REPORT NO. DOT-TSC-OST-76-39

COMPUTER-BASED RESOURCE ACCOUNTING MODEL FOR AUTOMOBILE TECHNOLOGY IMPACT ASSESSMENT

J. Barton DeWolf
Christian Davis
Peter C. Heinemann

The Charles Stark Draper Laboratory, Inc.
68 Albany Street
Cambridge MA 02139

OCTOBER 1976

FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
OFFICE OF THE SECRETARY
Office of the Assistant Secretary for
Systems Development and Technology
Office of Systems Engineering
Washington DC 20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT-TSC-OST-76-39		

4. Title and Subtitle	5. Report Date
COMPUTER-BASED RESOURCE ACCOUNTING MODEL FOR AUTOMOBILE TECHNOLOGY IMPACT ASSESSMENT	October 1976
	6. Performing Organization Code
7. Author(s) J. Barton DeWolf, Christian Davis, Peter C. Heinemann	8. Performing Organization Report No. DOT-TSC-OST-76-39 R-938
9. Performing Organization Name and Address The Charles Stark Draper Laboratory, Inc.* 68 Albany Street Cambridge MA 02139	10. Work Unit No. (TRAIS) OS714/R7508
	11. Contract or Grant No. DOT-TSC-1021
12. Sponsoring Agency Name and Address U.S. Department of Transportation Office of the Secretary Office of the Asst. Sec. for Sys. Dev. and Tech. Office of Systems Engineering Washington DC 20590	13. Type of Report and Period Covered Final Report July 1975-February 1976
	14. Sponsoring Agency Code

15. Supplementary Notes

*Under contract to: U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge MA 02142

16. Abstract

A computer-implemented resource accounting model has been developed for assessing resource impacts of future automobile technology options. The resources tracked are materials, energy, capital, and labor. The model has been used in support of the Interagency Task Force on Motor Vehicle Goals Beyond 1980. The report describes the methodology.

Annual production requirements for up to thirty materials are accumulated. Projected demand is disaggregated among primary and secondary materials, imports and domestic sources. Capital and labor impacts of auto design changes, disaggregated by two-hundred industries are determined using a modified input/output model.

17. Key Words	18. Distribution Statement
Resource Accounting, Automobile, Motor Vehicles, Materials, Energy, Capital, Labor, Input-Output Model, Technology Assessment	DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	74	PC A04 MF A01

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

NOTICE

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

PREFACE

As part of the Nation's long range effort to conserve petroleum, a joint Federal Task Force, led by the Secretary of Transportation, was created to present the long range energy goals for the motor vehicle fleet that are compatible with environmental, safety, and economic objectives. In support of this effort the Transportation Systems Center initiated several studies in 1975.

The work described herein was initiated and directed under the auspices of the Applications Division, Office of Systems Research and Analysis, with Bruce Rubinger as the contract monitor. It has been funded under the Automotive Energy Efficiency Program. This study resulted in the creation of a series of integrated computer models that track the energy, materials, capital, and labor impacts associated with various auto design concepts.

The Materials and Energy Resources Accounting Model goes beyond earlier tools by allowing more flexible and realistic new car design implementation schedules. These models accumulate annual requirements for up to thirty major materials used in the production of automobiles. The requirements for each material are translated into projections for recycled materials, imported processed materials, imported raw materials, and domestic raw materials. Energy consumption associated with auto fabrication, fleet operation, and material production are also derived.

Capital and labor effects of auto design changes, disaggregated by two-hundered industries, are also captured by using a modified version of an existing model of the inter-industry flows within the U.S. economy (INFORUM). This input/output model has been adjusted to reflect the final demands, capital requirements, and technology inherent in the scenarios.

Work is currently underway to further disaggregate the models developed under this effort. These advances will be documented in the final report covering the second phase.

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

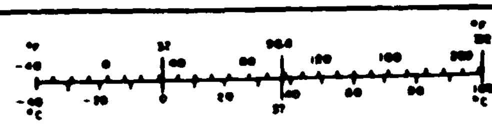


TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. INTRODUCTION

This report describes a Resource Accounting Model developed for the Department of Transportation, Transportation Systems Center. The model has been used for impact assessment in connection with the Interagency Task Force on Motor Vehicle Goals Beyond 1980,* but the methodology introduced is of general applicability in connection with impact assessment for advanced automobile technologies. The resources accounted for consist of the materials and energy required for producing and operating the automobile fleet in future years, and the capital and labor impacts in the economy of future production and use scenarios. The model has been implemented as a series of data files and computer programs which produce tabular and graphical summaries for each of the resources.

