TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-86/53+421-3F		

4. Title and Subtitle	5. Report Date
Developing a Freeway Data Base Model	June 1986
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Gene P. Ritch	Research Report 421-3F
9. Performing Organization Name and Address	10. Work Unit No.
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843	11. Contract or Grant No. Study No. 2-18-84-421
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas State Department of Highways and Public Transportation; Transportation Planning Division P. O. Box 5051 Austin, Texas 78763	Final September 1983 June 1986
	14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with DOT, FHWA.
Research Study Title: Developing A Freeway Data Base Model

16. Abstract

A microcomputer that communicates to traffic measuring devices (Golden River and TRIDAQS) via RS 232 port is equipped to emulate a 3278 workstation. Due to the emulation software and hardware type and the host computer program, data files could not be uploaded or downloaded. The mainframe's program was modified and a different emulation package employed now enables file transfers (after Project ended). New lap top microcomputers configured as TRIDAQS units now collect and process travel time data in four Districts.

17. Key Words	18. Distribution Statement
Golden River, TRIDAQS, microcomputers, IBM-PC.	No restrictions. This document is available to the public through the National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	53	

Form DOT F 1700.7 (8-69)

DEVELOPING A FREEWAY DATA BASE MODEL

By

Gene P. Ritch
Associate Research Specialist

Research Report 421-3F
Research Study Number 2-18-84-421
Developing A Freeway Data Base Model

Sponsored by
Texas State Department of Highways and Public Transportation
in cooperation with
The U.S. Department of Transportation
Federal Highway Administration

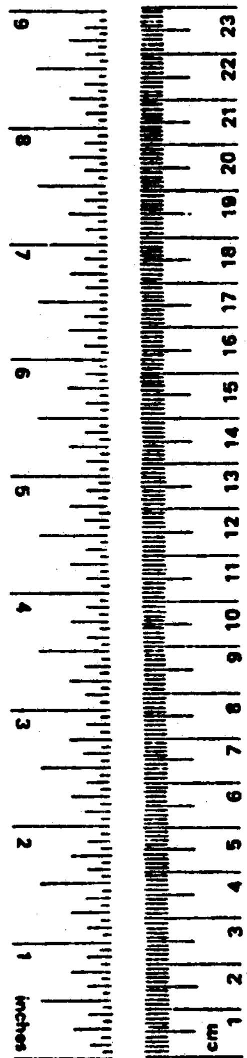
June 1986

Texas Transportation Institute
The Texas A&M University System
College Station, TX 77843

METRIC CONVERSION FACTORS

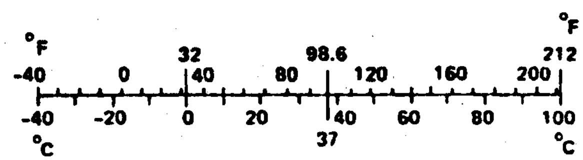
Approximate Conversions to Metric Measures

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	0.95	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	35	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



*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

ABSTRACT

A microcomputer that communicates to traffic measuring devices (Golden River and TRIDAQS) via RS 232 port is equipped to emulate a 3278 workstation. Due to the emulation software and hardware type and the host computer program, data files could not be uploaded or downloaded. The mainframe's program was modified and a different emulation package employed now enables file transfers (after Project ended). New lap top microcomputers configured as TRIDAQS units now collect and process travel time data in four Districts.

DISCLAIMER

SUMMARY

The conceptual design in developing a freeway data base model was utilizing a microcomputer to serve as an interface between traffic measuring devices and a host mainframe computer where the data base was to reside. The microcomputer received slower serial data from the RS 232 interfaces in the traffic measuring devices. With the addition of an emulation package, the microcomputer is to appear as a 3278 workstation. The microcomputer would function as a 3278 workstation but could not transfer data files to the host mainframe computer.

The SDHPT has hardware and software that supports data file transfers using different software and hardware than used in the study.

An Epson PX-8 lap computer was programmed as a travel time data acquisition system for use in a vehicle. A special interface box was designed and built to input pulses from a speed sensor, as well as pushbutton inputs from a hand held control box. The output of the interface box was serial asynchronous data characters in an RS-232 compatible link. As an extension to the project, four additional units were acquired with printers. Additional programming was added to process the travel time studies and compile relevent statistics. These travel time data acquisition systems are know as TRIDAQS units, an acronym for Travel Time Data Acquisition System.

IMPLEMENTATION STATEMENT

For those users of Golden River equipment and the IBM-PC microcomputers with a serial I/O port, data collection and analysis programs in Turbo Pascal provide stand alone (without mainframe support) processing.

Five TRIDAQS units have been delivered. One each were delivered to Houston, Austin, Corpus Christi and El Paso Districts for acquiring and processing travel time data, and one remains at D-18T in Austin as a master unit for additional programming.

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INTRODUCTION

The objectives for the first year 1983-84 are:

1. Develop microcomputer capabilities for inputting data from automatic and semi-automatic data collection devices, as well as from manual count data records.
2. Develop the software capabilities for (1) editing, formatting and storing these data on the microcomputer's diskettes; and (2) forward these data to the host computer.
3. Design a coding system and internal storage format for processing traffic data within the context of a data management and retrieval system.

The objectives for the second year 1984-85 are:

1. Complete the development of application programming for the data base microcomputer.
2. Maintain and enlarge the freeway database.
3. Survey and acquire a portable lap computer for collecting travel time data. A hand held operator's console will be developed to assist the driver in the operation of the data collection unit.
4. Acquire four (4) lap computers and associated peripheral equipment for use in advanced field testing of travel time data acquisition systems and local data processing.

Objective 4 in the second year was added in May 1985 along with funding only for the additional equipment.

BASIC CONCEPT FOR MICROCOMPUTER IMPLEMENTATION

Timely traffic measures provide the traffic engineer with information needed for prudent roadway operations. State of the art traffic measuring devices are illustrated by (1) the Golden River automatic traffic volume MARKSMAN data collection and storage unit and (2) the lap size microcomputing semi-automated TRIDAQS travel time measuring, data collection and storage unit. Large storage devices are needed to contain extensive area wide traffic data collection efforts. Large storage units exists in the mainframe computers operated and maintained by the State Department of Highways and Public Transportation (SDHPT). A problem develops when traffic data stored in the MARKSMAN or TRIDAQS devices are to be placed into the host mainframe computer's storage units. The communications protocol for the traffic measuring devices is typically slower serial data transmission. The host computer is configured to support only the higher speed synchronous data link control (SDLC) protocol. An interface is needed that can convert both data transmission speeds and methods between the traffic measuring devices and the host mainframe computer. The microcomputer is to function as this interface.

The microcomputer will be used to receive traffic data from the traffic measuring devices, process and store these data on its floppy diskettes. A special communication device will be employed in the microcomputer (along with an emulation software program) to enable a link up with the host mainframe computer. The traffic data stored in the microcomputer can then be transferred to the host computer for storage. The large quantity of traffic data in the host computer would serve as a data base but should be managed in a systematic manner for data integrity and interrogation. All data base manipulations would occur within the host computer where ample memory, processing speed and mass storage could best be utilized.

MICROCOMPUTER ACQUISITION

Due to establishment of the IBM system network architecture (SNA) employed in the SDHPT's mainframe computer's communications protocol, the decision was made to keep the link up equipment as compatible as possible. Since Texas Transportation Institute (TTI) was to furnish the microcomputer, every effort was made to insure the unit chosen could be interfaced correctly and also be used as a word processor. In 1983, microcomputers had not been approved to be included in State equipment contract. A microcomputer (word processor) was specified and bids solicited in November 1983. The bid responses did not meet specifications. Twice more, specifications were developed and bids solicited before acceptable equipment was offered. In June 1984, an IBM-PC was delivered containing the components shown in Table 1.

Initial inquiries to the SDHPT concerning the necessary specifications to insure correct interfacing revealed the requirement that the SNA communication protocol be employed. IBM had available a communication interface unit between microcomputer and host computer only through its mainframe computer division and emulation software for the IBM-PC was unavailable for the 3278 unit. As shown in Figure 1, the microcomputer has to function as a 3278 work station. This designation requires that the microcomputer not only have the correct interface for the communication speed and method but also must emulate every keyboard function normally attributable to the work station. The emulation is accomplished by a keyboard matching software program that provides instructions to the communication interface module. In this manner, both software and hardware must function correctly before information can be passed between microcomputer and the host computer. Since IBM could not furnish the total emulation package, other vendor products were analyzed. Several manufacturers seemingly provided identical modules. The AST Research Co.'s BSC (binary synchronous communications) emulation package was delivered. The SDHPT determined that the BSC module would not function properly because present SNA technology required SDLC support. Consequently, the AST BSC emulation package was exchanged for the AST PCOX emulation package which supports SNA SDLC protocol. As indicated in Figure 1, the SNA protocol requires a coaxial cable connection to the microcomputer interface whereas the BSC module provided only twisted wire pair implementation.

TABLE 1

IBM-PC MICROCOMPUTER INVENTORY

Monochrome Display
Display/Printer Adapter
Asynchronous Communications Adapter
512 Kbyte System Unit
Dual Diskettes
Keyboard
Okidata Dot Matrix Printer
Cables (Printer, Power, RS 232)
AST-BSC Emulation Unit

