many of the DCG sheets are also used directly with the Specific Pavement Study (SPS) sections. Additional data sheets

and tables have been designed and used to record data collected from the SPS project sections. These additional data sheets and data collection requirements are described in SPS Guideline documents. (Ref 7)

DCG Chapters

The data collection activities and the database structure were organized in logical segments to promote communication, sufficiency in data collection and efficiency in handling data. The information has been categorized in the following DCG chapters which have also become the data modules within the NPPDB.

<u>Chapter</u>	<u>Data Type/Module</u>	<u>Module Abbreviation</u>
2.	Inventory	INV
3.	Monitoring	MON
4.	Traffic	TRF
5.	Environmental (climate)	ENV
6.	Maintenance	MNT
7.	Rehabilitation	RHB
8.	Materials Characterization	TST

MATERIALS GUIDES

Data collection methodology and reporting procedures for the Materials and Testing program (testing data module, TST, in the IMS) are extensively described in two basic documents and several Directives. The

basic documents are the SHRP-LTPP Guide for Field Materials Sampling, Testing, and Handling (Ref 8) and the SHRP-LTPP Interim Guide for Laboratory Material Handling and Testing (PCC, Bituminous Materials, Aggregates and Soils) (Ref 9). These documents contain the protocols for various testing and handling procedures and include appropriate data sheets.

MONITORING DATA COLLECTION MANUALS

The Data Collection Guide (Ref 5) and SHRP-LTPP Manual for Falling Weight Deflectometer (FWD) Testing (Ref 10) provide guidelines concerning test locations and test types and conditions under which data collection was undertaken.

The basic method of obtaining distress data from 35mm photographic film is presented in a PASCO Film Interpretation Manual (Ref 11) while the guidelines for performing a manual or visual surface distress survey are presented in the Manual for Field Distress Surveys (Ref 12) and the Distress Identification Manual for the LTPP Studies (Ref 13).

Guidelines for performing longitudinal profile measurements are presented in the SHRP-LTPP Manual for profile measurements (Ref 14) while the method used to obtain transverse (or cross) profile data for the SHRP-LTPP sites is described in a PASCO Roadrecon Operations Manual (Ref 15).

The climatic data is stored in the National Pavement Performance Database and was derived from National Oceanic and Atmospheric

Administration (NOAA) weather data. The data elements are described in an Earth-Info Draft document (Ref 16).

SCHEMA REPORT

The SCHEMA Report defines the various tables (categories of data) and fields (individual pieces of data) housed within the LTPP database (NPPDB) and identifies how they are stored in the database. In addition, the schema identifies within the database the fields which belong together as a record; the records which reside in a certain table, and the tables that comprise a specific data module.

Each of the data modules, (e.g., inventory, traffic, distress, etc.) is composed of numerous tables (encompassing one or more data sheets) which represent a collection of information about a specific item, e.g., the location of all LTPP pavement sections by state, elevation, coordinates, etc. Each IMS table is a collection of records that contains data about a specific pavement section. Each record is composed of individual fields that represent the smallest category of information in the database.

Excerpts from the inventory (INV) data module of the IMS Schema are presented in Figure 2. Specifically, the INV_AGE and INV_GENERAL tables are included in the figure. These tables can be used to aid in explaining the various aspects of an IMS Schema Report.

INV_AGE Age of pavement data (Data Sheet: Inventory 4).

<u>Key Fields</u>	SHRP_ID	NUMBER(4,0)
	STATE_CODE	NUMBER(2,0)
	CONSTRUCTION_NO	NUMBER(2,0)
	CONSTRUCTION_DATE	DATE(7)
<u>Other Fields</u>	TRAFFIC_OPEN_DATE	DATE(7)
	CONSTRUCTION_COST	NUMBER(5,0)
	YEAR_WIDENED	NUMBER(2,0)
	ORIGINAL_NO_LANES	NUMBER(1,0)
	FINAL_NO_LANES	NUMBER(1,0)
	LANE_ADDED_NO	NUMBER(1,0)
	RECORD_STATUS	CHAR(1)

INV_GENERAL Geometric, drainage, and other general information requiring the construction number. (Data Sheets: Inventory 1, 2, 3).

<u>Key Fields</u>	SHRP_ID	NUMBER(4,0)
	STATE_CODE	NUMBER(2,0)
	CONSTRUCTION_NO	NUMBER(2,0)
<u>Other Fields</u>	NO_OF_LANES	NUMBER(1,0)
	PAVEMENT_TYPE	NUMBER(2,0)
	PAVEMENT_TYPE_OTHER	CHAR(40)
	LANE_WIDTH	NUMBER(3,1)
	LANE_NO	NUMBER(1,0)
	SUB_DRAINAGE_LOCATION	NUMBER(1,0)
	SUB_DRAINAGE_TYPE	NUMBER(1,0)
	SUB_DRAINAGE_TYPE_OTHER	CHAR(40)
	LONG_DRAIN_DIAMETER	NUMBER(2,1)
	LATERALS_SPACING	NUMBER(3,0)
	DEPTH_TO_RIGID	NUMBER(3,1)
	RECORD_STATUS	CHAR(1)

FIGURE 2
SCHEMA reports for two tables developed from Inventory Data.2

For example, one of the records in the Inventory Module is the type of pavement surface (i.e., PAVEMENT_TYPE) existing when a specific pavement section (SHRP_ID and STATE_CODE) was accepted in the LTPP program. This field and many other closely related fields (e.g., LANE_WIDTH, SUB_DRAINAGE_TYPE, etc.) which further describe the pavement section are combined to form the IMS INV_GENERAL table. The inventory data is related to one of the seven modules comprising the LTPP IMS database.

Key Fields

Key Fields are the fields defined within a table which identify a unique set of fields (data set) that form a record. Similar to indices for arrays, the key fields define how the data will be stored or retrieved. The two principal key fields within the IMS are SHRP_ID and STATE_CODE, which are the two unique fields that identify a specific pavement section. All data for a particular section is stored based on some form of relationship with these two fields. The key fields are identified in the schema by left-justified names composed of all capital letters. For example, the key fields for IMS table INV_AGE are SHRP_ID, STATE_CODE, CONSTRUCTION_NO and CONSTRUCTION_DATE while the key fields for table INV_GENERAL are SHRP_ID, STATE_CODE, and CONSTRUCTION_NO.

Other Fields

The Other Fields (i.e., besides the key fields) are used to identify the individual pieces of data in records and are identified by capitalized

name combinations indented 1 column space to the right. For example, the Other Fields in IMS Table INV_AGE which are related to the project identified by the key fields are TRAFFIC_OPEN_DATE, CONSTRUCTION_COST, YEAR_WIDENED, ORIGINAL_NO_LANES, FINAL_NO_LANE, LANE_ADDED_NO, and RECORD_STATUS.

These Other Fields can be composed of several types or forms, such as NUMBER, CHAR(acter), or DATE. The assignment of numerical fields (or NUMBER) must be made with a knowledge of the expected ranges of values, based on engineering knowledge and judgments. The assignment of a numeric value including the total number of digits and decimal digits implies an absolute range that will be stored in the IMS database. For example NUMBER(5,2) implies a maximum of five total digits with two of the digits located to the right of the decimal, e.g., 123.45. Therefore the maximum value that could be stored in this field is 999.99 and the minimum value would be -99.99 (the minus sign counts as a digit). Therefore, the NUMBER(5,2) sets an absolute value range for numeric fields. CHAR(10) type fields are alphanumeric fields that may contain any valid alphanumeric character up to the number specified in the parenthesis, such as 10 in this example.

DATA DICTIONARY REPORT

The Data Dictionary is a supplemental report which provides the IMS user with descriptions of the various fields or data elements contained within each table. The data dictionary entry identifies the origin of the data (i.e., what data sheet and item, etc.), and presents a brief

description of the field (data type), data ranges and associated information. An excerpt of the Data dictionary for portions of the (SKID) data module is presented in Figure 3.

The rules associated with the IMS Data Dictionary determine the amount and type of data which may be input in each field. For example, the Data Dictionary defines the length of a field, the type of data to be entered (e.g., numeric, alphabetic, date, etc.), and the acceptable ranges for the data (e.g., a positive number from 1 to 100). For example in Figure 3 it can be seen that the SKID_SURFACE is identified as a number (1.0) data type or integer (i.e., length of 1 with no decimal). The surface type can then be either an AC (1), Concrete (2), surface treatment (3), or other (4).

Range checks are conducted to ensure that the numeric field values fall within certain defined limits. Some ranges are absolute and define the maximum (and/or minimum) values possible for that data element. For example in a sieve analysis the value must be less than or equal to 100% passing a sieve (i.e., maximum limit of 100) or greater than or equal to 0% passing a sieve (i.e., minimum limit of 0). In this case the absolute range would be 0 to 100. Other range checks represent comparison of numeric data with normally expected limits of the data element (e.g., a SKID_NO_BEGIN or SKID_NO_END is expected to be between 30 and 70 for treaded tires).

SKID_NO_BEGIN

IMS Table: MON_SKID

The skid number (friction number) between the vehicle wheel tire and the pavement at the beginning of the section (between station 0-2).

Data Type:	NUMBER(2,0)	
Units:	Percent	Validation:
QA Minimum:	X	QA Range: 30 - 70
Source:	MONITORING SKID SHEET 1.	Item number: 3

SKID_NO_END

IMS Table: MON_SKID

The skid number (friction number) between the vehicle wheel tire and the pavement at the end of the section (between station 3-5).