This volume of the report** summarizes the objectives, results, and conclusions of the work performed, and describes the Model in detail. Section 2 of this volume describes the accounting procedure for material and energy resources, Section 3 discusses capital and labor accounting, and Section 4 contains a summary and recommendations. Some of the material presented in this volume also appears in the appendices to the Task Force report.

1.1 STATEMENT OF PROBLEM AND OBJECTIVE

The Resource Accounting Model was developed as a policy assessment tool for the Task Force on Motor Vehicle Goals Beyond 1980, and the problem statement is best explained in that context.

---

* "Interagency Task Force on Motor Vehicle Goals Beyond 1980," <u>Federal Register</u>, Vol. 40, No. 217, 10 November 1975, p. 52431.

** The Final Report and the User's Guide are published as separate documents as follows: Final Report—Phase 1, R-938, February 1976; User's Guide, C-4684, February 1976; and Program Listing, May 1976.

These reports will be followed by a second and final version of these documents: Final Report—Phase 2, R-983, July 1976; User's Guide, R-984, July 1976; and Program Listing, July 1976.

In May of 1975, the Chairman of the Energy Resources Council requested the Secretary of Transportation to lead a joint task force to "examine long-range energy goals of the motor vehicle fleet, compatible with environmental, safety, and economic objectives."* The resulting Task Force included representatives from the Energy Research and Development Administration (ERDA), the Environmental Protection Agency (EPA), the Federal Energy Administration (FEA), the National Science Foundation (NSF), the Department of Transportation (DoT), and many other agencies. Within DoT, participants included the Federal Highway Administration (FHWA), the National Highway Traffic Safety Administration (NHTSA), and the Transportation Systems Center (TSC).

The problem faced by the Task Force was to find a method whereby future motor vehicle goals relating to fuel economy, emissions, noise, and safety could be presented in a balanced and understandable fashion for public debate. The establishment of a coordinated federal policy involves value judgments on the relative merits of fuel economy, environmental quality, and safety, taking into account the associated resource costs and consumer costs. These value judgments must necessarily be made as part of the political process.

At the heart of the Task Force's approach to this problem was the analysis of a series of case studies or scenarios based on possible future automotive technologies. Each of the cases provided a different emphasis with regard to future motor vehicle goals. For example, one case might emphasize fuel economy while holding safety and environmental standards constant, whereas another might emphasize air quality, etc. Task Force personnel were organized into a series of panels** for the purpose of defining and evaluating the cases and presenting information in a number of interrelated areas. In addition, a systems integration and report generation staff at TSC was charged with integrating the individual panel reports in a single Task Force report together with a detailed case-by-case analysis.

---

* "Interagency Task Force on Motor Vehicle Goals Beyond 1980," Federal Register, Vol. 40, No. 217, 10 November 1975, p. 52431.

** The panels consisted of: Air Quality, Noise, and Health; Safety; Fuels and Materials Resources; Automotive Design and Maintenance; Automotive Manufacturing; Marketing and Mobility; National/Industrial/Consumer Economics; and Alternative Implementation Strategies.

In order to accomplish detailed case-by-case analysis based on inputs from the various panels, the systems integration staff found it necessary to develop a series of computer models as shown in Figure 1-1. The Resource Accounting Model described in this report is shown as a part of the overall modeling effort.

In brief, the process begins with scenario generation and a translation of the scenario definition into a technical description of a number of advanced automotive vehicle types or families. A family is a vehicle type having a uniform technological description (e.g., Otto cycle engine, weight-conscious structure, oxidation catalyst, moderate emissions standards, crashworthiness level I). Within each family, three different sizes or classes of vehicles are defined (small, medium, and large) and curb weights* are assigned. Automobile characteristics assigned to each class and family are assumed to remain unchanged as long as that family is in production.

In addition to vehicle description, the scenario definition includes a specification of how the advanced vehicle families are to be phased into the existing fleet. Each of the Task Force scenarios consisted of three or four families, with each family being phased into full production over a 10-year period.

Following scenario generation, a manufacturing assessment takes place which determines the materials and fabrication energy as well as the assembly labor required for producing each of the vehicle families. The motor vehicle capital investment associated with each scenario is also determined. This information enables estimates of manufacturing and maintenance costs which are used, in turn, by the New Car Price Model and the User Cost Model. Once new car prices are determined, then new car sales, market shares (for small, medium, and large), fleet size, scrappage, and fleet vehicle miles traveled (VMT) can be projected using any of a number of demand models or assumptions.