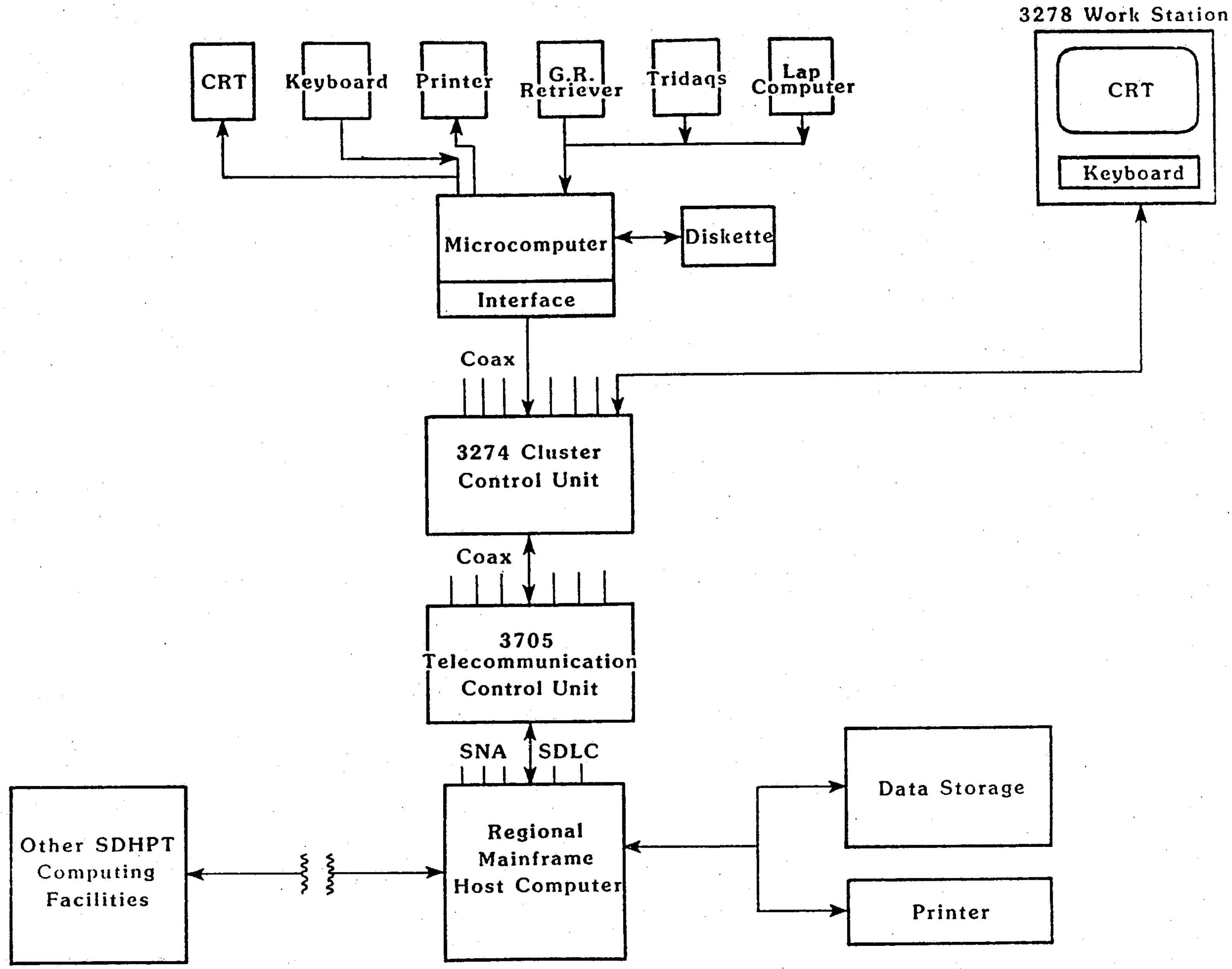


FIGURE 1. Conceptual Design of the Microcomputer Utilization

In October 1984, the IBM-PC was completed with the emulation interface correctly matched. A request was made to the SDHPT for a test connection onto the host computer. Before request approval, the Houston office was burglarized (late November 1984). All microcomputer equipment was taken. The microcomputing equipment was replaced by January 1985 with project funds being used to purchase the AST PCOX emulation package. None of the software and traffic data base information was taken.

SOFTWARE IMPLEMENTATION

To accomplish full utilization of the microcomputer depicted in the conceptual design in Figure 1 requires extensive communications capabilities. Under normal processing activities the communication tasks for the diskette, printer, keyboard and CRT display are supported by the operating system of the microcomputer. Communication software must be obtained for the operation of the asynchronous traffic measuring devices and the 3278 emulation link to the host mainframe. It was determined during equipment specification development that an asynchronous communication adaptor unit supporting RS 232 devices would be sufficient for the traffic measuring devices. The more complicated communication to the host computer would be supported by the additional 3278 emulation package. Therefore, two sets of communications software programs were needed.

Commercially produced asynchronous communications programs are readily available and more cost effective than developing an inhouse program. Several communications packages were considered. From the practical approach, whichever software package chosen should be available or transferable to the SDHPT without copyright infringement or other legal ramifications. Public domain communication programs were also considered. PC-TALK III (1) was tried and proved acceptable. While not exactly public domain software, it is termed "user-supported software" and can be freely transferred between non-commercial users. A nominal donation message is urged by the program author for each new user.

Positive features of the PC-TALK III program are 1) variable software setting of the serial data transmission speed which can reduce user's time when loading traffic data, 2) definitive program pauses are provided which enables the user sufficient time to manipulate the traffic measuring devices during data file selection and transfer and 3) the complete program documentation is included on the delivered diskette in a document file which should be printed and consulted for proper program operation. An indepth discussing of the PC-TALK III program operation as applied in the research study is fully explained in Research Report 421-2 "Golden River Traffic Counter Analysis and Data Storage for the IBM PC" (2).

While there was a selection process for the asynchronous communications software, there is not alternative software for the microcomputer-to-mainframe communications link. The software available is tied to the operations of the emulation (hardware) unit. During the equipment specification and bid solicitations, two different emulation "packages" were offered. AST Research markets an AST PCOX emulation unit and Digital Communications Associates, Inc. provides an IRMA unit. Since the microcomputer equipment was bid "in toto", the AST PCOX unit was in the lowest qualifying bid quote. Furthermore, all specifications indicated that the AST PCOX unit would function as intended.

The acquisition process for the microcomputer equipment was begun in October 1983. In October 1984 all equipment was ready for implementation. A formal request to the SDHPT to provide a test connection point to the host Region computer was initialized in September 1984. All microcomputer equipment was stolen in November 1984 and replaced in January 1985. Permission to test was received and conducted in late February 1985.

One primary objective of the study is to transfer traffic data files from the microcomputer to a host mainframe computer's storage unit. To perform a valid test of the operating capabilities of the emulation unit within the microcomputer, the end results should be examined.

The Division of Automation (D-19) is responsible for all data processing equipment within the SDHPT. To provide access to as many users as possible, it is necessary to isolate the primary operating system(s) programs from the very same users. If the operating system(s) were not protected, computer program and/or equipment malfunctions could severely inhibit the computer's orderly operations; thus its utilization. This isolation is provided by employing "foreground" programs, i.e. ROSCOE, while the operating system(s) programs (TSO) remain in the "background". Malfunctions experienced by the "foreground" programs simply reset and reinitialize, while the operating system continues service. To test the usefulness of the stored traffic data files, users should be encouraged to access the data files without severe entry clearance (as per TSO requirement) or concern about causing system-wide malfunctions.

To delineate the ROSCOE program is beyond the scope of this report. ROSCOE is an interactive program that allows the users to 1) prepare and modify data, 2) retrieve and store data files, 3) submit programs for execution and 4) view program results. All four of these functions were exercised by the microcomputer when connected via the coaxial cable to the host computer and entering via ROSCOE. The microcomputer did function as a 3278 workstation. Data files could not be transferred from the microcomputer to the host computer (or vice versa) under ROSCOE. Data file transfer under TSO was not attempted because of security clearance.

Subsequent to this test session, Applied Data Research (ROSCOE producers) provided, for a fee, a modification to the SDHPT's mainframe ROSCOE program. Also, a PC resident ROSCOE program was developed and must be in operation along with the IRMA emulation unit for successful traffic data file transfers. It has been determined by the Division of Automation that only the IBM and IRMA emulation units perform satisfactory. The AST PCOX will not function properly. Currently the ROSCOE product, termed PTE (Personal Terminal Environment) is marketed for the IBM PC and IBM PC-XT.

Programming efforts were initiated on software that would perform summary routine information on the Golden River data that was being collected and destined for intermediate storage on the microcomputer. Due to the long delay in acquiring the microcomputer equipment, this programming had to began in College Station. Research work conducted and reported in Research Report 290-2, "Data Reduction System Utilizing Golden River Counting and Recording Equipment" (3) was used as a model. By June 1984 when the original microcomputing equipment was delivered, a battery of analysis programs written in Fortran 77 was available and used for traffic volume documentation. SDHPT requested that the programs be written in Turbo Pascal. Much of the second year was spent in converting the data analysis programs from Fortran 77 to Turbo Pascal. A full description of the analysis programs and their use is reported in Research Report 421-2, "Golden River Traffic Counter Analysis and Data Storage for the IBM PC" (2).

DATA BASE DESIGN

The conceptual design of the freeway data base was 1) main storage to be in mainframe computer 2) access to the data base could be from microcomputers operating as 3278 emulation workstations and 3) data base manipulations, analysis programs, summations, etc. to take place in the host mainframe computer where processing speed, large storage capacity, etc. could best be utilized. Due to the long delays experienced in acquiring equipment and the inability to access the mainframe through the proposed 3278 emulation link, the actual data base design, management and operational theory is severely restricted.

A conceptual design of the freeway data base can be represented by the tree like organization exhibited in Figure 2. Discussions held with SDHPT representatives suggest that the futuristic TRANSNET System will not provide roadway locations by the currently used control, section and milepoint designations but will use facility names and mileposts to locate roadway information. Utilizing this nomenclature so as to be consistent with future data bases, a typical data base management system might bring up the first menu suggested in Figure 3. This menu will present facilities that have data in the freeway data base. Note that continuous facilities may be divided into sections. Facility subparts will enable quicker access to the eventual final data. Moving the cursor to the desired facility and striking the entry key will bring up Menu 2 depicted in Figure 4.

The second menu will enable the user to select which direction on the facility the data is located and the location of the data. Cursor movement and entering will bring the third menu exhibiting date and data type.

It is in this third menu that the user must be discrete in chosing the actual data to be analyzed. Note that on the same date, daily or weekly data can be specified at this roadway location. If daily data is desired, cursor movement and entry could cause data output as depicted in Figure 6. If weekly data were chosen, Figure 7 may represent the summary data. Note that in earlier years, a 24-hour ADT number may only be available as depicted by the last entry in the menu.