Data Type:	NUMBER(2,0)	
Units:	Percent	Validation:
QA Minimum:	X	QA Range: 30 - 70
Source:	MONITORING SKID SHEET 1.	Item number: 4

SKID_SPEED

IMS Table: MON_SKID

The speed at which the vehicle was traveling when the skid numbers were obtained.

Data Type:	NUMBER(2,0)	
Units:	MPH	Validation:
QA Minimum:	X	QA Range: 35 - 45
Source:	MONITORING SKID SHEET 1.	Item number: 5

SKID_SURFACE

IMS Table: MON_SKID

Code for the general type of pavement surface.

Data Type:	NUMBER(1,0)	
Units:		Validation: AC (1), Concrete (2), Surface Treatment (3), Other (4)
QA Minimum:		QA Range:
Source:	MONITORING SKID SHEET 1	Item Number: 11

FIGURE 3
Data Dictionary Excerpt for Friction (SKID).

When data is entered in a field, the computer QA program checks the data in the field against the format specified for that field in the Data Dictionary. If the data falls outside the normal expected range, but within the absolute limits, the computer displays warning messages but allows data entry to continue. In this situation the data can be double checked for accuracy. If the data falls outside absolute limits, an error message is displayed, the value will not be allowed as input, and data entry correction is required before moving from the particular field.

Certain fields (particularly the primary Key Fields) are mandatory and cannot be successfully completed until an acceptable entry has been entered in that field. Since some records depend on information residing in basic parent records, data for parent records must be successfully entered before data can be entered in subsequent dependent records or an error message will occur.

DATA TYPES AND ELEMENTS AND SOURCES OF THE DATA

The NPPDB (or NIMS) is the central repository for all LTPP data. The NPPDB consists of data uploaded from the four regional centers along with data entered directly at the national center. All requests for LTPP information or data files from the user community are processed at the NPPDB (or NIMS). The data processed directly at the NIMS includes the environmental data and all administrative data (e.g., information for new pavement sections, experiment assignments, and codes tables). Each region is responsible for the data on the SHRP pavement sections located within

its assigned states; therefore, there is no overlap between states of the data collected. An IMS Data Processing summary is presented in Table 1.

The process of transferring data from the RIMS to the NIMS is termed a "NIMS upload," and the collection of programs that control the process is called "NIMS upload software." Administrative data are periodically sent to the RIMS. All new procedures, modifications to the IMS structure, and code changes are also initiated at the NIMS. This process of transferring data from the NIMS to the RIMS is termed a "NIMS download." The procedures for the transfer of information are described in the SHRP Programmer's Reference Manual (Ref 17) and in the LTPP NIMS and RIMS User Manuals (Refs 18,19).

INVENTORY

Inventory data was developed from state records of a construction job and characterize in general the pavement condition, status and structure for a segment of a roadway which includes the individual SHRP test section. The inventory data, therefore, is not necessarily representative of the specific conditions of the SHRP section at time of inclusion in the LTPP study. Inventory data include location of the GPS section, pavement structure, material properties, layer composition, construction improvements, anticipated traffic, and other background information about the LTPP section.

TABLE 1
IMS Data Processing Summary (Ref 5)

Data Type	Collection Frequency	Source
Inventory	Once	SHA
Maintenance	Per activity	SHA
Monitoring		
FWD	Varies (1)	FWD
Distress	Every 1 to 2 years	PASCO/Manual
Transverse Profile	Every 1 to 2 years	PASCO/Dipstick
Profile	Annual	Profilometer/ Dipstick
Skid	Every 2 years	SHA
Rehabilitation	Per activity	SHA
Materials Testing	Once	SHRP Testing Lab
Traffic	Varies (2)	NTDB
Climate	Update every 2 years	NCDB (3)

- (1) 12-14 times per year in alternate years for seasonal monitoring; once every 5 years for other sites
- (2) Continuous Weigh-in-Motion (WIM) or Continuous Automatic Vehicle Classification (AVC) plus seasonal WIM
- (3) Data obtained from National Climatic Data Center (NCDC)

The INVENTORY Module consists of 25 tables that contain data describing the condition and other general information about the pavement at the time the section was chosen for inclusion in the LTPP experiment. The table INV_ID (Inventory Identification) provides the basic location information about the section. The primary keys throughout INVENTORY is the STATE_CODE and SHRP_ID. These keys are contained in every table and uniquely identifies a pavement section.

State Supplied Inventory Data

Inventory data were obtained from SHA historical records. Data collection sheets were developed to record the information for each SHRP section and were distributed to the states. The SHAs completed as much of the data collection sheets as possible using their existing historical information on the SHRP section. The states then submitted the data sheets to the SHRP Regional Coordination Office Contractors (RCOCs) for RIMS data entry.

MATERIALS SAMPLING AND TESTING

The Testing (TST) module consists of a number of tables that record information on field and laboratory tests performed on SHRP pavement sections. A table exists for each type of laboratory and field test, and separate tables contain information on the holes drilled and the samples taken. If two or more tests are essentially the same, they may be combined in the same table. The primary keys are the section ID number (STATE_CODE||SHRP_ID) and the sample date. In addition to the section

identification keys, laboratory test tables use the layer number, location of the hole, field set, and test number to uniquely identify a test.

MAINTENANCE

Over the course of the LTPP program, the SHRP test sections may require upgrading or maintenance to preserve and/or extend the life of the pavement. Maintenance activities could include crack sealing, spot pavement repair, and application of a seal coat. These actions are reflected in the data entered in the Maintenance module which houses information concerning all maintenance applications and treatments applied to the SHRP sections. Chapter 6 of the DCG (Ref 5) provides descriptive definitions, as well as, specific guidelines for all maintenance work conducted on SHRP sections since inclusion in the LTPP program. The IMS input screens closely resemble the data collection sheets included in Chapter 6 of the DCG.

The maintenance module consists of 17 sheets/screens and the first involves historical data. The remaining 16 sheets are referred to as monitored data and are entered in RIMS by RCOC personnel, with the exception of the maintenance survey sketch (maintenance data sheet 2). The DCG provides work type codes for each activity included in the Maintenance module. Range checks are completed during the screen input action including an absolute range enforced according to the SCHEMA definition, and a warning type message that may be overridden by the operator. The warning message appears on the screen when data exceed

predetermined normal (expected) ranges for that particular condition. This process is conducted for all data entered through the IMS screens.

A critical data integrity issue is the recording of changes to the pavement structure which occurs during routine maintenance activities. The original pavement layer information (INV_LAYER) is compiled by the RCOC from the inventory data supplied by the SHAs while actual in situ pavement layer information was extracted from the materials sampling and testing activities performed by SHRP contractors. The changes in the pavement structure over the life of the pavement were then documented by either maintenance or rehabilitation activities on the appropriate data sheets. Representative in situ layers structure information (designated in IMS Table TST_LO5_B is not entered directly from any data sheet, and it is the RCOC responsibility to create and update this table appropriately. The only maintenance activity that effects the layer structure is the placement of seal coats on a test section. A warning message has been incorporated in the IMS data entry procedure as an automatic reminder to the regions to take the appropriate, required action when a seal coat maintenance activity is undertaken.

REHABILITATION

Major maintenance activities performed on a section are referred to as rehabilitation and are recorded in the Rehabilitation module. Rehabilitation activities could involve extensive milling, grinding or grooving, overlays, and retrofitting underdrains or edge drains. The DCG (Ref 5) provides work type codes for activities to be recorded in this

module. Historical data of rehabilitation activities undertaken prior to acceptance as a SHRP test section was included in the Inventory Rehabilitation module. All rehabilitation activity undertaken after initiation of LTPP monitoring program for the section was collected and stored within the Rehabilitation module. This data was provided by the SHAs on paper forms to the RCOCs and was entered in the RIMS via data screens similar to the data sheets. The data from the appropriate rehabilitation sheet was used by the RCOCs to update the in situ pavement structure.

Originally the REF_LAYER IMS Table was used to define the overall representative layer description and thicknesses for a LTPP section but was recently (May 1992) augmented by layer descriptions and thicknesses representing the pavement structure at the beginning (TST_L05A) and end (TST_L05B) of each LTPP section. The REF_LAYER IMS Table, however, has been retained and used in conjunction with the IMS Quality Assurance program.

TRAFFIC

The Traffic module in NPPDB (or NIMS) houses yearly estimates of traffic volumes, axle loads, and Equivalent Single Axle Loads (ESALs) for each site. Traffic estimates for the years prior to 1990 have been developed by the states based, in most cases, on limited non site-specific data. It is anticipated that the traffic estimates for most of the study sites for the year 1992 and beyond will be more reliable since they will be developed from site-specific data. For the transition period between

1990 and 1992, estimates will be based on a mix of historical and monitored traffic data. Numerical estimates of reliability for these estimates will also be included in the NIMS. The reliability indices for this traffic data will be based on type, amount, location, and timing of collected data.

The Central Traffic Database is an "off line" database which will include the raw traffic data used to estimate the annual traffic estimates included in the NIMS. Monitored traffic data is not yet available to researchers from the NIMS (September 1992).

MONITORING

A goal of the SHRP-LTPP program was the development and implementation of a plan to uniformly and thoroughly monitor the performance of pavements identified in the General (GPS) and Specific Pavement Studies (SPS). As a result of this goal, the pavement monitoring task was established to provide guidelines and procedures to SHRP personnel and contractors to ensure that data collection efforts would result in high quality research data.

