COMPUTER PROGRAM DEVELOPMENT

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DEVELOPMENT OF COMPUTER PROGRAMS

I INTRODUCTION

In as much as the need for computer programs arises continually throughout the year and because this need for assistance comes from all areas of the Texas Highway Department, this report will illustrate an outline procedure of the general progress followed in the development of a computer program. Following this procedure, an analysis will be presented for the major categories of program development during the research period. These major categories are listed as follows:

1. DEVELOPMENT OF ENGINEERING PROGRAMS
2. DEVELOPMENT OF ACCOUNTING PROGRAMS
3. DEVELOPMENT OF COMPUTER PROGRAMS FOR MANAGEMENT CONTROL
4. DEVELOPMENT OF GENERAL UTILITY PROGRAMS

The Highway Research Project Number 1-21-63-42, Federal Number HPR-1 (3) for the development of computer programs within the above categories, was charged with the employee time from a staff of twelve members. In addition, a considerable amount of machine time was required for the testing and correcting of new programs, modified programs and the systems development work during the transition period of changing from an IBM 650 computer to a much larger CDC 1604-A computer.

During the research period a Progress Report was prepared and submitted monthly, furnishing information on those computer programs that were being developed. Not all of these programs were completed during the research period as this final report will indicate. However, the programs under development will be found in one of four phases, namely (1) Investigation Phase, (2) Block Diagramming Phase, (3) Machine Testing Phase and/or (4) Operational Phase.

II ANALYSIS OF COMPUTER PROGRAM DEVELOPMENT PROCEDURE

For the benefit of readers of this report it will be beneficial to have a brief understanding of how and where computer programs are originated and the basic development procedure of any computer program, the organization of the Highway Department's Computer Section and the hardware involved in the area of research.

The Texas Highway Department functions as a separate unit of the State government under the administrative direction of the State Highway Engineer. The department is divided into twenty-five districts and sixteen divisions, comprising a total personnel of approximately 17,000 people. The general pattern of all twenty-five districts is shown as follows:

1. Administrative
2. Design
3. Construction
4. Maintenance

The sixteen divisions, all located in Austin, were established within the basic growth pattern of functional activities, each designed primarily to be of aid to the district personnel in the design, construction and maintenance of highways.

One of the sixteen divisions is titled the Operations Division (D-21) and it is within this division that the Computer Section was organized. The Computer Section itself is divided into two major functions, namely (1) Data Processing, or Production and (2) Computer Programming. It is, of course, with the Programming Section that this report is primarily concerned. This section normally consists of a staff of twelve personnel, each being equipped with the necessary background for developing computer programs. Out of this vast Highway Department with its varied functions and diverse activities, originates the requests for the development of computer programs. In most instances the requests, whether from district or division personnel, are made by verbal or written contact with the Director of the Computation Center. The Director, depending upon the nature of the work, assigns the problem to one of the available programmers. This is the beginning of a computer program, and a tremendous amount of discussion, investigation, block diagramming, machine coding and testing will follow prior to the completed finalized computer program.

The type of computer, and its' auxiliary equipment, in operation during the research period is listed as follows:

1. IBM 650, 2000 word drum memory, 60 word core storage, 3 index registers and three tape units. Used until March, 1964.

2. IBM 1401, 8000 character memory, card read, card punch and 600 line per minute printer, plus four 729 tape units.

3. CDC 1604-A, 32,768 words of core storage, four 606 tape units. Currently being used.

The types of programming language used during the research period are listed as follows:

	TYPE	DESCRIPTION
1.	SOAP	Symbolic Optimal Assembly Program for IBM 650.
2.	AUTOCODER	Symbolic programming language for IBM 1401.
3.	RPG	Report Program Generator for IBM 1401.
4.	FORTRAN	Formula Translator; a compiler program for the CDC 1604 which is oriented towards engineering work.
5.	COBOL	Common Business Oriented Language; a compiler program for the CDC 1604 which is oriented towards accounting work.