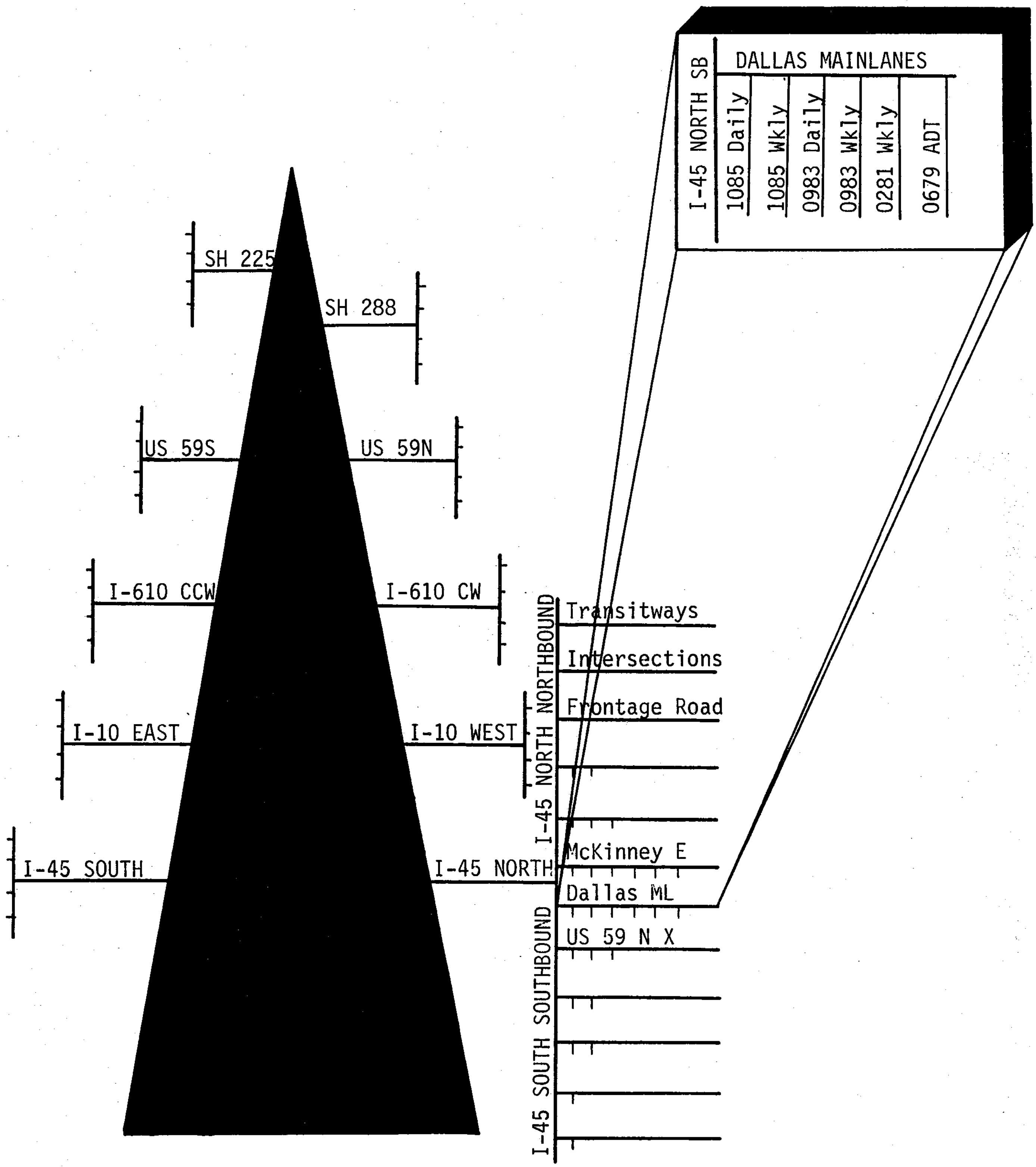


FIGURE 2. CONCEPTUAL TREE DESIGN OF FREEWAY DATA BASE

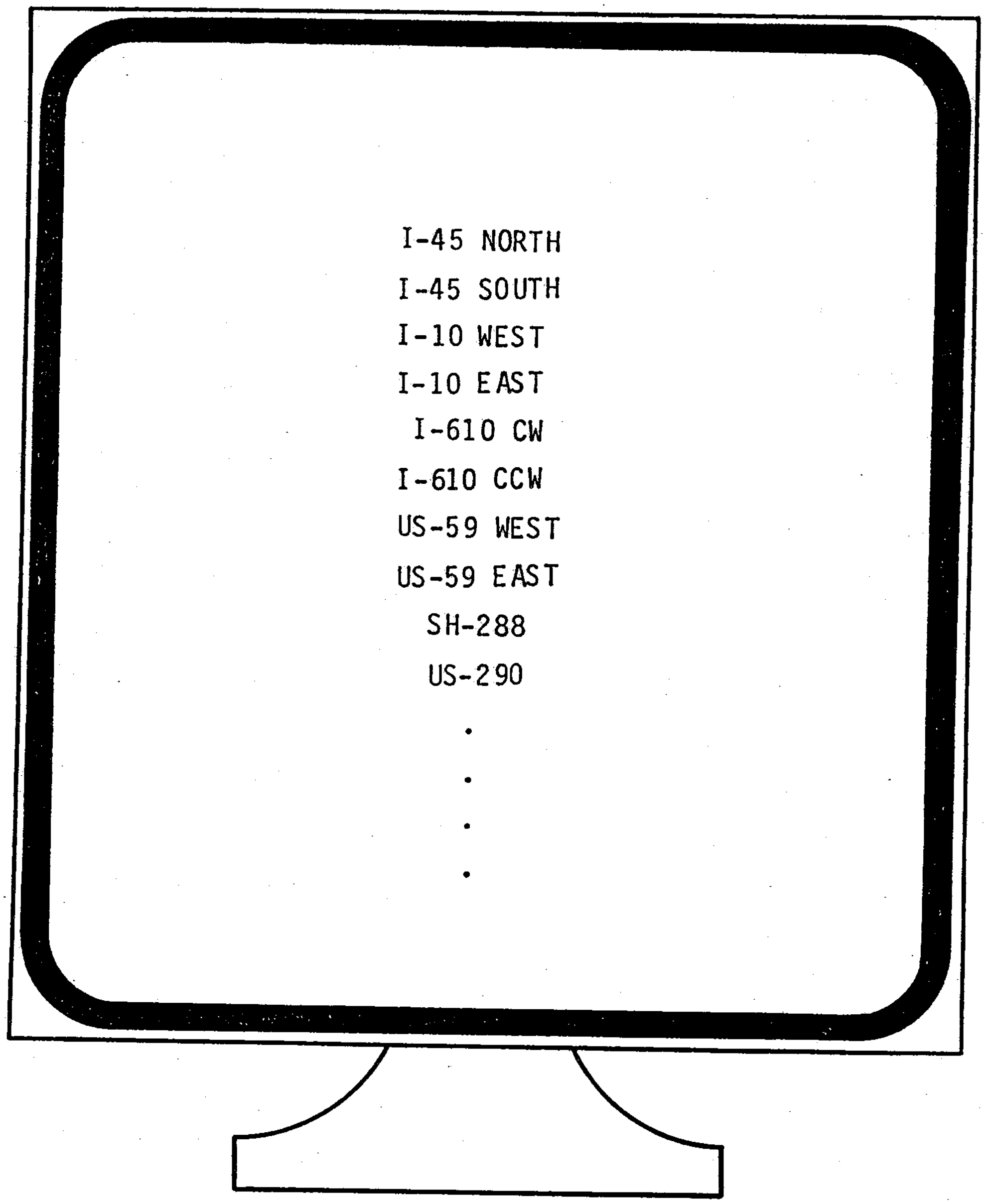


FIGURE 3. 1st Menu Facility Name

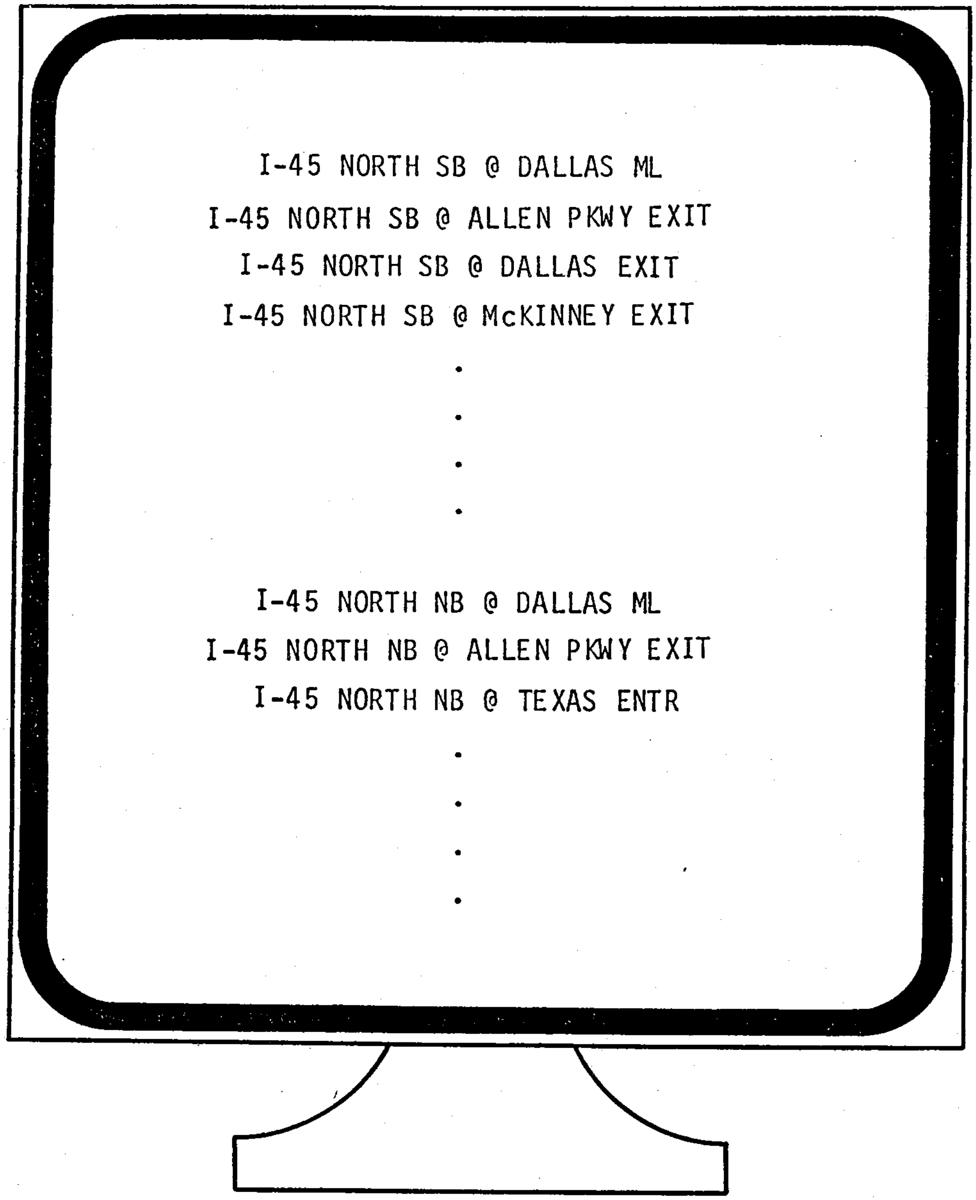


FIGURE 4. 2nd Menu Direction and Location

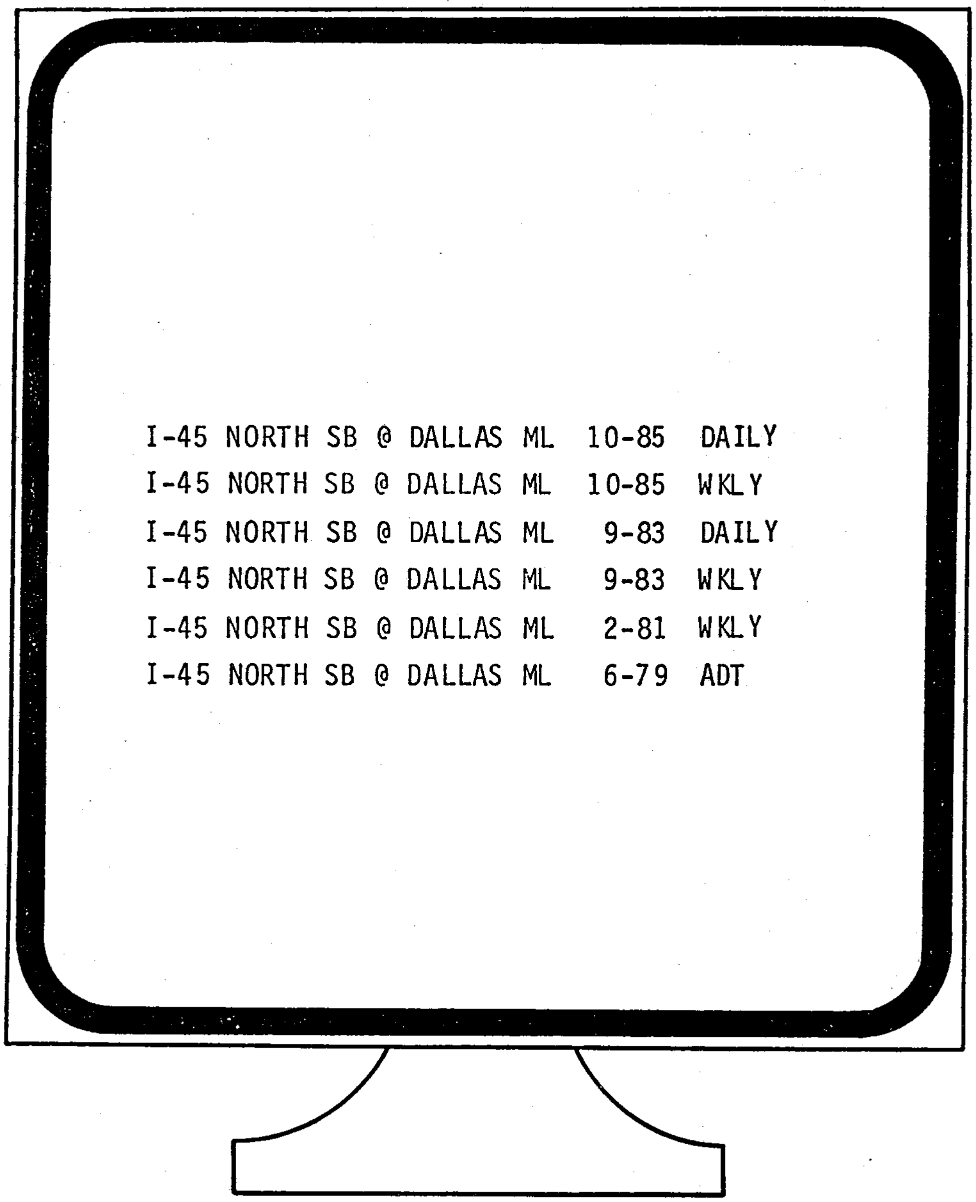


FIGURE 5. 3rd Menu Date and Data Types

T E X A S   T R A N S P O R T A T I O N   I N S T I T U T E

VOLUME COUNT

START DATE: 3- 3-1986   SITE NO: 03100017   COUNTER: GR
WEATHER: CLEAR   DIRECTION OF FLOW: I-610 EASTBOUND FR.RD. W.LOOP
LOCATION: I-610 EB FR.RD.BETWEEN W.JESTER&
CHANNEL : THIS IS 1 OF 6

TIME	VOLUME	HOURLY VOLUME	TIME	VOLUME	HOURLY VOLUME	TIME	VOLUME	HOURLY VOLUME	TIME	VOLUME	HOURLY VOLUME
0.00- 0.15	24		6.00- 6.15	73		12.00-12.15	290		*18.00-18.15	259	
0.15- 0.30	26		6.15- 6.30	105		12.15-12.30	316		*18.15-18.30	226	
0.30- 0.45	30		6.30- 6.45	123		12.30-12.45	285		*18.30-18.45	208	
0.45- 1.00	15	95	6.45- 7.00	157	458	*12.45-13.00	308	1199	*18.45-19.00	164	857
		(95)			(860)			(7071)			(14557)
1.00- 1.15	12		7.00- 7.15	206		*13.00-13.15	332		*19.00-19.15	150	
1.15- 1.30	18		7.15- 7.30	218		*13.15-13.30	295		*19.15-19.30	125	
1.30- 1.45	13		7.30- 7.45	281		*13.30-13.45	349		*19.30-19.45	112	
1.45- 2.00	7	50	7.45- 8.00	308	1013	*13.45-14.00	286	1262	*19.45-20.00	124	511
		(145)			(1873)			(8333)			(15068)
2.00- 2.15	14		8.00- 8.15	273		*14.00-14.15	270		*20.00-20.15	123	
2.15- 2.30	7		8.15- 8.30	271		*14.15-14.30	298		*20.15-20.30	92	
2.30- 2.45	5		8.30- 8.45	265		*14.30-14.45	279		*20.30-20.45	88	
2.45- 3.00	11	37	8.45- 9.00	257	1066	*14.45-15.00	324	1171	*20.45-21.00	81	384
		(182)			(2939)			(9504)			(15452)
3.00- 3.15	10		9.00- 9.15	282		*15.00-15.15	296		*21.00-21.15	114	
3.15- 3.30	15		9.15- 9.30	226		*15.15-15.30	267		*21.15-21.30	95	
3.30- 3.45	7		9.30- 9.45	247		*15.30-15.45	341		*21.30-21.45	93	
3.45- 4.00	12	44	9.45-10.00	225	980	*15.45-16.00	346	1250	*21.45-22.00	81	383
		(226)			(3919)			(10754)			(15835)
4.00- 4.15	13		10.00-10.15	224		*16.00-16.15	338		*22.00-22.15	87	
4.15- 4.30	5		10.15-10.30	228		*16.15-16.30	343		*22.15-22.30	49	
4.30- 4.45	16		10.30-10.45	222		*16.30-16.45	379		*22.30-22.45	41	
4.45- 5.00	11	45	10.45-11.00	228	902	*16.45-17.00	363	1423	*22.45-23.00	41	218
		(271)			(4821)			(12177)			(16053)
5.00- 5.15	21		11.00-11.15	243		*17.00-17.15	445		*23.00-23.15	42	
5.15- 5.30	19		11.15-11.30	257		*17.15-17.30	469		*23.15-23.30	50	
5.30- 5.45	35		11.30-11.45	264		*17.30-17.45	326		*23.30-23.45	27	