The monitoring module consists primarily of data recorded with various types of monitoring equipment. These data are generally received in machine-readable media, loaded in the IMS and eventually stored in the NPPDB. The five categories of monitoring data included in the module are deflection (FWD), longitudinal profile (profile), surface distress,

friction (skid), and cross profile (rutting). These categories of data are explained in more detail in the following paragraphs.

Deflection (FWD)

In situ deflection testing utilizing a falling weight deflectometer (FWD) device represents a primary source of data for assessing structural capacity of a pavement structure. The FWD testing activity was undertaken in two distinct phases. The first phase was linked to the original drilling and sampling scheme for the LTPP sections, while the second phase was concerned with a seasonal monitoring program. The phases involve deflection basin testing for flexible pavements and both deflection basin and load transfer tests for rigid pavements.

The Dynatest FWD was selected as the standard SHRP deflection testing equipment. Four devices were purchased and have been used to collect deflection data in each region. Because of increased data collection demands due to the Specific Pavement Study (SPS), FWDs from various State Highway Agencies will be used to supplement the SHRP devices. Calibration centers have been established to help ensure interregional calibration, as well as, to provide calibration services to the non-SHRP devices. SHRP has developed generic calibration procedures for FWDs to allow devices from different manufacturers to be calibrated.

Standard procedures for FWD testing were developed for GPS sites (Ref 10) and supplemental guidelines have been developed for use in tests of SPS-6 sites (Ref 7). The standards include considerations for the

collection of supplemental data (i.e., temperature, joint/crack widths, etc.).

The FWD data acquisition system has the capability for storage of the full time history of the applied load pulse and resulting deflection response. However, because of the database storage limitations, approximately seventy-five percent of the load-deflection historical data is stored "off-line" on optical disks, while the peak magnitudes of the impulse load and deflection responses are stored in the national pavement performance database (NPPDB).

Surface Distress (Distress), Longitudinal and Transverse Profiles

The general serviceability concept developed during the AASHO Road Test (Ref 20) in which the performance of a pavement was defined by its ability to serve traffic over time can be investigated in the SHRP-LTPP program. The results of the SHRP-LTPP program can provide an assessment of serviceability by combining profilometer data (longitudinal profile), PASCO cross profile data (lateral profile or rutting) with distress data from 35mm film interpretation (cracking and patching) to estimate present serviceability indices (PSI).

Surface Distress. The primary focus of the pavement distress monitoring activity was to document long-term pavement performance through the development of distress histories. The distresses that are observed eventually will be used to confirm and/or calibrate existing models and/or develop new predictive models of pavement performance (or pavement life).

In the SHRP program, pavement distress is principally collected photographically on 35 mm movie film, thereby providing a time related snapshot of distress. The eventual accumulation of a series of distress "snapshots" will provide documented historical records of pavement performance over a long period. The type, severity, and amount of distress for each pavement section is quantified through computer assisted interpretation of the film.

The number of potholes and the severity, length, or area of surface cracking, spalling, and edge cracking are some of the data types collected annually or biannually via high-resolution 35mm photographic methods. Manual distress surveys are conducted when and where photographic surveys are impossible or impractical.

Longitudinal Profile (Profile). The principal factor in the AASHO present serviceability index (PSI) equation is slope variance which represents a measure of variation in longitudinal profile (or roughness) (Ref 20) of a roadway section. The KJ Law profilometer is the SHRP device selected to monitor longitudinal profile variation (or roughness) within each GPS and SPS section.

The longitudinal profile of each SHRP test section is measured approximately one time per year. The data stored include the raw profile data for a minimum of five repeat runs. The International Roughness Index (IRI), Mays Ride Measurement Index (MRM), Root Mean Square Vertical Acceleration (RMSVA), and slope variance are the profile indices computed from the data and stored in the NPPDB.

Face DIPstick® Device/Rod and Level Surveys. Although, the Law inertial profilometer was the primary device selected for use in measurement of longitudinal profile variations, there were occasions when the profilometer was not be available for use because of scheduling or equipment difficulties. In these instances the Digital Increment Profiler (DIPstick®) manufactured by Face Construction Technologies, Inc. was used as the backup device for conducting profile measurements. The DIPstick® was the principal longitudinal profile measurement device for some SHAs (e.g., Hawaii, Puerto Rico). In rare instances rod and level surveys were used to develop longitudinal profile data. The database stores the type of device for each data set in a master record.

Transverse Profile (Rutting). Photographic transverse-profile measurements (Ref 14) were obtained at approximately fifty foot intervals along a test section with elevation data extracted for a maximum of thirty points across the pavement width (i.e. approximately five to six-inch intervals). Alternatively, a DIPstick® survey or rod and level survey was used to obtain manual cross-profile measurements with a transverse interval of one foot. The cross profile information is stored within NIMS but rut depth estimates must be developed using an external computer program (Ref 21).

Surface Friction (Skid)

The surface friction data is obtained by the various state or provincial agencies and submitted to the Regional Coordination Office Contractors (RCOCs) for entry in the RIMS. Friction measurements are

taken at least every two years by the respective agencies. The skid number, time of day, surface type, vehicle speed, and test method are some of the principal elements stored within the National Pavement Performance Database (NPPDB).

Climate (Environment)

The Climate (ENV) module consists of four tables containing information that could prove beneficial in defining the relationship(s) of environmental conditions to pavement performance. Environmental information is collected from a minimum of one to a maximum of five weather stations located near each LTPP site and an analytical process is undertaken to define "virtual" weather information assumed to be representative of the conditions at each pavement test section. The data stored in the IMS will include monthly and annual statistics for a variety of climatic parameters, weather station location information, and data relating the weather stations to the General Pavement Studies (GPS) sites. Because of the volume of the climatic data and the limited disk space on the NIMS, only the "virtual" station weather information and at least the single nearest weather station information will be stored in NPPDB. The data from the remaining existing stations will be stored "off-line" at this time.

LTPP INFORMATION MANAGEMENT SYSTEM (IMS) QUALITY ASSURANCE PROCESS

Introduction

The Quality Assurance (QA) concept of data checks is presented graphically in Figure 4. The data checks involve internal QA checks by SHAs of historical data and SHRP contractors of specific data such as environmental and distress data; regional QA checks of all data by RCOCs, and sophisticated and comprehensive quality assurance checks of all data within the NPPDB (NIMS). The latter checks result in the eventual release of data at the section (Level 1) or experiment (Level 2) levels. This QA process is necessary to provide the researchers with the confidence that the data can be trusted and that their findings and recommendations are based on quality data.

Specifically, the components of the IMS QA plan are performed in the following sequence:

1. Data collection procedures are documented and executed for each module in the IMS to insure that historical and monitored data are collected in similar format, types, conditions, etc. Internal QA checks are instituted to check for obvious mistakes, data anomalies, etc.
2. Regional review of all input at RIMS is undertaken to identify obvious data collection and data entry errors.