The Fleet Accounting Model keeps track of the vehicles composing the automobile fleet and provides fundamental data for a number of other models and impact assessment procedures, including the Resource Accounting Model. Safety, fuel industry, national macroeconomic, and

---

* The curb weight is the weight of the standard vehicle with liquids, in running condition, without disposable load.

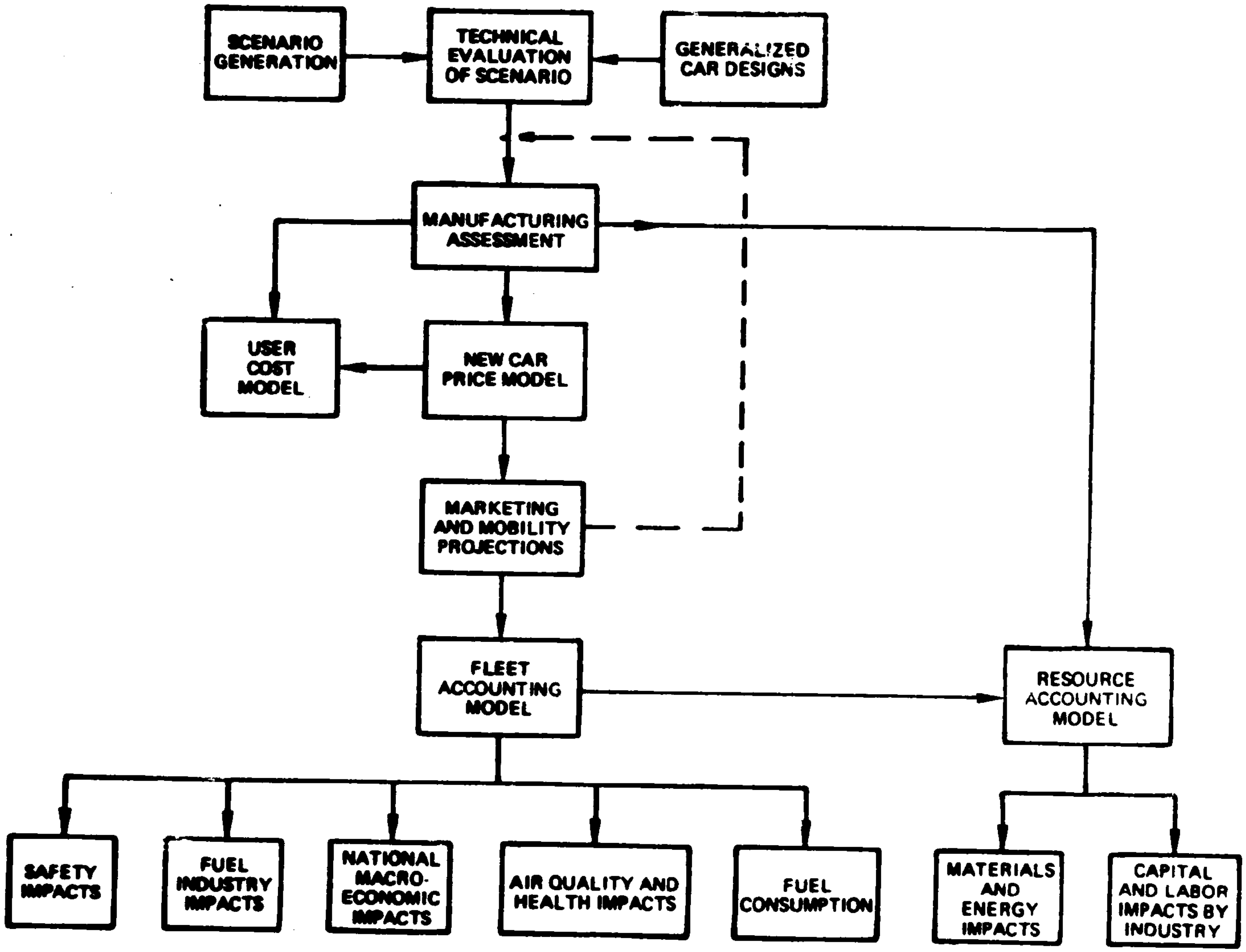


FIGURE 1-1. THE SCENARIO ANALYSIS PROCESS.

air quality and health impacts are estimated for each of the cases using models made available through the various panels. The Fleet Accounting Model also determines final fuel consumption statistics for gasoline (leaded and unleaded), diesel fuel, and broad-cut fuels (used for certain advanced automotive engines).