5.45- 6.00	56	131	11.45-12.00	287	1051	*17.45-18.00	283	1523	*23.45-24.00	32	151
		(402)			(5872)			(13700)			(16204)

AM PEAK (6:30 - 9:30) VOLUME: 2867   PM PEAK (3:30 - 6:30) VOLUME: 4118   DAILY
AM PEAK HIGHEST HOUR VOLUME : 1133   PM PEAK HIGHEST HOUR VOLUME : 1656   TOTAL: 16204
(NEAREST 15 MINUTE COUNT)   (NEAREST 15 MINUTE COUNT)
AM PEAK HOUR START : 7:30   PM PEAK HOUR START : 16:30

DAILY PEAK HOUR START : 16:30   DAILY PEAK VOLUME : 1656

( ) -- INDICATES CUMULATIVE HOURLY TOTAL   * -- INDICATES THE START DAY

Figure 6. Daily Freeway Traffic Data Form

T E X A S   T R A N S P O R T A T I O N   I N S T I T U T E

WEEKLY VOLUME COUNT SUMMARY SHEET

LOCATION : I-610 EB FR.RD.BETWEEN W.JESTER&
DATE : 3- 3-1986   DIRECTION OF FLOW : I-610 EASTBOUND FR.RD. N.LOOP
CHANNEL : THIS IS 1 OF 6   SITE NO : 03100017

DAY OF WEEK:	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY	5 - DAY	7 - DAY
WEATHER	CLEAR	CLEAR	-	-	-	-	-		
	3 / 3	3 / 4	3 / 5	3 / 6	3 / 7	3 / 8	3 / 9	AVERAGE	AVERAGE
TIME	HOURLY VOLUME	HOURLY VOLUME	HOURLY VOLUME	HOURLY VOLUME	HOURLY VOLUME	HOURLY VOLUME	HOURLY VOLUME	HOURLY VOLUME	HOURLY VOLUME
0- 1	-	95	110	-	-	-	-	102	102
1- 2	-	50	53	-	-	-	-	51	51
2- 3	-	37	49	-	-	-	-	43	43
3- 4	-	44	61	-	-	-	-	52	52
4- 5	-	45	32	-	-	-	-	38	38
5- 6	-	131	136	-	-	-	-	133	133
6- 7	-	458	453	-	-	-	-	455	455
7- 8	-	1013	1012	-	-	-	-	1012	1012
8- 9	-	1066	1099	-	-	-	-	1082	1082
9-10	-	980	934	-	-	-	-	957	957
10-11	-	902	946	-	-	-	-	924	924
11-12	-	1051	1000	-	-	-	-	1025	1025
12-13	-	1197	-	-	-	-	-	1197	1197
13-14	1262	1264	-	-	-	-	-	1263	1263
14-15	1171	1169	-	-	-	-	-	1170	1170
15-16	1250	1273	-	-	-	-	-	1261	1261
16-17	1423	1411	-	-	-	-	-	1417	1417
17-18	1523	1444	-	-	-	-	-	1483	1483
18-19	857	914	-	-	-	-	-	885	885
19-20	511	720	-	-	-	-	-	615	615
20-21	384	550	-	-	-	-	-	467	467
21-22	383	429	-	-	-	-	-	406	406
22-23	218	256	-	-	-	-	-	237	237
23-24	151	169	-	-	-	-	-	160	160
AM PEAK (6-9) VOLUME:	-	2537	2564	-	-	-	-	2549	2549
AM PEAK HIGHEST HOUR:	-	1066	1099	-	-	-	-	1082	1082
PM PEAK (3-6) VOLUME:	4196	4128	-	-	-	-	-	4161	4161
PM PEAK HIGHEST HOUR:	1523	1444	-	-	-	-	-	1483	1483
DAILY TOTAL:	9133 +	16668	5885 +	-	-	-	-	16435	16435

+ --- INDICATES SUM IS NOT FULL 24-HOUR TOTAL
- --- INDICATES DATA IS UNAVAILABLE

Figure 7. Weekly Freeway Traffic Data Forms

Although freeways were used for the facilities in all examples in the menus, intersections, turning movements, transitways, etc. could all be entered into the data base and interrogated in the same manner.