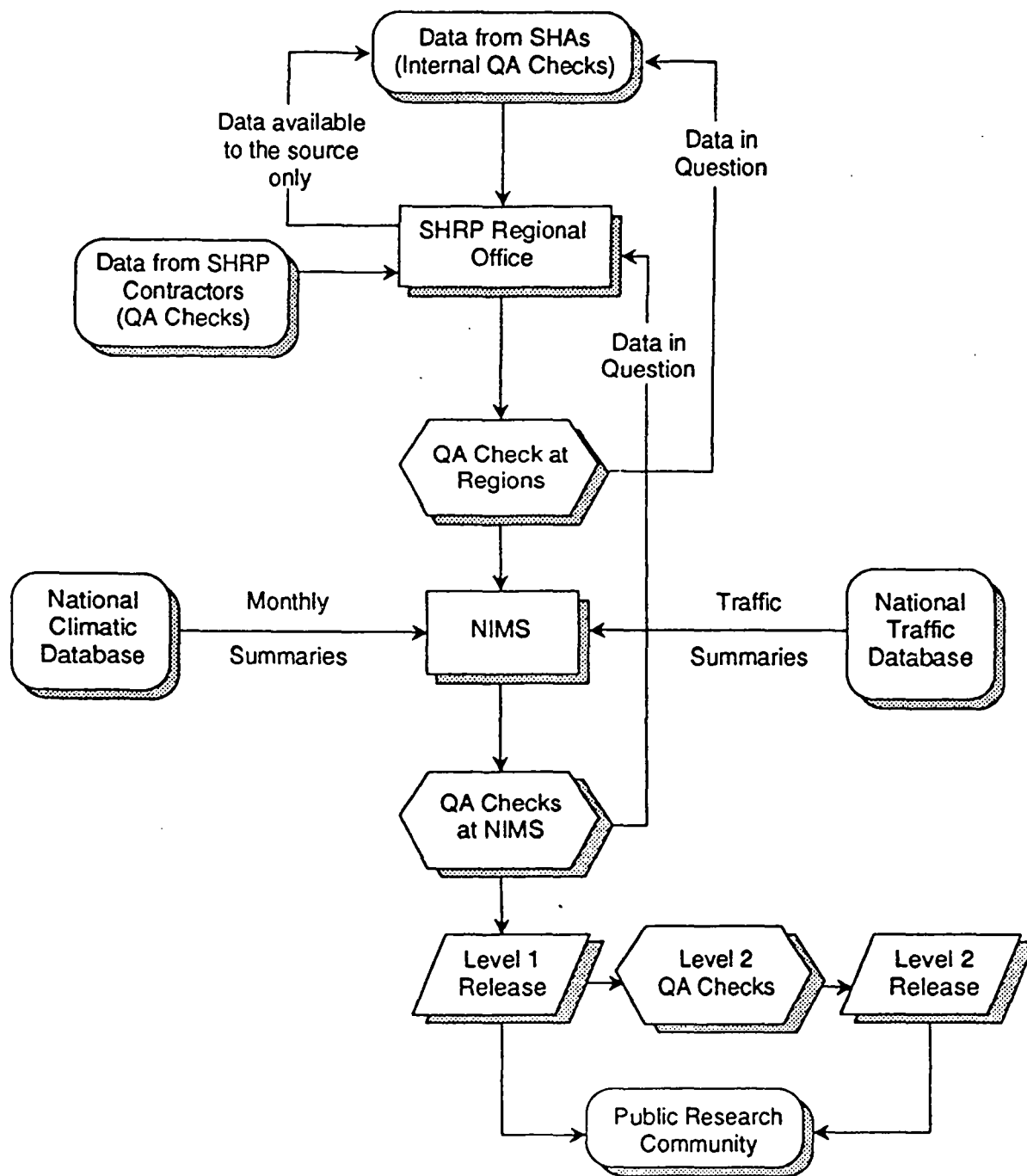


FIGURE 4
Data Flow in the LTPP IMS

3. Internal checks are executed at the NIMS to identify data entry problems/errors.
4. The formal IMS QA software programs are executed at the NIMS. This component involves nine categories of quality assurance checks defined within two release levels.

The formalized, computer based QA checks involve data entry checks at the RIMS and NIMS, five QA/QC checks at the NIMS on section-by-section basis, and four QA/QC checks at the NIMS on an experiment-by-experiment basis.

RIMS/NIMS Data Entry Checks

Data entry checks programmed in the RIMS/NIMS include mandatory, logic, range and data verification checks (Ref 22). The mandatory checks involve checks for non null entries in all key fields and other designated fields. The RIMS will require entry in these position or will invoke an audible warning and message that data is required in the field.

Logic checks are also included to ensure data compatibility across tables. An example of a logic check is:

The "minimum data value \leq mean \leq maximum" for a given parameter.

Range checks are enforced to ensure that numeric field values fall within a defined value. Both absolute (i.e. theoretically possible range

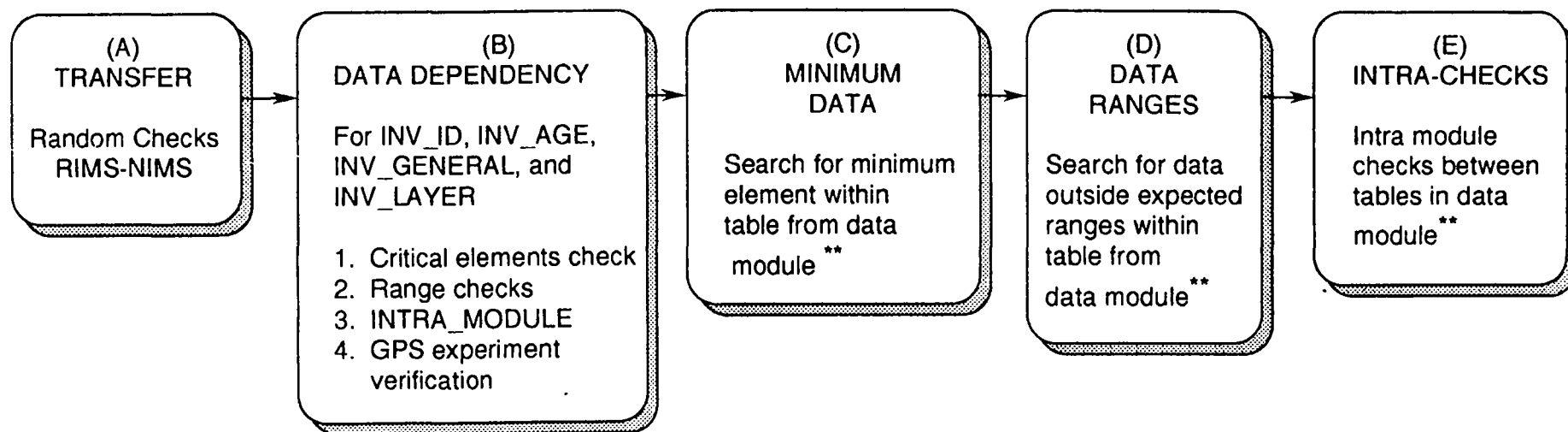
limits), and warning or expected limits (i.e. practical range limits) are utilized.

Verification checks are instituted system wide in the NIMS to verify that the SHRP-LTPP sections have been authorized for the LTPP program and are included within the EXPERIMENT_SECTION Table before any data from that section can be entered in the IMS.

QA/QC Data Checks Required for a Level 1: Section Release

The first release level is a section by section release process involving five individual QA/QC checks defined as A through E checks (Ref 4). The Level 1 release QA/QC checks are presented in Figure 5 and involve the following activities.

<u>Check</u>	<u>Description</u>
A	Random checks to ensure correct RIMS-NIMS upload exchange,
B	Data Dependency Checks to ensure that basic, essential section information is recorded in NIMS (e.g. location, elevation, etc.),
C	Minimum data Search for critical elements (e.g. friction data should include skid number),
D	Expanded Range Checks to identify data elements which fall outside an expected range,



** Except INV_ID, INV_AGE, INV_GENERAL, and INV_LAYER tables in inventory module

FIGURE 5
IMS Level 1 (Section) Release Quality Check

E Intramodular Checks to verify the consistency of data within data modules.

These Level 1 data checks are structured to assure quality data within a particular SHRP section, but do not address QA/QC requirements between sections, states, and regions. These more sophisticated checks are required at the next release level.

The five checks (i.e. A - E) in the Level 1 Release category are hierarchal in concept and must be conducted in succession as indicated in Figures 5 and 6. In this concept, the data dependency checks (i.e. B check) will not be processed until the RIMS-NIMS data check transfer (i.e., A check) has been successfully completed. Similarly the E level Checks (Intramodular) are not initiated until the range checks (Check D) have been successfully completed. After the Level E check has been conducted and the data within the particular IMS table passes the check, that IMS table can be released for public use.

It should be noted that the QA/QC checks are conducted on the individual tables within IMS and not on the SHRP sections as a whole. For that reason, the Level 1 release could allow some data to be released for a section (e.g. friction results) while other section data which fail to meet the checks (e.g., climate) would not achieve the release status.

Once records have passed through sublevel E, the data are available for a Section Release (Ref 4). These data are accompanied with an appropriate disclaimer from SHRP.

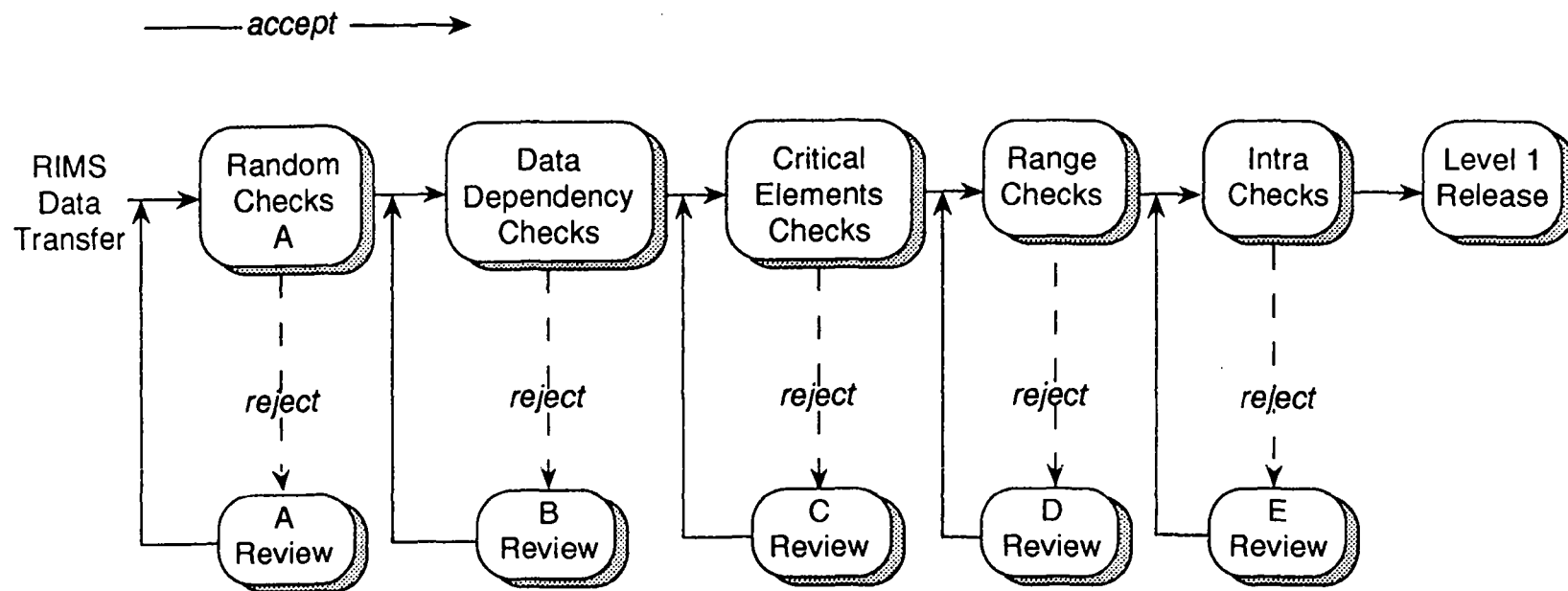


FIGURE 6
Data Level Advancements With Quality Control Checks

SHRP LTPP Section Release Disclaimer

The SHRP LTPP data are available for release at two levels. The first level of data release (Level 1) involves section-by-section data availability searches of the IMS, and includes a minimal number of pre-release data checks on the individual SHRP test sections. The second level of release data checks on the data availability searches of the IMS on an experiment- by-experiment basis, and requires the completion of a designated number of global data checks before approval for release.