It should be mentioned at this point that a great deal of the programming work conducted during the research period was involved in the necessary preparations for the change over from the IBM 650 to the CDC 1604-A Computer. These preparations consisted primarily of modifications and rewriting of existing programs, learning new programming languages, writing new programs, training, testing, etc. for the 1604-A Computer.

The remaining pages of this report will present information pertaining to the computer programs worked on and developed during the research period of 1963-1964.

III DEVELOPMENT OF ENGINEERING PROGRAMS

For the purposes of this report this major area of work referred to as "Engineering" has been categorized into four sub-sections of computer programming activity.

A. BRIDGE COMPUTER PROGRAMS

1. Blocking and Framing for Bridge Structures

Personnel from the Bridge Division (D-5) and various field engineers in the districts jointly originated the request for this program. The primary purpose and objective of this program is to determine the dimensions of beams and diaphrams for cutting and fitting into a bridge structure. The basic investigation with the originating personnel included extensive analysis into the methods currently being employed to solve the mathematical equations, and then developing new equations for the computer. These equations have been developed and preliminary input sheets have been designed. At the end of the research period this program remained in the development stage.

2. Tape Oriented Curved Bridge

This program was originated by the programming staff of the Computer Section in an effort to make data processing more efficient in terms of machine time and operator handling. The purpose of this program was to modify four other bridge programs in order to permit continuous processing of problems involving curved bridges. To accomplish this, intermediate answers, or data, had to be stored on tape and be available for recall when the four bridge programs were being used. Investigation, block diagramming and machine testing are complete, and this program is in operation.

3. Modified Bridge Structure

The Bridge Division (D-5) requested that a program be developed which would furnish a more detailed breakdown of the materials used in the construction of a bridge. Consequently, this program was modified to accomplish this objective and the program is operational.

B. EARTHWORK COMPUTER PROGRAMS

1. Plotting Cross Section Data

This program was requested by field personnel with the purpose

and then additional information required for the proper solution of earth quantities. This program is operational.

6. Alteration of Inside Ditch Design

This program was originated within the computer section. The primary purpose is to combine the Inside Ditch Program with the Earthwork Design Program for a more economic and efficient use of the CDC 1604-A computer. The basic investigation, block diagramming and testing has been completed. This program is operational.

7. Altered Coordinates of Rod Readings

Being initiated by the computer section, the basic purpose of this program was to modify an IBM 650 program in a manner that it could operate on the CDC 1604-A and IBM 1401 computer system. This modification has been accomplished and the program placed into operation.

C. TRAFFIC COMPUTER PROGRAMS

1. Traffic Counts Tabulation

The request for this program originated from the Planning Survey Division (D-10). The primary purpose of this program is to furnish listed data involving the movement of vehicles throughout the entire highway system. The input data for this program originates from all districts each month and consists of counts of vehicles at hourly intervals for predesignated spots. The program lists, or tabulates, the number of vehicles passing through each traffic count station by the day and the hour. In addition, certain weather data is recorded and listed for each day involved. The Planning Survey Division has varied uses for this output data, such as aiding them in the annual preparation of State and District road maps. This program also produces a monthly report that is furnished to the Bureau of Public Roads. Developed for use on the IBM 1401, this program is fully operational.

2. Accident Detail for 1963

A modification of the Accident Program was requested by the Maintenance Division (D-18) for the purpose of conforming to the new 1963 card format for input data. All necessary changes were accomplished and the program continued to be operational.

3. Intersection Capacity Input Data Check

The Highway Design Division (D-8) requested that a program be developed that would compute intersection capacities and would process survey data of traffic flowing through intersections.

Initial investigation revealed that the Minnesota Highway Department had developed a similar program for their use on an IBM 1620, and also that the Department of Highways and Traffic, Washington D. C., had developed a fortran program. After a careful review of the various programs available, the computer section designed a 1401 program on the basis of the rules and formulas as set forth in the Highway Capacity Manual, U. S. Department of Commerce, Bureau of Public Roads, 1950 edition.