One sidelight to this approach is that once data is stored into the data base it need not be "moved around" each time more data is added. More data can be packed in this manner.

TRIDAQS DEVELOPMENT

The TRIDAQS (Travel Information Data Acquisition System) research conducted during the course of this study has focused toward incorporating a lap computer as the primary logic device. Previous development work with the TRIDAQS (HPR Study 2-18-81-290) resulted in a custom built suitcase unit that recorded travel time data on cassette tape. The initial version utilized a very low cost tape recorder, based on a converted audio unit. This arrangement proved to be unsatisfactory, and the playback of data was frequently unreliable. A later effort replaced the tape recorder with a high quality digital cassette unit, and the suitcase package performed well. By this time, however, the thrust of this work was dampened, and the prototype was expensive and inflexible. Meanwhile, microcomputer technology had surged forward and lap computers were beginning to establish their worth. To take advantage of this new technology, it was seen that it would be useful to generalize the computer-to-car interface so that the computer could accept data through an RS-232 serial port. Since most microcomputers have such a serial port, this step would vastly improve the availability of equipment for logging the data. While portable, battery-powered lap computers are the primary candidates for this role, in fact any microcomputer could be used so long as the size and power requirements of the larger chassis are satisfactory to the user.

Although battery-powered units offer the convenience of acquiring data in a vehicle without electrical power hookup, the RS-232 port has high power consumption. With the particular lap computer being used (an Epson PX-8), the computer would run about 8 hours if the RS-232 port was not opened, but only about 5 hours if the port was open and terminated. So, the real value in battery power for this application is useful only when the data is being recorded in volatile memory, and at a minimum, is needed for memory backup while the computer is carried from the vehicle to the office location where the data is to be off-loaded or processed. For long periods of data acquisition, some method of sustaining the battery charge is required.

If data can be stored on floppy disk or other nonvolatile medium in the car, then an inverter can be used to supply the 120 volts AC to the microcomputer from the vehicle's 12 volt electrical source, and battery power is unnecessary.

For further information on the previous generation of TRIDAQS units, refer to the following publications:

> **Travel Information Data Acquisition System (TRIDAQS) Reference Manual**, by Charles W. Blumentritt, TTI Research Report 290-3, Study 2-18-81-290, Texas Transportation Institute, Texas A&M University, College Station, Texas 77843, December 1983.

> **TRIDAQS Data Processing Programs - WYLBUR Commands and Operating Instructions**, by Charles W. Blumentritt, TTI Research Report 421-1, Study 2-18-84-421, Texas Transportation Institute, Texas A&M University, College Station, Texas 77843, August 1984.

> **Travel Information Data Acquisition System (TRIDAQS) Users Manual**, by Charles W. Blumentritt, TTI Research Report 269-1F, Texas Transportation Institute, Texas A&M University, College Station, Texas 77843, March 1981.

Advanced Testing

The TRIDAQS research phase of this study was primarily concerned with developing a prototype unit for interfacing the speed sensor and pushbutton box to a lap computer, acquiring a lap computer, and programming this computer for data acquisition and transfer of data to an IBM PC. Subsequently, the data would be transferred to the SDHPT regional computer in Houston. While the work proceeded somewhat behind schedule, the results were encouraging and the Texas Highway Department requested that an additional 4 units be procured and packaged for advanced testing. It was requested that the additional units have disk drives and printers for an office environment so that study data could be processed on site, due to the wide geographical distribution of the units. In conjunction with this, two disk drives and a printer were acquired for the prototype system, which was to become a master unit for further testing and program development. Thus a total of 5 units were configured for extended field testing. To support the final configuration, an extensive data processing program was developed in a style that complemented the data acquisition program, and an integrated package was delivered.

Interface Unit

The design of the interface unit, sometimes referred to as the "black box", was the critical element in the system. The black box had data input from 2 sources: the speed sensor and a pushbutton box.

The speed sensor is a MassTech TR-10-6 (unit price $44.63) purchased from Trend Instruments, P.O. Box 431612, Houston, Texas 77243, telephone (713) 827-1200. This speed sensor is manufactured by MassTech Corporation, Swamp Road, Route 313, P. O. Box 2001, Doylestown, Pennsylvania 18901, telephone (215) 345-5300. The device is about 2 inches long and fits in the speedometer drive line. Technically, it can be installed by disconnecting the speedometer cable from the speedometer head, connecting the speed sensor to the speedometer head, and connecting the speedometer cable to the speed sensor. From a practical standpoint, the tightly confined area behind the dash of a modern vehicle renders this approach practically impossible. However, if the vehicle has a cruise control unit, it is usually possible to install the speed sensor under the hood, at the cruise control interface unit. The third alternative for installing the speed sensor is to use a MassTech TR-8-2525-6 speed sensor (unit cost $29.37), which can be fitted in the speedometer drive line at the transmission. Both of these speed sensors consist of 6 radial magnets rotating past a reed switch. The U.S. standard for speedometer drive lines is 1000 revolutions per mile. With a 6 magnet speed sensor, 6000 pulses are output per mile, or a pulse every 0.88 foot. Two wires emanate from the speed sensor for connecting to the black box.

The other data input to the black box is a pushbutton box that is held by the operator to control the data acquisition process. This box is about the size of a package of cigarettes, and consists of a miniature bat handle switch with center off position, and 4 momentary contact pushbuttons. With respect to the center off position, the bat handle switch is pushed forward to start a study and pulled back to stop a study. The 4 pushbuttons are event markers.

The black box outputs ASCII characters at 4800 baud from its serial port. A speed sensor pulse causes a question mark ("?") to be transmitted. The "start study" switch transmits a zero ("0"), "stop study" transmits a one ("1"), and the event switches transmit a two ("2"), three ("3"), four ("4"), or five ("5"). So, if a serial printer is connected to the black box, it would print a question mark for each 0.88 foot the vehicle travels and "0", "1", "2", "3", "4", or "5" whenever a pushbutton box switch was actuated. The resolution of simultaneous speed sensor and pushbutton box inputs is handled by buffering a single character when coincident events occur. The pushbutton box can accommodate a maximum of 16 switch inputs, including the speed sensor input. In the present configuration, the following 7 switch functions are assigned:

1. speed sensor
2. start study
3. stop study
4. event 1
5. event 2
6. event 3
7. event 4

Nine (9) manual switch inputs remain unassigned. A schematic diagram and parts list for the interface box, and a wiring diagram of the pushbutton box are shown in Appendix A. The interface box was designed by Mr. Dick Zimmer of the TTI Proving Grounds Electronics Laboratory, and packaged units were built by his staff.

The lap computer interprets incoming serial port characters according to their type. Speed sensor inputs are accumulated over a one second period, up to a maximum of 127 pulses per second (76 mph). Event button characters are logged as they are received, and the start/stop study characters are also logged, and secondarily cause other internal bookkeeping functions to occur.

Lap Computer

The lap computer selected for this application was an Epson PX-8, a battery powered unit weighing approximately 5 pounds. It has a pop-up liquid crystal (LCD) screen which displays 8 lines of 80 characters. As with most of the currently available LCD screens, it is difficult to read because of the combination of glare and critical viewing angle. The main microprocessor chip is a low power (CMOS) Z-80, which runs the CP/M operating system. Two auxiliary microprocessors are used to support various hardware functions of the machine, such as display, keyboard, RS-232 port, etc.

The main memory of the PX-8 is 64K bytes, and an optional 120K ram disk was fitted for use as the storage medium for the travel time data. Roughly one half of the ram disk is used for resident programs, and the balance (60K) can accommodate well over 12 hours of study data. List prices in 1985 for the PX-8 and ram disk are about $1000 and $500 respectively.

The choice of the PX-8 was a compromise between what would work, what was needed, and cost. Initially, the Radio Shack Model 100 and NEC PC-8201A lap computers were considered, but the lack of dealer and technical support caused reservations about their use. The decision was delayed as long as possible, and it was finally decided that, between the Model 100 and the 8201A, the 8201A was more desirable because of the auxiliary ram storage box that could be inserted on the side of the chassis. This box could accommodate 32K bytes of auxiliary memory, sufficient for logging about 8 hours of travel time data. Fortunately, the Epson PX-8 was announced in tame to avoid the commitment of resources to either of the earlier candidates.

From the outset, the PX-8 hardware and software was flawless, and never gave any problems. The first machine was acquired early after announcement, and the lack of technical documentation necessitated much trial and error work to decode some internal operations. In the end, the machine fully performed to expectations. But the assigned task, that of simple data acquisition, is about all it can handle. The Z-80 is taxed in a nontrivial real time application, and the CP/M operating system is limited in scope. Good or bad, the path between the PX-8 and either the Highway Department or TTI mainframes is an IBM PC, and a PC compatible lap computer is needed to remove one of the incompatibilities from the data path, as well as to bring this application within the arena of today's intense programming activity.

Program Description

The PX-8 TRIDAQS application programs are menu driven. Essentially, there are only 2 substantial programs, one to acquire data and one to process these data. A third program is a main menu program used to select one of the other two.

When the PX-8 is powered up, the main menu program is loaded and the display requests selection of the data acquisition program, the data processing program, or operating instructions. The instructions feature is not implemented at this time, but will be a procedural guide that can be printed out or selectively scanned to answer specific questions. When either of the main programs are selected, that program is loaded and further menus are displayed.