The SHRP LTPP information and data from a Level 1 release represent a release on a section-by-section basis. At this time there are insufficient data available in the IMS to support a Level 2 release. Because of this situation, it is recommended that the data and information only be used for evaluation and analysis at an individual section level. If a report, paper or technical document is generated using results from this release, then a statement must be included indicating that the SHRP LTPP information and data were obtained from a SHRP LTPP Level 1 release and the date the data were obtained.

During SHRP-LTPP, the Level 1 checks have been defined and installed within NIMS. Four Level 1 data releases have been completed utilizing the

checks. In the process the checks have been reviewed, expanded, and revised as necessary.

QA/QC Data Checks Required for a Level 2: Experiment Release

A Level 2 IMS Release is classified as an Experiment Release and includes QA checks across data modules (Ref 23), confirmation of GPS experiment and cell assignments (Ref 24), and statistical checks on the data and IMS Tables (Ref 25) within each designated GPS experiment. The successful completion of these checks means that the LTPP data would be available for a general experiment-by-experiment evaluation and analysis. The IMS Level 2 release QA/QC checks involve the following activities:

<u>Check</u>	<u>Description</u>
F	Intermodular cross checks are applied to verify existence and consistency of data for related categories,
G	Experiment and cell assignment checks based on collected data,
H	Various checks involving frequency distributions, bimodal and variance checks,
I	Statistical checks for outliers, missing data, and completeness of experiment.

An example of the type of intramodular cross checks (QA/QC Check F) included in the QA program are presented in Figure 7. For assessing FWD

INTER-MODULAR CROSS CHECKS Behavior Considerations

NDT - FWD	---	Load deflection
Environment	---	Mean monthly temperature
Materials	---	Layer thickness
Materials	---	Depth to rigid layer
Materials	---	Mr values

INTER-MODULAR CROSS CHECKS Performance Considerations

Profile	---	IRI
Distress	---	Cracking & patching
Rutting	---	Rut depth
Materials/ Inventory	---	Surface type

FIGURE 7
IMS Level 2 - F Checks

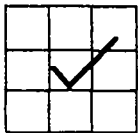
deflection data at SHRP sites, it would be essential to have information on environment (temperature), materials (layer thicknesses and resilient modulus estimates), and on depth to rigid layer. Similarly an analysis of AASHTO performance (i.e., PSI) would require information on roughness (profile), cracking and patching (distress), rutting and surface material types. This check is in fact conducted for a specific SHRP-LTPP section but, represents the type of checks that are performed across data modules. This check must be completed prior to the initiation of the experiment and cell assignment checks (or G check).

The experiment/cell verification (G check) is essential for establishing the completeness of each GPS experiment matrix. As illustrated in Figure 8, the process is conducted for each SHRP section and involves:

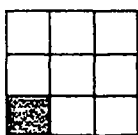
- Confirmation of the GPS experiment assignment,
- Confirmation of the cell assignment within the GPS experiment matrix
- Assessment of experiment completeness.

In essence, this IMS QA check is used to assure appropriate GPS experiment assignment and to confirm that the distribution of LTPP sections within the experiment matrix is good enough to assure unbiased data. This check must be successfully completed before checks H and I are commenced.

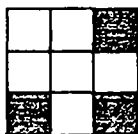
EXPERIMENT / CELL VERIFICATION



GPS Experiment Confirmation



Experiment Cell Confirmation



Completeness Of Experiment

GPS Experiment Definitions

GPS-1	Asphalt Concrete (AC) on Granular Base
GPS-2	AC on Bound Base
GPS-3	Jointed Plain Concrete
GPS-4	Jointed Reinforced Concrete
GPS-5	Continuously Reinforced Concrete
GPS-6A	Existing AC Overlay on AC
GPS-6B	New AC Overlay on AC
GPS-7A	Existing AC Overlay on Portland Cement Concrete (PCC) Pavements
GPS-7B	New AC Overlay on (PCC) Pavements
GPS-9	Unbound PCC Overlays of PCC Pavements

FIGURE 8
IMS Level 2 - G Check

The variation in data across regions, as well as, within regions for each experiment will be analyzed as part of the H check to assess non-uniformity in variance distributions and to check for unusual occurrences or biases that may impact future analyses. Examples of this type of QA check are presented in Figure 9.

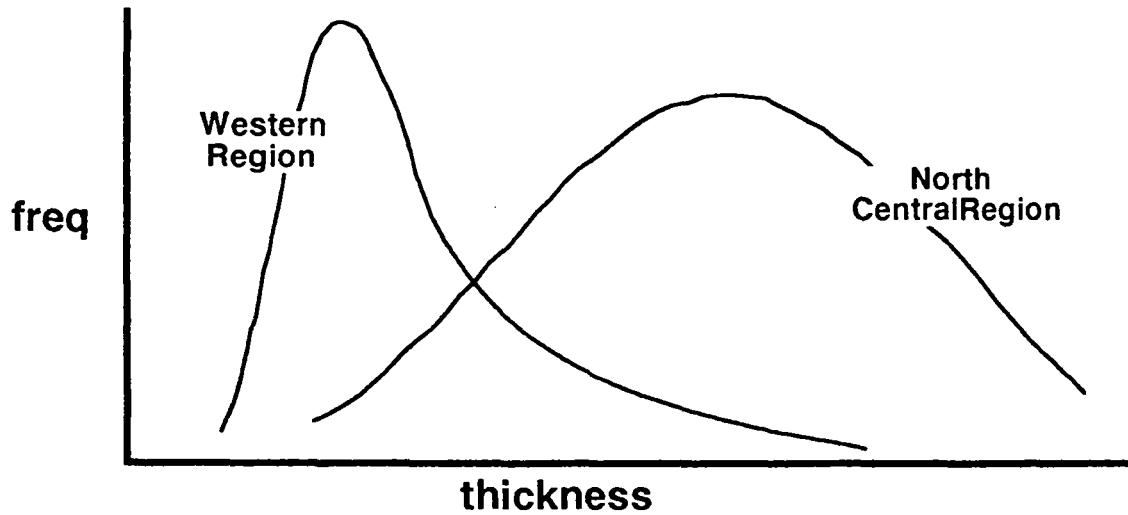
The final check prior to an IMS Level 2 release is illustrated in Figure 10 and involves statistical checks of each GPS experiment to identify missing and aberrant data and to confirm outliers. The process will include initial variance analyses at both the regional and national levels and preliminary regression analyses to investigate important factors and materials/ construction variability.

Once the data and IMS tables have passed through levels A-I, the data are available for an Experimental Analysis release. These data are accompanied with the following disclaimer (Ref 4) from SHRP.

SHRP LTPP Experiment Analysis Release Disclaimer

The SHRP LTPP data are available for release at two levels. The first level of data release (Level 1) involves section-by-section data availability searches of the IMS, and includes a minimal number of pre-release data checks on the individual SHRP test section. The second level of release (Level 2) involves data availability searches of the IMS on an experiment-by-experiment basis, and requires the completion of a designated number of global data checks before approval for release.

**FREQUENCY - VARIANCE
DATA DISTRIBUTION CHECKS**



**FREQUENCY - VARIANCE
BIMODAL DISTRIBUTION CHECKS**

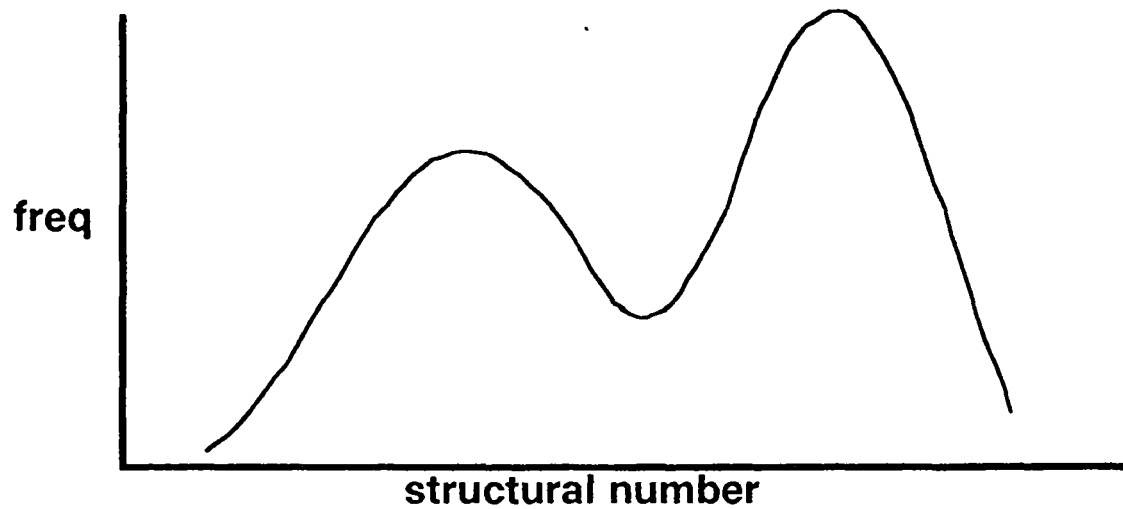


FIGURE 9
IMS Level 2 - H Check

STATISTICAL CHECKS / ANALYSES

Data Investigation

- **Missing data**
- **Aberrant data**
- **Outliers**

Initial Variance Analyses

- **Regional**
- **National**

Regression Analyses (Prelim)

- **Important factors**
- **Materials/construction variability**

FIGURE 10
IMS Level 2 - I Check

The SHRP LTPP information and data from a Level 2 release represent a release on an experiment-by-experiment basis. Unless specifically notified otherwise, there should be no limitation on evaluation or analysis of the released data. If a report, paper, or technical document is generated using the results from this release, then a statement must be included indicating that the SHRP LTPP information and data were obtained from a SHRP LTPP Level 2 release and the date the data were obtained.