After this program had been fully documented and placed into operation for a period of several weeks, it was modified and extended to include editing for classification and coding. In addition, error printouts were added for data which could not be classified in accordance with the manual. This program is currently in operation and has been widely used by the major cities in the State of Texas.

4. Origin And Destination Study Programs

The Planning Survey Division (D-10) requested that programs be developed that would furnish basic information to permit the proper analyses of the origin and destination of traffic. The input data for these programs is furnished by the originating division and consists of basic vehicular movement in and through a metropolitan area. This data is analyzed for local and external traffic movements, both directional and non-directional, land use properties of the metropolitan area, purpose of trip by time of day, type of parking available, purpose of travel and land use properties, average occupancy of the trips, and trip movements to major traffic generators - such as central business sector. These analyses are listed for each mode of travel both by zones and districts within the metropolitan area.

After the basic analysis has been accomplished, the data is arranged in a manner that permits the forecasting of future traffic movement. In order to furnish the Planning Survey Division with the necessary information, twelve programs were developed and placed into operation during the research period. The programs are listed as follows:

a. Programs Developed For O & D Studies

(1) Retrieval
(2) Serial Conversion To District
(3) Land Use
(4) Type of Parking
(5) Total O & D By Mode
(6) External Land Use
(7) External Movements, Directional and Non-Directional

(8) Occupancy
(9) Land Use For Purpose To
(10) Land Use For Purpose From
(11) Input Format Conversion Programs
(12) Forecasting

As mentioned above, twelve programs were developed and placed into operation during the research period; in order to furnish the complete information requested by the Planning Survey Division an additional seven programs are currently in the process of being developed.

D. RESEARCH COMPUTER PROGRAMS

1. Slab Deflection Analysis

The request for this program originated in the Research Section of the Highway Design Division (D-8) and was originally developed for use on the IBM 1401 Computer. In an effort to increase efficiency of operations, the Computer Section developed a new program for the CDC 1604-A Computer. The primary purpose of this program is to reduce the data collected on concrete pavement cracks to more meaningful figures and then to compute the standard deviation and standard error for these figures. The block diagramming, testing, etc. has been completed and this program is operational.

2. Regression Analysis - Linear, Multiple

The request for this program originated in the Highway Design Division (D-8). This program was developed to compute linear regression coefficients and to print and/or plot observed and calculated values. It should be mentioned that although this program was developed in a manner to permit the processing of a large data file of pavement crack deflections versus widths, the program itself is easily adaptable to any linear regression problem. This program is operational.

3. Aero - Triangulation Program

The Photogrammetric Section of the Highway Design Division (D-8) initiated the request for this program. The primary purpose is to compute the swing and tilt of a stereo-plate to be used in a Kelsh Plotter. It was believed that by measuring three points on a plate and knowing the ground distance, it would be possible to then compute the swing and tilt factors of the plate. A considerable amount of library research has been conducted and the problem has been thoroughly discussed with the personnel in D-8; however, the block diagramming has not, as yet, been completed.

4. Critical Path Modification

It was the decision of the Computer Section to modify the existing programs involving Critical Path Scheduling, in an effort to obtain a greater efficiency in operations. These programs provide a basis for scheduling the component activities in a project, such as determining time schedules on construction contracts. The modifications involved reprogramming these programs for operation on a 16 K 1401 and a CDC 1604-A. Investigation and block diagramming of these modifications have been completed and the programs are operational.

5. Pavement Depth Determination from AASHO Test Results

This program was requested by the Research Section of the Highway Design Division (D-8). The primary purpose was to make basic pavement depth determination of Texas pavements by using equations furnished from an analysis of the AASHO Test Results. This was a "one-time solution" and has been completed.

6. Least Squares Curve Fit and Matrix Inversion for Nuclear Densitometer Data Correlation

At the request of the Construction Division (D-6), the Computer Section conducted research in non-linear multiple regression in an effort to aid in the calibration of nuclear moisture and density instruments. The investigation revealed the data to be almost linear over the desired operational range. Further research and investigation proved that a program could be developed that would be of assistance by adopting a multiple linear regression to accomplish the necessary work. The investigation and block diagramming is complete and this program is operational.