The data acquisition program (DAQP) consists of 2 parts: 1) a real time assembly language program for capturing, formatting, and logging travel time data, and 2) a BASIC program which loads, executes, and communicates with the real time program, and interfaces with the user via the keyboard and screen. When initiated, the DAQP performs housekeeping tasks and loads a portion of the assembly language program to establish the areas of memory that are used to communicate between the two programs. Then a menu sequence is displayed which prompts the driver for updates/entries for the following study parameters: date, time, driver name, vehicle identification (usually license #), vehicle distance calibration, beginning study #, weather status, pavement status, and an indication of whether to erase the previous log file or append new data to the old log file. Next, the remainder of the assembly language program is loaded and a screen template is displayed. The screen template is for the real time display of a speed profile plot, date, day of week, time (to nearest second), speed, weather status, pavement status, driver name, vehicle identification, study #, cumulative study distance in feet and miles, and battery voltage. When a study is in progress, all of these data items are routinely displayed in real time. The program does not refresh the screen for non-applicable items when no study is in progress. Additionally, there are features to interact with the program via the keyboard, in real time, to update the driver name, pavement condition, study #, and weather condition, and provisions for performing distance calibrations for specific vehicles.

The data processing program interprets, formats and prints the data from ram disk to the dot matrix printer (Epson FX-80+), in a variety of formats. This program is written entirely in BASIC and executes quite slowly when doing bit-mapped plots, yet it processes travel time data at about a 10 to 1 ratio, e.g., 10 hours of travel time data can be processed in an hour. An initial main menu is displayed for user choice selection and depending on the choice, various sub menus may be displayed for additional options. Processing choices include:

1) **Study summary statistics only** - for each study, the following information is printed on 1 line: study #, date, day of week, study's starting time (to nearest second), driver name, vehicle identification, weather status, pavement status, study's average speed, study's duration in seconds, number of stops during study, study distance in feet, and study distance in miles.

2) **Print speeds in 100' segments** - for each study, the following information is printed for each 100' station along the study: station distance in feet, time of day arrival, elapsed time since beginning of study, average speed over 100' interval, and identification of any pushbutton events that occurred during the 100' interval.

3) **Miniplots** - a miniplot is a compact speed profile plot with each 100' interval represented by one dot width on the dot matrix printer. Each plot is approximately 1 inch high and eight inches wide and represents 45,000 feet (8.5 miles). Study lengths of up to 99 miles can be represented by successive plots, and there is a one half mile overlap between successive plots for correlation. A submenu is displayed for additional parameter entry, such as the

speed integration interval (100-500 feet), a shading option (bar chart versus line plot), 10 mph speed lines option (horizontal dotted lines), and unidirectional printing option (optimum alignment for report quality).

4) **Printer plots** - a printer plot is a coarse "sideways" plot with the printer's vertical space representing a 100' interval, and each horizontal space representing 1 mph, with a plot symbol capping the appropriate number of mph spaces. A submenu requests additional parameters, similar to the miniplot sequence described above.

5) **Summary, pushbutton and speed statistics** - this is the default option for study data processing. The summary data described in 1) above is printed in a slightly different format, followed by a pushbutton interval summary which provides information on the intervals from one pushbutton event to the next. The information printed includes: which pushbutton was pressed, the time of day the event occurred (to nearest second), the interval distance traveled, the interval travel time, the average speed over the interval, the spot speed when the button was pressed, and the number of stops that occurred during the interval. Finally, a speed statistics table is printed. This is a horizontal bar graph, where each bar represents a 5 mph speed interval in the 0-70 mph range. The length of the bar represents the percentage of the time that the vehicle was traveling within the speed interval during the study.

A sample printout of some of these options is show in Appendix B.

FINDINGS AND RECOMMENDATIONS

Data Base Model

The findings of the study are even more positive than if all objectives of the study has been achieved. The SDHPT, particularly the Division of Automation, has achieved in the 2 year period working (not just short term tests) microcomputer to mainframe communications hardware and software systems. The potential users of these study findings are much closer to implementing the study information than if all objectives were reached yet the SDHPT was not able to implement the microcomputer to mainframe computer link up.

Emergent technology, since 1983 when a large microcomputer contained 512 Kbytes of memory and a 10 Meg hard disk, has generated faster microcomputers, larger memories, larger and faster hard disks, ever increasing software applications and costs even less than before. The larger hard disks and memories along with creative data base management systems especially written for microcomputers suggests that a wholly contained freeway data base model could be applied in a microcomputer (IBM-PC XT or equivalent).

It is recommended that further research be conducted in applying data base management systems to a PC contained freeway data base.

TRIDAQS Recommendations

The TRIDAQS system is operational and 5 units are in the field. The following recommendations are made for any future systems that might be contemplated:

1. Any additional units should be based on an IBM PC compatible lap computer.

2. The interface unit (black box) falls short of the flexibility needed.

The simplicity of the box causes too much processing time to be expended by the lap computer. An option should be available to accumulate distance pulses over 1 second intervals within the box, with the trasmission of accumulated counts serving as the real time clock to the receiving device. This would allow the use of a very low cost computer to be used for data acquisition when desired.

3. A documentation file should be developed for the present TRIDAQS, to be used as an operating and reference manual.

4. The procedure for distance calibrations is still in need of simplification, to encourage frequent vehicle distance calibrations.

5. Program options should be added to utilize the 3 1/2" disks, particularly where storage of summary statistics is concerned.

6. Similar to the study data processing program previously developed for a mainframe, some programming is needed to combine studies which occur over the same study section.

7. A program is needed to off-load study data to an IBM PC.

8. A percentage stop time calculation should be made and printed out with the study results.

9. The user has a choice of speed integration interval, and the selected interval should be included on the printout.

10. Study printouts should be annotated with surface milestone names (overpass designation, intersection name, ramp identification, etc.) so that a clearer picture of the study section can be presented on the printout.

11. The process of creating a microtape containing object programs requires extensive operator interaction. This process should be programmed for automatic operation.

12. If a BASIC compiler is available to support the special features of the PX-8, one should be acquired to speed up the execution time to the existing BASIC programs.

13. The correlation of studies (identified by study #, date and time) with the physical location of the study section remains a problem. A technique needs to be developed to do "training runs" with the TRIDAQS over study sections. These runs would determine the section distances and milestones for later annotation. The introduction of recent navigator map devices (GM will offer this feature in next year's luxury cars) suggests that a low cost inertial guidance (IG) system is feasible. Integrating the "training runs" with IG hardware would solve some fundamental problems conducting large numbers of travel time studies.

14. Voice input to the lap computer should be implemented so the driver need not take his hand or eyes off the road. So few commands are required for operating the TRIDAQS, and a low cost voice input unit should be possible. As a confirmation of voice input, a low vocabulary voice response unit would be helpful.

15. Future designs for the interface unit should utilize one of the more accurate MassTech speed sensors, such as the Hall Effect model or an optional disk version.

REFERENCES

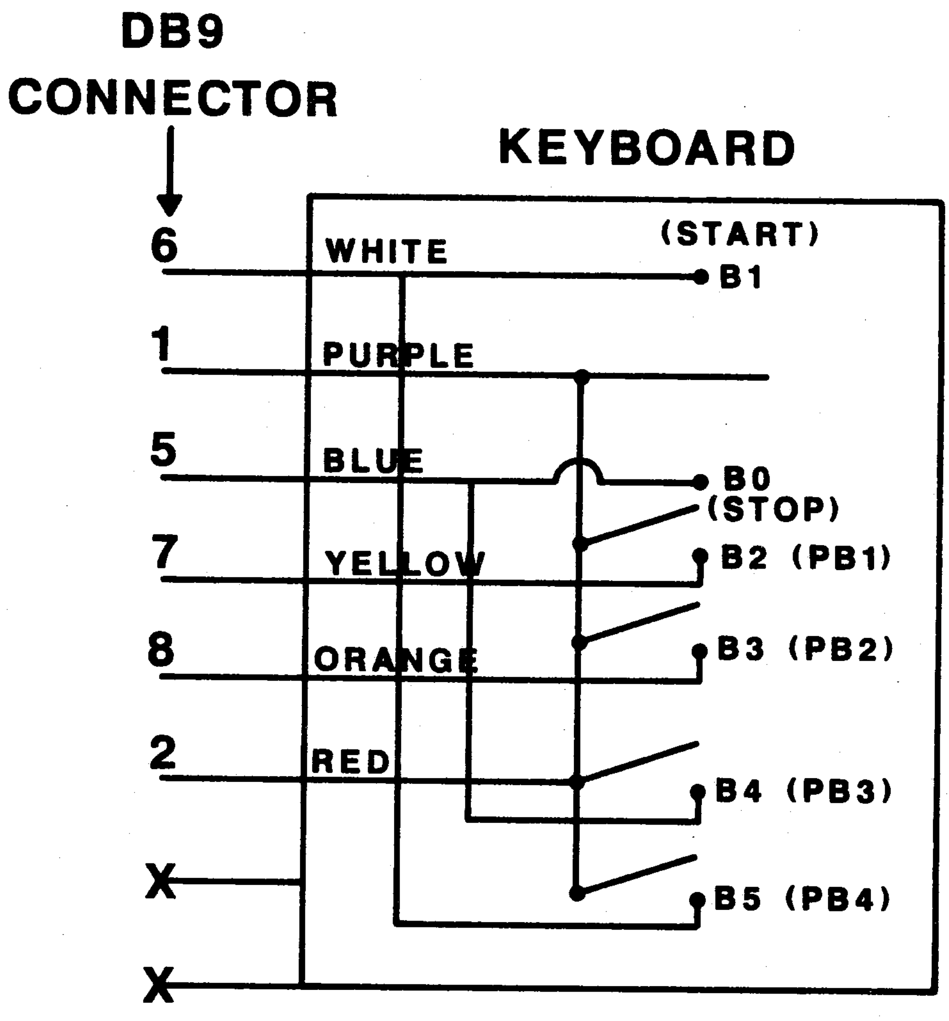
1. Fluegelman, A., PC-TALK III Documentation, Freeware, Tiburon, CA 94920.

2. Chang, D.J., Lee, J., and Ritch, Gene P., "Operations Guide for the PC Header and Report", Texas Transportation Institute, Research Report 421-1, December 1985.