EQUIPMENT AND OPERATIONS

The operation and maintenance of the IMS is documented in the Operations and Quality Assurance Manual, Revision 1, April 1990 (Ref 3). The manual includes details on the structure, operations, quality assurance, and the maintenance of the IMS (RIMS and NIMS). Additional information is available in the following IMS manuals:

- 1) LTPP Programmer's Reference Manual, Draft April 1990 (Ref 17).
- 2) LTPP RIMS User's Manual, (Ref 19).
- 3) LTPP NIMS User's Manual, (Ref 18).

HARDWARE

The computers housed at the RIMS are Compaq Deskpro 386/25, while a MicroVAX 3900 computer handles the NIMS operations. The RIMS reside on 386-class, IBM-compatible PC running version 3.3 of DOS with the following hardware specifications:

- 300-MB hard disk
- 5 MB RAM
- 5 1/4" 1.2 MB high density drive
- 3 1/2" 1.44 MB high density drive
- enhanced color display adaptor
- color monitor
- parallel/serial ports
- 125 MB external cartridge tape drive

- 2400 baud modem
- tractor feed printer with 32 K RAM buffer

The NIMS resides on a Digital Equipment Corporation (DEC) MicroVAX 3900 minicomputer at the Transportation Research Board (TRB). The MicroVAX 3900 runs on VMS version 5.2 and has the following configuration.

- 32 MB memory
- 1 RA90 disk drive with 1.2 gigabyte storage capacity
- 1 TU81 9-Track tape drive
- 1 DELNI LAN Interconnect
- 1 DEC Server 200 8-port terminal server
- 1 TK50 cartridge tape drive

Because of a large volume of data and the resulting processing requirements required at the Regions, additional hardware was added to the RIMS, including the following items.

Intel 80387-25 Math Coprocessor

Storage Dimensions SCSI Optical Disk and Controller

Storage Dimensions 651 MB SCSI Hard Disk with driver
compatible with optical disk and controller.

SOFTWARE

The LTPP software requirements include operating systems and database management (ORACLE).

Operating Systems

At the RIMS, the Compaq Deskpro 386/25s (Compaq's version of MicroSofts - Disk Operating System (MS-DOS) version 3.31) is utilized and can be expected to support hard disk partition sizes larger than 32 MegaBytes.

DEC's standard Virtual Memory System (MVS) version 5.3, is used with DEC MicroVAX 3900 located at the NIMS. A number of upgrades have been installed during the first five years of LTPP.

ORACLE

SHRP specified the use of a relational DBMS for the IMS. ORACLE was selected from the group of candidate RDBMSs after an evaluation that included product capabilities, vendor stability, hardware support, technical support, and market share. Although the 640K RAM boundary on the PC configuration was a concern, it was ascertained that this was not a limitation since ORACLE can run in extended memory.

ORACLE uses the industry standard Structured Query Language (SQL), which offers an extremely powerful command set for data base setup, data base maintenance, and data manipulation. ORACLE includes the additional features of host language interfaces, a menu manager, a forms management package, a report writer, and extensions to the basic SQL commands. A number of third party products are also available for use with ORACLE. Since ORACLE has compatible versions for both of the IMS hardware

platforms, training requirements are easier, data compatibility is assured, and software development and maintenance is simplified and reduced.

All non-ORACLE applications for the IMS are written in American National Standards Institute (ANSI) C language. The C language was chosen to ensure portability of the system software since this is the "accepted" language of choice by software programmers/developers. Some of these applications are the "filter" or data load programs written to process the machine-readable data, to develop special user reports, and to output user-exits to enhance the capabilities of ORACLE.

INTERNATIONAL INFORMATION MANAGEMENT SYSTEM (I-IMS)

SHRP provided assistance in setting up an International IMS (I-IMS) in the LTPP study for participating countries. The I-IMS in each country is like a node to the NIMS similar to the RIMS. During SHRP-LTPP, I-IMS was operational in Finland, Australia, the United Kingdom, and the Netherlands. Several other countries acquired the hardware and software to install the IMS.

SUPPLEMENTARY DATABASE(S)

There are a number of supplementary databases which have evolved during the first five years of SHRP-LTPP including:

- a. Nomination Database - a database used by the Technical Assistance contractor to identify, assess and select those LTPP sites which fulfilled the requirements for GPS experiments.
- b. FWD and Profile Databases - because of data volumes and database limitations, FWD and Profile data are stored "off-line" at the Regions. Representative FWD deflection data and characteristic roughness results are stored in the NPPDB.
- c. Climatic - Because of volume of climatic data, only the "virtual" and nearest weather station data are stored in NIMS. The other weather station information is stored "off-line" at the NIMS.
- d. Traffic (regional and central)

The traffic database is divided into five levels of information. Each level represents a different aggregation of the traffic data. Each of these levels of data serves a different purpose and can be useful to a different group of researchers.

The five traffic database levels are as follows:

- Level 1 - Primary Loading Estimates, ESALs
- Level 2 - Annual Traffic Estimates by FHWA Classification Scheme,

- Level 3 - Daily Traffic Counts,
 - Level 4 - Detailed Traffic Measurements, and
 - Level 5 - Supporting Data.
- e. Products - The products database was developed by SHRP to identify those products emanating from the SHRP-LTPP program.

DATA AVAILABILITY

Data is generally made available to the public from the NIMS after appropriate quality assurance and quality control checks have been concluded. To obtain LTPP data from the NIMS, requests must be made to the TRB IMS Administrator using a completed LTPP IMS DATA REQUEST form as shown in Figure 11. All data requests are processed at TRB by the IMS administrator.

In return, TRB will provide the requestor with a package including the data on the requested media, a diskette containing significant portions of the *Data Structures Manual* (Ref 6), and a notice describing major changes to the database in the previous six months. The package will include a detailed LTPP Schema and the LTPP Data Dictionary. The schema identifies the fields in each IMS table along with the columns where these data are available in flat ASCII files. The LTPP data dictionary includes a description of each field including the size, units, expected ranges, and identifies the table name where the field can be found.

ORGANIZATION INFORMATION

Date _____

Name _____
 Title _____
 Organization _____
 Address _____
 & _____
 Phone _____

TYPE OF ORGANIZATION:

- ☐ Federal Government
☐ State Government
☐ Educational Institution
☐ Research Consultant
☐ International User
☐ Other (Specify) _____

MEDIA

- ☐ 5-1/4" 1.2 MB HD Diskette (\$5 ea) ☐ Optical Disk (\$320 ea)
☐ 3-1/2" 1.44 MB HD Diskette (\$5 ea) ☐ Hard Copy (\$5 /50 sht)
☐ 9-Track Magnetic Tape (\$25 ea)

DATA FORMAT

- ☐ ASCII Flat File
☐ Formatted Reports
 specify:

DATA CATEGORY

- | | | |
|---|--|---------------------------------------|
| <input type="checkbox"/> All Data Available | <input type="checkbox"/> Inventory | <input type="checkbox"/> Monitoring |
| | <input type="checkbox"/> Materials Testing | <input type="checkbox"/> Profilometer |
| | <input type="checkbox"/> Maintenance | <input type="checkbox"/> Deflection |
| | <input type="checkbox"/> Rehabilitation | <input type="checkbox"/> Friction |
| | <input type="checkbox"/> Climatic | <input type="checkbox"/> Rutting |
| | <input type="checkbox"/> Traffic | <input type="checkbox"/> Distress |

SPECIFIC DATA

To limit the data further, please complete the appropriate section. For more detailed requests, attach a separate sheet with a complete description.

Section(s) _____
 State(s) _____
 Experiment Type(s) _____
 Region(s) _____

FEES

The total cost will be based on the media chosen, the volume of data requested, and the other fees as outlined in the LTPP IMS Researchers Guide.