IV DEVELOPMENT OF ACCOUNTING PROGRAMS

A. Right of Way Computer Programs

1. Parcel Cost Program

The request for this program was originated by personnel within the Aid Division (D-7). The primary purpose of this program is to develop an invoice, or breakdown, of all federal participating charges incurred by the Texas Highway Department in the acquisition of Right of Way for the construction of highways. The output listing itemizes by each right of way parcel all costs incurred within the project. The initial investigation of the specific accounting methods indicated that a revision was necessary for gathering and maintaining

these charges. The required changes for effecting this revision were adopted and have been implemented. The investigation, block diagramming and machine testing have been completed and this program is operational.

2. Right of Way Certificates

The Aid Division (D-7) requested that a program be developed that would enable them to furnish the Bureau of Public Roads the necessary information concerning Right of Way. The primary purpose of this program is to produce a comprehensive tabulation of charges incurred in the acquisition of Right of Way. The initial investigation and research, block diagramming and machine testing have been completed and the program has been placed into operation.

3. Closed Out Right of Way Projects Report

The request for the development of this program originated in the Aid Division (D-7), with the primary purpose being to tabulate all charges for right of way regardless of degree of federal and/or state participation. The initial investigation and research, block diagramming and machine testing have been completed and this program has been placed into operation.

4. Right of Way Grantor File Maintenance

The request for the development of this program originated within the Computer Section, and consists of nothing more than a program necessary for file maintenance in the programs referred to above. This particular program is operational.

B. Contract Letting Programs

1. Average Bid Price Determination

Mr. D. C. Greer, State Highway Engineer, requested that a program be developed that would collect data from contract lettings relative to reinforcing steel prices. Consequently, following Highway Contract Letting each month, a listing is produced on the IBM 1401 that furnishes the necessary data. The investigation, block diagramming and testing have been completed and this program is in operation.

2. Average Bid Reports

As requested by the Highway Design Division (D-8), a modification of the existing program was needed in order to furnish additional information concerning average bids. This modification has been completed and this program remains operational.

3. Letting Price Indexes

The Construction Division (D-6) requested that a program be developed that would furnish them a running average of selected bid items on a monthly, quarterly and annual basis. The basic investigation concerning the development of this program has been completed and approved by the Construction Division. The block diagramming has been completed and the development of this program is now in the machine testing phase.

4. Bureau of Public Roads Report of Projected Contractural Work

The request for the development of this program originated in the office of Mr. D. C. Greer, State Highway Engineer. The primary purpose of this program is to furnish a report that projects and lists by quarters the number and dollar volume of contracts to be let in the ensuing year. The report furnished by this program is prepared and run semi-annually with a copy being furnished to the Bureau of Public Roads. Developed for operation on the IBM 1401 computer, the investigation, block diagramming and machine testing have been completed and the program is operational.

C. Billing Procedures Programs

1. Reproduction Charges

At the request of the Reproduction Section of the Operations Division (D-21), a program was developed that would compile and compute charges for work performed by the Reproduction Section. The initial investigation revealed that the work conducted in the Reproduction Section involved all twenty-five districts and the seventeen divisions comprising the Texas Highway Department. It was also revealed that the final printed charges for Reproduction work must represent only that work considered to be "participating" in so far as federal funds are concerned. Consequently, employee time sheets were established in addition to all other necessary records for furnishing absolute participating cost. All reproduction charge tickets are key punched, listed and checked for proper budget and authorization. All charges are accumulated and listed by each district and division, with copies being furnished to the Accounting Division and to the respective district or division. This program has been block diagrammed, machine tested and placed into operation.

2. HPR Accounting Program

The development of this program was requested and authorized by the Aid Division (D-7) with the intended purpose of providing a computerized method of maintaining and distributing all expenses involved in Highway Planning Research. Since this program encompasses work being conducted throughout the Texas Highway Department a considerable

amount of investigation was required. This investigation was completed and followed by the necessary block diagramming and machine testing; however, due to problems involving input data, it was determined that the program was inadequate and that further investigation would be necessary.