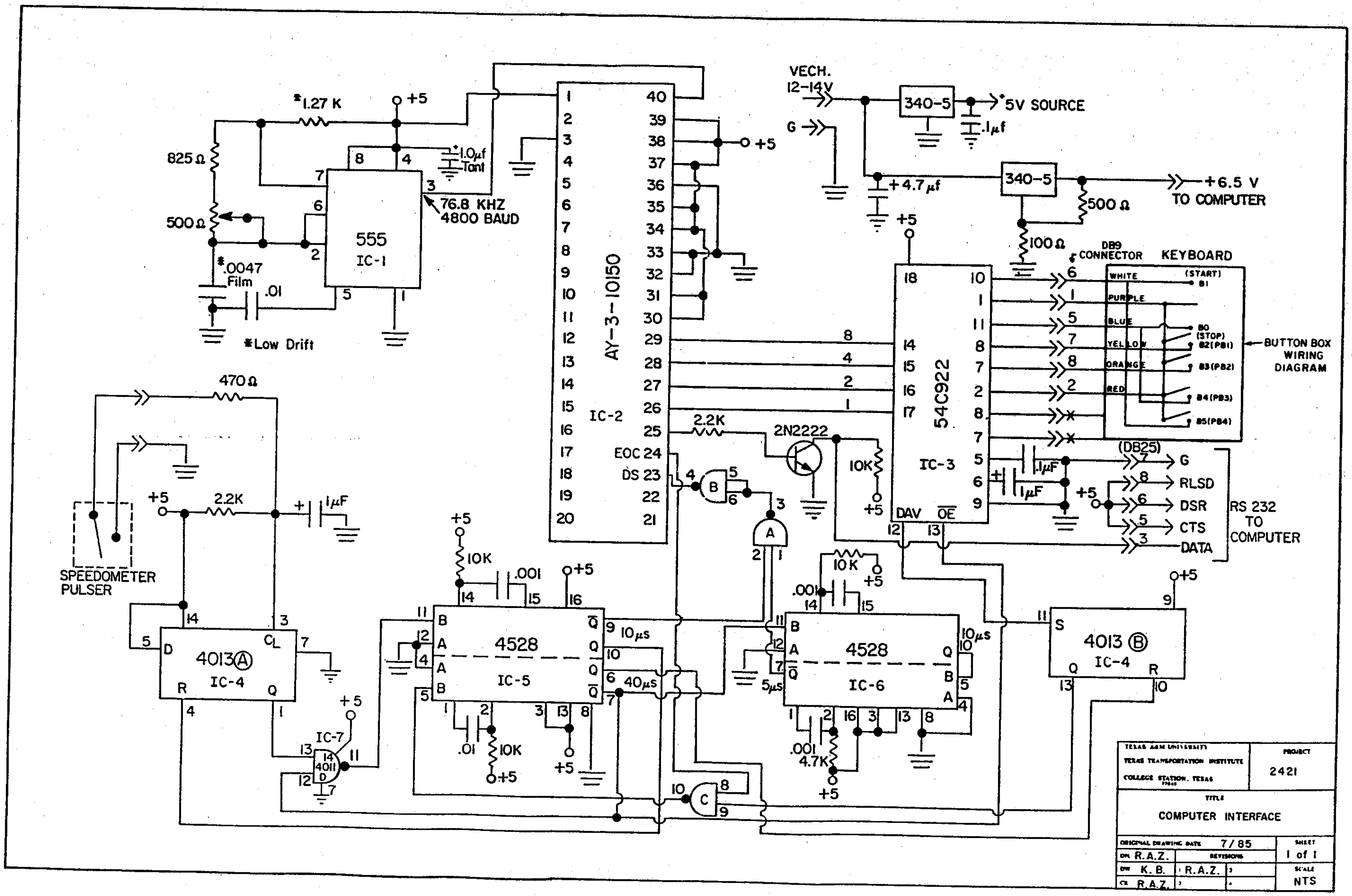
3. Lee, Jae Y. and Ritch, Gene P., "Data Reduction System Utilizing Golden River Counting and Recording Equipment", Texas Transportation Institute, Research Report 290-2, November 1983.

APPENDIX A

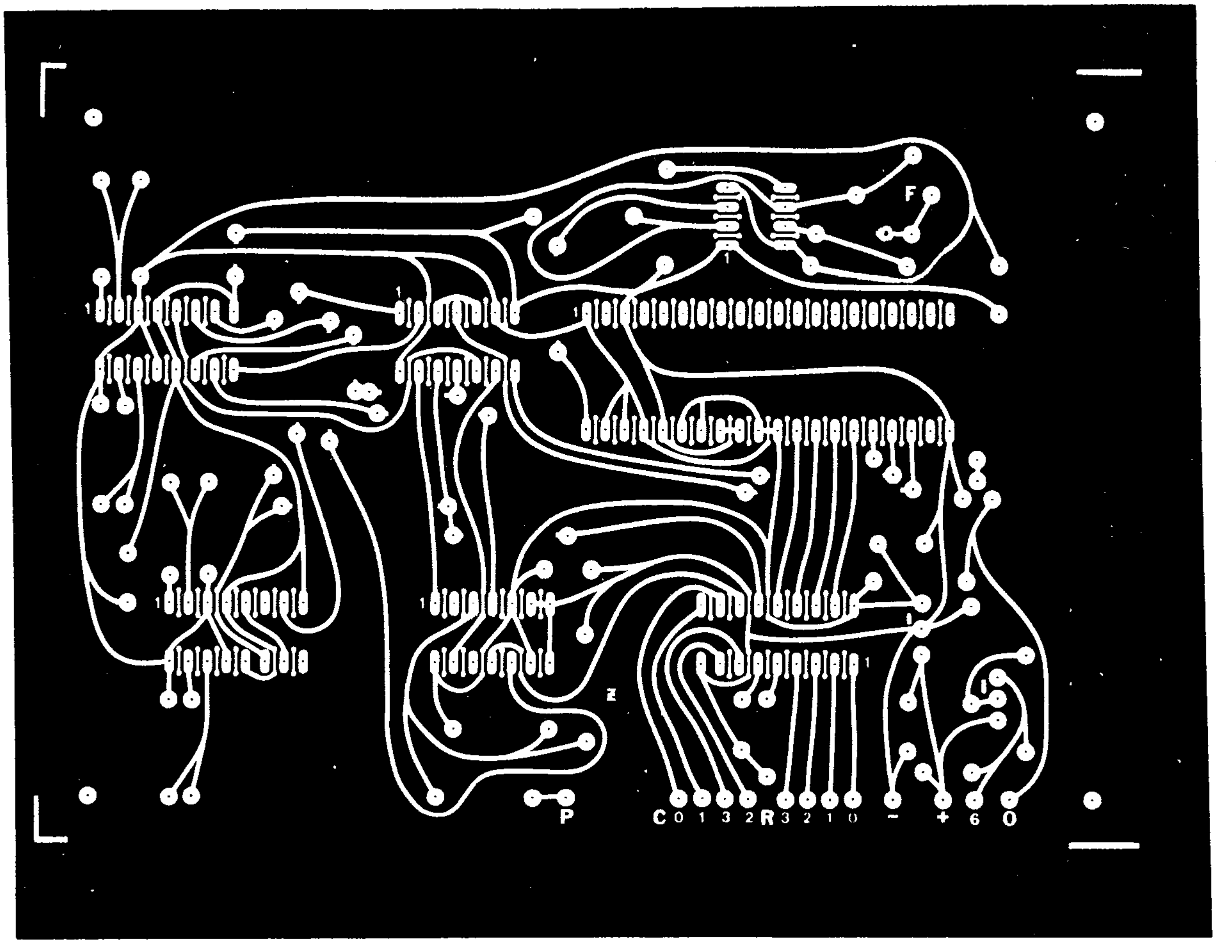
TRIDAQS INTERFACE SCHEMATICS



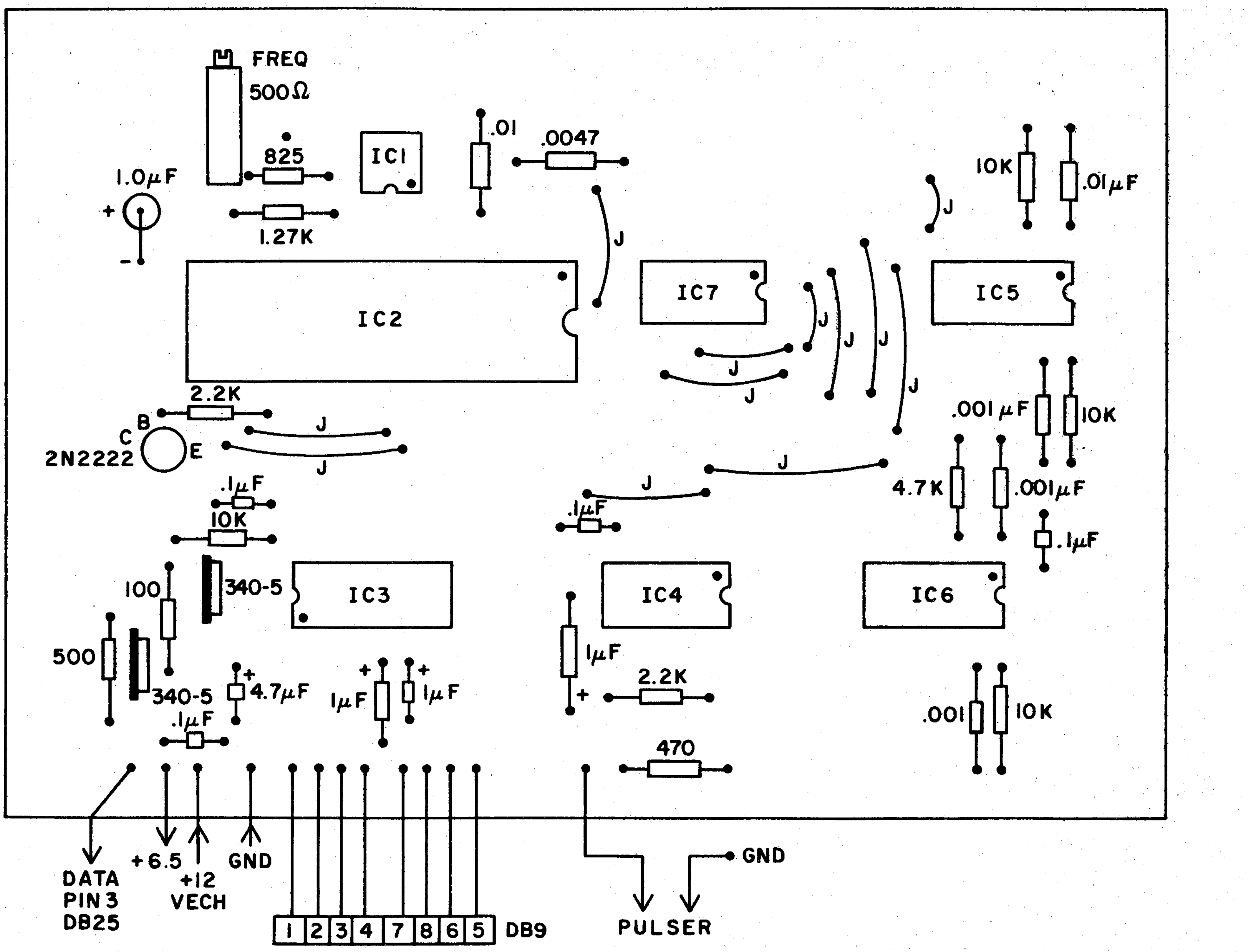
Push Button Box Wiring Diagram



Vehicle Interface Schematic



P.C. Board Neagative



P.C. Board Layout

COMPUTER INTERFACE
PARTS LIST

IC1	LM555
IC2	AY-3-10150 (G.I.)
IC3	54C922
IC4	4013
IC5, 6	4528
IC7	4011
IC8, 9	340-5
Q1	2N2222
R1	1.27K OHM METAL FILM
R2	825 OHM
R3	500 OHM TRIMMER
R4	470 OHM
R5, 10	2.2K OHM
R6, 7, 8, 9	10K OHM
R11	4.7K OHM
R12	100 OHM
R13	500 OHM
C1, 2, 3	1.0 microfarads 25V
C4	.0047 microfarads MYLAR
C5, 12	.01 microfarads
C6, 7, 8	.001 microfarads
C9	4.7 microfarads 25V
C10, 11	0.1 microfarads Disk 25V
J1	DB25 CONNECTOR
J2	DB9 CONNECTOR