RETURN ADDRESS

Please submit the completed form to:

Penny Passikoff, IMS Administrator
 National Academy of Science
 TRB, GR322
 2101 Constitution Avenue
 Washington, D.C. 20418
 Tel: (202) 334-3259

The diskette also houses a report indicating the codes used in the IMS and their associated description. The use of codes provides more quality control by reducing the amount of data entry and storage. For example, comment codes were established for use in recording laboratory test results. Each numeric code corresponds to an individual comment relating to conditions that may affect the results (i.e., color, condition, insufficient size, sample, etc.). The codes and their corresponding descriptions are provided on the diskette distributed with each completed request. The following sections describe portions of the request form in more detail.

Media

A MicroVAX 3900 running VMS is used to maintain the IMS data. In addition, a 386 class PC running DOS is available to the TRB-IMS center. The following storage devices and peripherals are available for output as shown below.

- 3 1/2" diskette
- 5 1/4" diskette
- 9-Track Magnetic Tape
- Optical Disks
- Line Printer

The DOS Copy command can be used to produce either high density or regular density diskettes. Nine-track tapes can be prepared using DCL COPY command and DCL BACKUP command. They may also be written in an IBM

standard format with a fixed record size and block size. IBM formatted tapes are available in either ASCII or EBCDIC.

The desired media format should be identified on the request form. At TRB Storage Dimension 1 GB Maxtor cartridges optical disks and a Storage Dimension Erasable Optical Disk Drive are used. However, to use this media, the requester must have a disk drive compatible with the one used by TRB.

Data Format

Currently, two basic formats are available for LTPP data: flat ASCII files and formatted reports. Each of these formats is discussed below.

Flat ASCII Files. ASCII flat files are one option for LTPP data output and are expected to be the most frequently requested format. In this format each requested IMS table written to a file identified by the extension shown in the schema (distributed on diskette), with one file per table. The data will be stored in specific column format identified in the LTPP schema. A sample of the format for the INV_MAJOR_IMP table is shown in Table 2. The file extension is shown on the first line.

Requests must identify specific data tables and not data elements within tables. The user must extract the elements of interest using his own software package or program. Selection capabilities are currently

TABLE 2

Sample Schema Definition

INV_MAJOR_IMP: Major Improvement Data (Sheet 4) File Ext - 105 (Ref 7)

COLUMN NAME	FORMAT	COLUMNS	FORTRAN	C	SAS
SHRP_ID	CHAR(4)	1-4	A4	%4.4s	S4
STATE_CODE	NUMBER (2,0)	5-7	13	%3d	3
CONSTRUCTION_NO	NUMBER (2,0)	8-10	13	%3d	3
MAJOR_IMP_YEAR	NUMBER (2,0)	11-13	13	%3d	3
MAJOR_IMP_TYPE	NUMBER (2,0)	14-16	13	%3d	3
MAJOR_IMP_QUALITY	NUMBER (5,0)	17-22	16%	6d	6
MAJOR_IMP_THICKNESS	NUMBER (3,1)	23-27	F5.1	%5.1f	5.1
MAJOR_IMP_COST	NUMBER (3,0)	28-31	I4	%4d	4
MAJOR_IMP_TYPE_OTHER	CHAR(40)	32-71	A40	%40.40s	40
RECORD_STATUS	CHAR(1)	72-72	A1	%1.1s	S1

available to allow for selection of groups of pavement sections, all sections, all sections in a given region, all sections in a state, or all sections of a specific experiment type.

Formatted Reports. Several reports in an easy-to-read format are available which provide specific information and could prove beneficial to the user. Reports are divided into general interest and data-specific categories.

General interest reports are by definition not specific to a particular data category and provide general data availability status. The general reports available are described in Table 3.

Data-specific reports are available for a given data module in easy-to-read format. The reports were developed primarily for the regions to visually check data input and basically identify all data entered for a given section under a specific category of data. A report of this type is available for the following data categories:

- Inventory
- Friction
- FWD Deflection
- Profilometer Summary/Graph
- Distress Summary

TABLE 3
General Reports.

Report	Title	Description
1	Section Total Per State	Matrix showing the number of pavement sections in LTPP study by state and experiment type.
2	Section by State	Available for a single state or all states, this report shows all pavement sections for a state grouped by experiment type. Section number, route, number of lanes, direction milepoint, and county are shown.
4	Pavement Summary	Available for a single section, single state, or all sections, this report shows the construction sequence of the pavement structure.
3	Section Reference	Available for a single section, single state, or all sections, this report lists general information about the pavement section.
4	Module Data Status	For a given pavement section, this report provides a detailed summary of all the data collected and currently in the IMS.
5	Data Collection Summary	For a single section, single state, or all sections, this report provides a general summary of the type of data currently in the IMS for each test section.

- Cross Profile
- Maintenance Summary
- Maintenance Cost/History
- Field Testing
- Laboratory Testing

For the general interest and data specific reports, report requests may be made for a single section, all sections within a state, or all sections within GPS.

Traffic Data

The SHRP traffic data collection plan (Ref 26) identified three alternatives for traffic data collection and allowed each SHA the option of selecting any one of the three alternatives. Since the selection could be made independently for each LTPP site, this approach allowed the use of differing levels of traffic data collection at the various LTPP sites located within a state or province.

The three alternatives for monitoring traffic data are defined as follows:

- Preferred traffic data collection - permanent, year-round weigh-in-motion (WIM) equipment installed at each site and operated continuously.

- Desirable traffic data collection - a permanent, year round automatic, site specific, vehicle classifier, supplemented by one week of weigh-in-motion measurements for each season at each study site.
- Minimum traffic data collection - a year-round vehicle classifier, counting a minimum of one full year during each five-year period, supplemented by one 48 hour weekend and one 48 hour mid-week weigh-in-motion session conducted during each season of the year.

The SHRP traffic data collection plan allowed the SHAs flexibility to better utilize their scarce resources and staffing limitations. At the same time, the traffic data collection requirements could provide enough information to SHRP researchers for development of reasonable estimates of traffic loadings at each LTPP pavement test sections.

Requests for traffic data must specify a data availability code. Descriptions of available codes are provided below and indicate the data used to generate the annual ESAL totals. The codes are assigned based on the type of detailed information available to support the annual estimates of traffic loadings. For example, if an availability code of 7 is chosen, all records with an availability code of 7 or higher will be selected. These codes are subject to revision.

<u>Code</u>	<u>Description of Traffic Data Availability Code</u>
9	Continuous Weigh-In-Motion (WIM) information meeting the ASTM standard E1318 (Ref 27) is available.
8	Continuous WIM information which does not meet the ASTM standard E1318 (Ref 27) or hasn't yet been tested against the ASTM standard.
7	Permanent vehicle classifier operating continuously, with portable WIM for all seasons and weekday/weekend time periods.
6	Continuous vehicle classification with some seasonal WIM measurements
5	Continuous vehicle classification with limited WIM
4	Continuous Automatic Vehicle Classification (AVC) information is available but no WIM data is provided.
3	Continuous Automatic Traffic recorder (ATR) volume station counts are available but with limited vehicle classification and a minimal measurement of truck seasonality.
2	Vehicle classification and WIM data is available with some measure of seasonality.

- 1 Limited data (only short duration counts) for either vehicle classification or truck weights.
- 0 Data collected on a different roadway than the LTPP site, including system level estimates.

Specific Data

Requests may be submitted for individual sections, states, regions, or experiment types. To specify data for a specific SHRP test section, however, the researcher must supply the SHRP section number. States may be specified by entering the standard two character abbreviation or the full state name. The map shown in Figure 1 identifies the four LTPP regions. The regions are also identified in Table 4 with their respective states and provinces. Regional data may be requested by specifying the region name. Experiment types and definitions are listed in Tables 5 and 6.

Status of IMS Releases

During SHRP-LTPP, four public data releases were conducted, all at Level 1 involving only GPS data. The releases were completed at six month intervals because of the large volume of data inserted in the RIMS during this start-up period. This can be seen in the amount of data that was released each time as shown in Table 7. The table names (e.g., INV_ID) were selected to represent the status of the data module that the tables associated with.

TABLE 4
SHRP Regions

1. North Atlantic (NA)	CT, DC, DE, MA, MD, ME, NC, NH, NJ, NY, PA, RI, VA, VT, WV - NB, NF, NS, ON, PE, QC
2. North Central (NC)	IA, IL, IN, KS, KY, MI, MN, MO, ND, NE, OH, SD, WI-MB, SK
3. Southern (S)	AL, AR, FL, GA, LA, MS, NM, OK, SC, TN, TX
4. Western (W)	AK, AZ, CA, CO, HI, ID, MT, NV, OR, PR, UT, WA, WY-AB, BC, YT, NT

TABLE 5
GPS Experiment Definitions

GPS-1	Asphalt Concrete (AC) on Granular Base
GPS-2	Asphalt Concrete (AC) on Bound Base
GPS-3	Jointed Plain Concrete
GPS-4	Jointed Reinforced Concrete
GPS-5	Continuously Reinforced Concrete
GPS-6A	Existing Asphalt Concrete (AC) Overlay on Asphalt Concrete (AC) Pavements
GPS-6B	New Asphalt Concrete (AC) Overlay on Asphalt Concrete (AC) Pavements
GPS-7A	Existing Asphalt Concrete (AC) Overlay on Portland Cement Concrete (PCC) Pavements
GPS-7B	New Asphalt Concrete (AC) Overlay on Portland Cement Concrete (PCC) Pavements
GPS-9	Unbound Portland Cement Concrete (PCC) Overlays of Portland Cement Concrete (PCC) Pavements