V DEVELOPMENT OF COMPUTER PROGRAMS FOR MANAGEMENT CONTROL

A. Warehouse and Equipment Inventory Programs

1. Programs Developed for Warehousing

At the request of the Equipment and Procurement Division (D-4), the Computer Section initiated the basic research on developing computer programs that would solve and maintain all areas of work involved in inventory control for the Texas Highway Department.

It was revealed from a statistical study of warehouse stock levels that ten per cent of the stock on inventory represented ninety per cent of the dollar investment.

The ultimate objective of the programs involved in Warehouse Inventory is to forecast, requisition and maintain stock items in the most economical manner. Numerous programs were developed to compute the initial conditions necessary for initiating a forecasting system that would be useable. Several service levels were developed and the cost for maintaining these levels was computed and compared. Also computed were the economical order points, absolute mean deviation, safety factors and lead times for all stock. It was necessary to develop a separate lead time program in order to up-date the lead times on a yearly basis. This program has been developed but has not been thoroughly tested.

The inventory transaction check list program has been modified in order to check for valid equipment numbers. It was also necessary to develop a Check Program for Warehouse Inventory, which has been investigated, block diagrammed and partially tested.

2. Equipment Inventory Program

The Equipment and Procurement Division (D-4) requested the development of a program that would maintain and up-date a permanent equipment file on magnetic tape. The necessary original data was secured from the Equipment File maintained for the Accounting Division. Additional coding was necessary to facilitate the classification of items required by the Equipment and Procurement Division. An additional program was developed for use on the 1401 with a routine for error print outs. The primary purpose of this program is to enable the Equipment and Procurement Division to obtain reports on specific items of equipment and to furnish immediate access for up-to-date tallies and locations of equipment.

The initial investigation has been completed, as has the block diagramming, testing and documentation. The program is operational; however, continued research is being conducted in order to expand this file and program to include all equipment data normally maintained in card files on a manual basis.

3. Equipment Expense and Rental Report Program

The Accounting Division (D-11) requested that a program be developed that would establish a permanent magnetic tape file of equipment expense and rental, plus the complete identification of each item of equipment involved in each transaction.

On a monthly basis all transactions of expense and rental are furnished by the districts through the Accounting Division and processed to this permanent file. Each transaction is verified against a master file for authenticity of equipment number and classification prior to being processed. District totals of equipment expense and rental are printed out as transactions are processed, with cards being punched for erroneously coded transactions. Annual reports are also prepared from this file by district and by classification. It is also planned in the future that the Equipment and Procurement Division will use this file to gather certain federal statistics to aid them in evaluating the various classes of equipment.

The initial investigation, block diagramming and machine testing have been completed and the program placed into operation.

B. Construction Progress Reports

1. Bridge Inventory

At the request of the Bridge Division (D-5) the Computer Section began the initial investigation for the development of this program. The investigation indicated that this program would be more feasible after a permanent bridge file was created from the use of the Bridge Structure Program. The type and form of the input data to be added to the permanent file was decided upon and the Bridge Division is currently in the process of compiling the necessary data. A tape record was designed and a program developed that will add the necessary data into the permanent bridge file. As soon as this file is complete, this program will be block diagrammed, machine tested and documented for placing into operation.

2. Programs Involved In Interstate System Program Reports

The Planning Survey Division (D-10) authorized the development

of programs that would furnish the Bureau of Public Roads with certain reports on the progress and development of the Interstate Highway System in the State of Texas. The primary purpose of the main computer program for this work, is to up-date the master file of the Interstate System Descriptions and to list the most recent addition by highway number. This program has been block diagrammed, tested and placed into operation. It was later determined that a modification of this program was necessary in order to list the Interstate System Descriptions by district number and to also list a summerization of the money assigned to the Interstate System Descriptions. This modification has been completed.