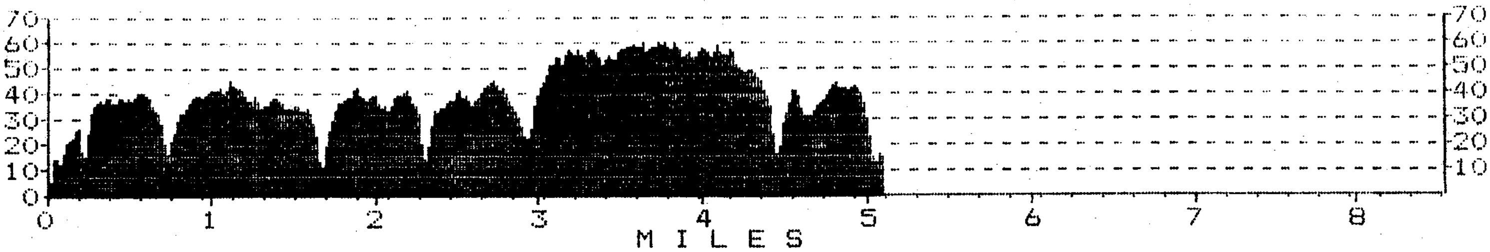
APPENDIX B

TRIDAQS SAMPLE OUTPUT

TEXAS STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

TRIDAQS TRAVEL TIME STUDY 3 10/12/1985 Saturday 14:30:18

DRIVER CHBLUM VEHICLE MEY497 WEATHER PARTLY CLOUDY PAVEMENT DRY



AVERAGE SPEED 30 DURATION 9:58 STOPS 6 DISTANCE 26982 FEET 5.1 MILES

>>> PUSHBUTTON EVENT INTERVAL SUMMARY <<<

EVENT	TIME OF DAY	DISTANCE	TRAVEL TIME	AVERAGE SPEED	SPOT SPEED	NUMBER STOPS
STRT	14:30:18	0	:00	0	0	0
PB3	14:32:35	3837	2:17	19	0	2
PB2	14:38:36	19605	6:01	37	10	2
END	14:40:16	3541	1:40	24	0	2

SAMPLE PRINTOUT

APPENDIX C

TRIDAQS EQUIPMENT SPECIFICATION

Specification

PORTABLE LAPSIZE MICROCOMPUTER AND PERIPHERAL EQUIPMENT

This specification is for the following items. Further details follow the item list.

Item	Quantity
Portable Lapsize Computer and Documentation	4
Disk Drive and Cable	6
Serial Dot Matrix Printer, Cable, and Documentation	5
RAM Disk Storage Unit	4
Modem Cable	4

NOTE: 1) A MINIMUM OF 15 CABLES ARE TO BE SUPPLIED, REGARDLESS OF WHETHER SOME OF THE CABLES ARE IDENTICAL.

2) ALL EQUIPMENT IS TO BE DELIVERED PREPAID, SO DELIVERY CHARGES SHOULD BE INCLUDED IN THE BID PRICE.

PORTABLE LAPSIZE MICROCOMPUTER

This specification is for a portable, lapsize microcomputer not weighing more than 5 pounds, with dimensions not exceeding 12 inches square by 3 inches high. The unit shall be battery powered, consisting of a main battery and a backup battery. The main battery shall be capable of operating the computer for at least 12 hours, and the backup battery shall preserve memory contents during recharging of the main battery. The batteries shall be nickel-cadmium and rechargeable. An AC adapter shall be supplied for battery charging. A liquid crystal display shall be a component part of the unit, consisting of a minimum of eight (8) lines of 80 characters each. The display shall have a viewing angle adjustment. A standard typewriter keyboard shall be an integral part of the unit, with a minimum of 5 function keys which can be sensed under program control.

The microcomputer chip shall be a Z-80 CMOS (complementary-symmetry metal-oxide semiconductor) technology version, capable of supporting the CP/M 2.2 operating system. A standard memory of 64K RAM, accommodating the full address space of the Z-80, shall be included as an integral part of the computer. The CP/M operating system shall be included as a ROM module of the computer. Additionally, the BASIC programming language shall be supplied in a ROM version for the computer. Both CP/M and BASIC ROMs shall be simultaneously accommodated as standard, integral parts of the computer. The BASIC language shall be capable of supporting machine language subroutines, and the documentation shall clearly state the procedures for calling and returning from these subroutines. A user accessable timer shall be capable of generating program interrupts at intervals not exceeding 5 milliseconds. It is understood that user supplied machine code is required for servicing such an interval timer. A real time clock, which may be separate from the interval timer, shall be accessable under program control and capable of signaling one second time intervals.

Peripheral connections shall include RS-232 and serial I/O ports and a bar code reader input port. Bit rates of 300, 1200, 2400, 4800, 9600, and 19,200 bits per second shall be supported by the RS-232 interface. The bar code reader input shall be capable of generating a machine interrupt with a +5 volt pulse.

Documentation shall be supplied for all aspects of the hardware and software. The documentation shall include, but not be limited to, the following manuals:

1) BASIC Programming Language Reference Manual
2) User's Manual
3) User's CP/M Reference Manual.

Documentation shall be included to explain how the user can interface an assembly language program as a service routine for interval timer interrupts, and how the time of day clock can be accessed both from BASIC and assembly language.

DISK DRIVE AND CABLE

The disk drive shall be a portable, battery powered drive which accommodates 3 1/2" double sided, double density mini-floppy disks. A minimum of 320K bytes shall be available per disk. The batteries shall be nickel-cadmium rechargeable type, and capable of recharging from a 120V AC source. The AC adapter for recharging shall be included. Up to two (2) disk drives shall be capable of being daisy chained, which will allow an online disk storage capacity of 640K bytes. The cable for connecting the disk drive to the computer shall be included. In addition, the cable for daisy chaining one disk drive to another shall be included, if different from the cable for direct connection to the computer.

SERIAL DOT MATRIX PRINTER, CABLE, AND DOCUMENTATION

A dot matrix printer with RS-232 serial interface shall be supplied. A minimum 9x9 print matrix is required, and the printer shall print at a rate of at least 160 characters per second. It shall have a bidirectional print mechanism and an integral RAM buffer not less than 2K bytes. The printer shall have both friction feed and tractor feed paper handling mechanisms, with both forward and reverse paper feed capabilities. The tractor feed shall have a horizontal adjustment which accommodates paper width from 4 inches minimum to 10 inches maximum. The character print capability shall allow 6 pitches from 6 to 20 characters per inch with emphasized and double-strike weights, super and subscript heights, and an underline mode. Character formatting shall be software controlled from the host computer, allowing both horizontal and vertical tabs, setting of left and right margins, specification of line spacing and page length, and designation of proportional spacing. Additionally, the printer shall allow a user designated character/graphic set of up to 256 symbols to be downloaded from the host computer. A graphics print capability shall be included which permits dot densities up to 240 per inch. The bidirectional print capability shall apply both to character and graphic modes.

The printer shall support the full ASCII character set as represented by string constant and string variable arguments of the LPRINT command of the BASIC interpreter supplied with the portable microcomputer. A printer cable shall be included which has a minimum four (4) foot length, and shall plug into the RS-232 port of the portable microcomputer without cable adapters. The printer end of the cable shall utilize a DB-25 connector.

A documentation manual shall be included which supplies information for setting up, operating, and maintaining the printer. In addition, control codes for the character print and formatting capabilities shall be fully documented with an example shown in the BASIC programming language for the use of each code.

RAM DISK STORAGE

A ram disk storage unit shall be supplied with a minimum capacity of 120K bytes. This unit is in addition to the 64K RAM primary memory of the portable microcomputer. This unit shall be either: a) included within the housing of the portable microcomputer, b) attached as an auxiliary component of the microcomputer, or c) a plug-in module of the microcomputer. The RAM disk storage unit shall be battery powered, either from its enclosed source, or from the battery power of the microcomputer. The unit shall be configured so that only a single connector is required for recharging the battery power source of both the microcomputer and the RAM disk storage. If the RAM disk storage is a plug-in module, it shall contain a battery backup to retain memory contents for a minimum of two weeks. Documentation shall be furnished to describe how to install the ram disk storage unit, and how to store and retrieve data both from assembly language and BASIC.

MODEM CABLE

The modem cable shall be a minimum of four (4) feet in length. This cable is used to connect the portable microcomputer to an acoustic coupler via the RS-232 port. A DB-25 connector shall be provided for the end of the cable to be connected to the acoustic coupler. The DB-25 connector shall provide the following pin assignments (pins not specified are unterminated):

DB-25 Pin	Function (with respect to microcomputer)
1	GND - ground
2	TXD - transmit data
3	RXD - receive data
4	RTS - request to send
5	CTS - clear to send
6	DSR - data set ready
7	GND - GROUND
8	DCD - DATA CARRIER DETECT
20	DTR - DATA TERMINAL READY

WARRANTY

The length and terms of warranty shall be clearly stated with the bid.

TECHNICAL CONTACT

Technical questions about this specification should be directed to:

DELIVERY

The items specified shall be delivered prepaid to:

PAYMENT

Payment will not be made until all hardware, software and documentation items described in this specification are delivered.