TABLE 6
SPS Experiment Definitions

SPS-1	Strategic Study of Structural Factors for Flexible Pavements
SPS-2	Strategic Study of Structural Factors for Rigid Pavements
SPS-3	Preventive maintenance Effectiveness of Flexible Pavements
SPS-4	Preventive Maintenance Effectiveness of Rigid Pavements
SPS-5	Rehabilitation of Asphalt Concrete Pavements
SPS-6	Rehabilitation of Jointed Portland Cement Concrete Pavements
SPS-7	Bonded Portland Cement Concrete Overlays of Concrete Pavements
SPS-8	Study of Environmental Effects in the Absence of Heavy Loads

TABLE 7
Examples of Level 1 Releases

TABLE	RELEASE DATES			
	JAN. 91	JULY 91	JAN 92	JULY 92
INV_ID	226	561	660	668
MON_SKID	95	416	560	720
MON_RUT_MASTER	-	2	355	896
REF_LAYER	-	118	296	456
MON_DEFL_MASTER	-	497	515	669
MNT_HIST	-	-	9	25
RHB_IMP	-	-	1	2
MON_PROFILE_MASTER	-	-	2860	4288
COMMENTS	-	913	2386	2800
TRF_BASIC_INFO	-	-	-	121
(Historical Traffic Only)				
MON_DIS (Manual)	-	-	-	398
MON_DIS_PADIAS	-	-	-	457

The first data release was in January of 1991 and was the initial trial of both the data release procedures and the QA/QC checking software. As expected, this initial release produced many anomalies involving missing Inventory data. Since this information would never be available because it was either never collected originally or had been lost or destroyed over the years since the GPS section had been built, a COMMENTS Table (Ref 28) was added to the IMS structure so that the regions could document the missing data and allow the data to pass through the QA/QC process without being permanently held at that level (and never being released). The initial release included 226 releasable sections (see INV_ID) and the only other module to successfully pass through Level 1 was Friction (skid). The first release of distress data (MON_DIS and MON_DIS_PADIAS) occurred during the fourth release.

For informational purposes, MON_RUT_MASTER is the Table that contains the Cross-Profile data. REF_LAYER represents the Materials and Testing Data Module, which includes records for each pavement layer. In addition, MON_DEFL_MASTER represents the Falling Weight Deflectometer (FWD) data, MNT_HISTORY represents the Maintenance data, RHB_IMP represents Rehabilitation data, and MON_PROFILE_MASTER represents the Profilometer data.

IMS PRODUCTS

The products generated during development of the Information Management System (IMS) include the NIMS and RIMS databases, the supplemental databases, and the quality assurance/quality control

methodology. All of these items represent significant improvements in the data entry, acceptance and processing of pavement performance data. All should serve the public well in future pavement performance research and evaluation.

RECOMMENDED IMS ACTIVITIES

There are a number of IMS activities which should be undertaken in a continuation of the Long-Term Pavement Performance Study. In particular technical support should be provided to:

- Assist the regional contractors and TRB on data entry and processing, QA/QC checks, and procedural issues.
- Review Data Anomalies and QA/QC concerns, and recommend QA/QC revisions.
- Resolve any upload problems and recommend operational improvements to RIMS and NIMS.
- Conduct periodic, staged uploads to relieve RIMS space problems (FWD, Profile especially).
- Establish procedures to archive (catalog and store) "original" data currently at RIMS, especially the FWD and Profile data.

- Encourage and supervise the collection of MNT (maintenance) and RHB (rehabilitation) data.

Complete the development of the QA/QC checks for all of the seven data modules in the IMS. Review and modify the existing QA/QC checks in the IMS as required.

- Complete Level 2 (H and I) QA/QC checks, implement and process Levels checks F-I, and review results for any needed changes.
- Define and implement QA/QC checks for the new GPS experiment types, 6C, 6S, 6D, 7C, 7S, and 7D.
- Review existing SPS QA/QC checks, revise/enhance the checks as necessary, implement the process, and review the results (IMS level 1 only),

Review existing IMS manuals and procedures, develop documentation of new IMS policies and procedures, and prepare revisions to existing documentation.

- Review existing IMS Manuals including RIMS, NIMS, Programmer's Guide, Operations & QA, QA/QC Documentation, Data Structures
- Document new policies & procedures including backup, upload, and QA/QC procedures

Execute the periodic (every 1 to 2 years) public releases of data in accordance with the two level release policy outlined in the LTPP IMS Researchers Guide. This process will involve assistance with data transfer from the four RIMS to the NIMS, preparation of data at the NIMS for the execution of the QA/QC checks, review of the COMMENTS Table, execution of all levels of the QA/QC checks, review of specific tables in each module, manual modification of status records data in various tables based on the comments, handling system issues which arise during data processing, and evaluation of the output for public release.

Assist in tracking the status of new and existing test sections, and ensure that status changes are properly recorded in the IMS.

- Establish tracking procedures for new experiment types
- Review status of SPS program

Evaluate the LTPP IMS as the development continues and provide recommendations for improvement.

- Respond to RCOC needs including multi-user access, storage limitations
- Investigate enhancement and/or development of supporting off-line data bases
- New software upgrades recommendations - ORACLE, DOS 5.0, Windows or OS/2 or Unix?

- Present recommendations on hardware requirements:
 - NIMS - Fast backup, More storage space, Off-line data bases, Optical directly on VAX?
 - RIMS - Faster/better hardware, MicroVAXes at regions, inspect & upgrade UPS as necessary, provide more memory.

Recommended IMS enhancements including:

- Identify IMS procedures that need to be updated or modified due to changes in monitoring equipment or acquisition of new monitoring equipment.
- Identify ways to make the IMS system more User Friendly including better definition of section specific data, and better editing features for data input/corrections
- Identify ways to improve usefulness of the data for data analysis purposes. For data extraction benefits, reverse SHRP_ID and STATE_CODE, reduce length of extracted records, provide more options for data extraction

ABBREVIATIONS AND SPECIAL TERMINOLOGY

Strategic Highway Research Program (SHRP)

National Pavement Performance Database (NPPDB)

Long Term Pavement Performance (LTPP)

National Information Management System (NIMS)

Transportation Research Board (TRB)

National Academy of Science (NAS)

National Academy of Engineering (NAE)

Regional Information Management Systems (RIMS)

Regional Coordination Office Contractor (RCOC)

SHRP Regional Engineer (SRE)

Federal Information Processing Standards Code (FIPS)

Data Base Management System (DBMS)

Quality Assurance/Quality Control (QA/QC)

State/provincial Highway Agencies (SHAs)

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Long-Term Pavement Performance Advisory Committee

William J. MacCreery, *chairman*
W.J. MacCreery, Inc.

Richard Barksdale
Georgia Institute of Technology

James L. Brown
Pavement Consultant

Albert J. Bush, III
USAE Waterways Experiment Station

Robert L. Clevenger
Colorado Department of Highways

Ronald Collins
Georgia Department of Transportation

Guy Doré
Ministère des Transports du Québec

Charles E. Dougan
Connecticut Department of Transportation

McRaney Fulmer
*South Carolina Department
of Highways and Public Transportation*

Marlin J. Knutson
American Concrete Pavement Association

Hans Jorgen Ertman Larsen
Danish Road Institute, Road Directorate

Kenneth H. McGhee
Consultant Civil Engineer

Raymond K. Moore
University of Kansas

Richard D. Morgan
National Asphalt Pavement Association

William R. Moyer
Pennsylvania Department of Transportation

David E. Newcomb
University of Minnesota

Charles A. Pryor
National Stone Association

Cesar A. V. Queiroz
The World Bank

Rolands L. Rizenbergs
Kentucky Transportation Cabinet

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Arizona Department of Transportation

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Wisconsin Department of Transportation

Ted M. Scott
American Trucking Association

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University of Illinois

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Consultant

Marcus Williams
H.B. Zachry Company

Liaisons

John P. Hallin
Federal Highway Administration

Ted Ferragut
Federal Highway Administration

Frank R. McCullagh
Transportation Research Board

Louis M. Papet
Federal Highway Administration

Expert Task Group

Newton Jackson, *chairman*
Washington State Department of Transportation

Paul E. Benson
California Department of Transportation

James L. Brown
Pavement Consultant

John P. Hallin
Federal Highway Administration

Alex Kazakov
Ontario Ministry of Transportation

Walter P. Kilareski
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Consultant

Robert L. Mason
Southwest Research Institute

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The World Bank

James A. Sherwood
Federal Highway Administration

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New Jersey Department of Transportation

Long-Term Pavement Performance Advisory Committee

William J. MacCreery, *chairman*
W.J. MacCreery, Inc.

Richard Barksdale
Georgia Institute of Technology

James L. Brown
Pavement Consultant

Albert J. Bush, III
USAE Waterways Experiment Station

Robert L. Clevenger
Colorado Department of Highways

Ronald Collins
Georgia Department of Transportation

Guy Doré
Ministère des Transports du Québec

Charles E. Dougan
Connecticut Department of Transportation

McRaney Fulmer
*South Carolina Department
of Highways and Public Transportation*

Marlin J. Knutson
American Concrete Pavement Association

Hans Jorgen Ertman Larsen
Danish Road Institute, Road Directorate

Kenneth H. McGhee
Consultant Civil Engineer

Raymond K. Moore
University of Kansas

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William R. Moyer
Pennsylvania Department of Transportation

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University of Minnesota

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New Jersey Department of Transportation