3. Road Inventory Tables

The Planning Survey Division (D-10) requested the development of a program that would tabulate mileage changes in the highway system for inclusion in an annual report furnished to the Bureau of Public Roads. The initial investigation, block diagramming and machine testing has been completed and this program is operational.

C. Personnel and Time Distribution

1. Personnel File - Current and Historical

The Personnel Division (D-13) requested that a program be developed that would readily furnish a tabulation of certain data pertaining to highway employees. Countless hours had been expended manually in the past to gather statistical data on the 17,000 plus employees. Consequently, a program was developed that maintains records containing the employee's date of birth, dates of employment, titles held and the respective pay group. This program is block diagrammed and operational.

2. Computer Time Distribution

The Computer Section realized that certain areas of highway accounting were inadequate in so far as the separation of costs were involved. In order to receive federal funds, the participating agency must maintain records that separate participating costs from non-participating costs. Also, the participating costs must be maintained and distributed to the proper accounts involved. A considerable amount of research and investigation was conducted for the development of this program. After the development of the necessary input data records, this program was block diagrammed, machine tested and placed into operation.

3. Personnel Time Report Summary

The development of this program was initiated by the Computer

Section, with the primary purpose being to summarize and distribute properly those charges made on Highway Planning Research projects. The initial investigation was completed, as was the block diagramming and machine testing; however, due to faulty input data and the difficulty encountered in requiring the proper maintenance of basic records throughout the other divisions and districts, this program was placed on a "standby" basis.

VI GENERAL UTILITY PROGRAMS

A. Areas of Development

1. System Development of 650 Simulator

At the request of the Computer Section, the Control Data Corporation furnished a 1604-A program that simulates the IBM 650. The primary purpose for this program is for processing routine IBM 650 production work that has not been re-programmed in 1604-A language. A considerable amount of testing this program on all of the IBM 650 programs was conducted prior to the acceptance of the Control Data Corporation's 1604-A Computer.

This program has been completed and placed into routine operation.

2. Input System Tape Preparation

In February, 1964, the Control Data Corporation's 1604-A Computer was installed in the Computer Section of the Operations Division (D-21) as a replacement for the IBM 650. Also placed into use at this time was a 650 Simulator Program. In order to maintain the existing system of 650 input for use with the 650 Simulator Program on the 1604-A, it was decided to develop a tape input that would be compatible with the 1604-A input format. The initial investigation revealed that this program would require simulating the 650 Input Control Panel, recording for identification of program and/or data cards, plus furnishing necessary console settings. In addition, IBM 1401 programs would need to be developed for the General Purpose Control Panel and for each of several other specifically wired control panels involved. The program investigation was completed, block diagrammed and machine tested and placed into operation.

3. Listing Simulator Output Data

The Computer Section initiated the development of this program in preparation for the new 1604-A computer. This listing system is composed of thirty-two programs that are used extensively each day.

Basically, the development of the Listing Simulator Output program required that 1401 listing programs be revised and/or modified in order to furnish listings from the output tape developed from the 1604-A.

All necessary changes have been completed and this program is operational.

4. Tape to Tape Utility Program

The request for this program was originated by the Computer Section. The development of this program involved nothing more than providing a generalized and flexible program to enable the copying of data from one magnetic tape to another. All work involved in the development of this program has been completed and the program placed into extensive use.

5. Analyzed Polyphase General Sort Program

The Computer Section initiated the development of this program. Due to the number of large files that required sorting, it was decided to modify the Control Data Corporation Sort Program to operate on the Texas Highway Department's 1604-A and the four 606 tape drives. It was determined that this modification would reduce sorting time required on the IBM 1401 and that multiple reels could be handled considerably easier.

During the phase of machine testing of this modification it was discovered that with the four tape-drive limitation, the polyphase sort feature offered no advantage over the use of the normal sort feature. This modification has been completed and all necessary changes made in the program. This program is operational.

VII CONCLUSION

During the research period, as this report indicates, numerous programs were developed in an effort to achieve maximum efficiency in the systems operation of the Computer Center. Each and every program developed must be in keeping with the Texas Highway Department's policy of constructing the best highway with the least costs involved.