The objective of the Resource Accounting Model is to keep track of total scenario resource requirements for materials, energy, capital, and labor, and to present this information for impact assessment. The materials to be tracked are the major materials used for automobile production.* The energy requirements to be tracked include the process energy for producing the materials from primary or secondary sources, the fabrication energy for manufacturing and assembling the vehicles, and the operating energy for the vehicle fleet. The process and fabrication energy components are jointly referred to as production energy. Capital accounting must include capital investment in a variety of industries related to motor vehicles production (such as the materials, fuels, auto repair, and distribution industries), as well as the motor vehicles industry itself. Similarly, labor accounting should be disaggregated by industry.

The scope of the accounting is limited to resources used for U.S. domestic production of passenger motor vehicles for U.S. use and for export. In particular, Canadian production by U.S. firms is excluded, as are other imported vehicles. The capital requirements are, thus, domestic capital requirements and can be related to the national accounts. The time frame for the analysis extends from 1975 (the base year) to 2000.

1.2 APPROACH TO MODEL DEVELOPMENT

The basic approach in resource accounting has been to emphasize completeness, consistency, traceability, and analytical simplicity. The automobile production process is complex in terms of interindustry relationships, and both incomplete accounting or duplicate accounting

---

* The Resource Accounting Model has been designed so that, with minor modifications, aftermarket materials data can be handled as well. Aftermarket data was not available for the first set of Task Force scenarios run in October, 1975.

are distinct possibilities. The important questions of resource cost, the valuation of nonreplenishable versus replenishable resources, import dependencies and strategic considerations, resource availability, etc., are best handled once a fundamentally consistent and understandable set of accounts has been established.

Two approaches to resource accounting were considered at the outset: family-tree, and economic input-output analysis. The approach selected turned out to be a hybrid which used a simplified family-tree approach for materials and energy accounting, with input-output being used for capital and labor.

The family-tree approach traces a material or fuel resource from finished form back through intermediate stages of production to its ultimate raw material origins, tracking capital, labor, and energy inputs required along the way. Its advantages are that it gives insight into the details of materials and energy flow in physical units. Materials and energy information are readily available in this form for steel, aluminum, and copper. The disadvantages of the family-tree approach are that data on capital and labor inputs tend to be unavailable on this basis. Information for defining the tree is less available for some of the economically less important materials, and information for service industries (e.g., auto repair) is conceptually difficult to handle. Finally, a tree structure can only appropriately be used to describe a tree-organized production process. In particular, the feedback of finished goods for use in the production process leads to difficulties in this approach.

Economic input-output analysis* is a network-based approach which traces the dollar flows (usually) of goods and services between industries required for satisfying a given level of final demand. Input-output forecasting models are available with time-varying coefficients and industrially disaggregated capital investment sectors.** Its advantages are as follows. It provides a uniform method for handling all

* Described in many economic references, a particularly good one being: Richardson, H.W., Input-Output and Regional Economics, Weidenfeld and Nicolson, London, 1972.

** Almon, C., et al., 1985: Interindustry Forecasts of the American Economy, Lexington Books, Lexington, Mass., 1974.

industries (including service industries and some of the economically less important materials). Data are available on capital and labor by industry which are consistent with the national accounts and statistics. Input-output analysis can handle network-organized production processes. The disadvantages of the input-output approach are the following. First, considerably less product detail is available in the materials area, even with models having a large number of industrial sectors. Second, the use of dollar flows for materials and energy, rather than physical units, makes it difficult to obtain the impacts in physical terms. Finally, input-output analysis is somewhat harder to explain than a family-tree analysis, and the impacts are sometimes more difficult to trace.

After considering the relative strengths and weaknesses of these two approaches, it was decided to account for materials and energy using a separate procedure from capital and labor. Thus, a distinct Materials and Energy Resource Accounting Model (MRAM) was established which tracks a list of detailed materials and energy types on a physical unit basis. The origins of the material are traced in terms of domestic versus imported and primary versus secondary (or scrap) sources. The outputs of the materials and energy accounting process are then used as inputs to a Capital and Labor Resource Accounting Model (INRAM) which uses an input-output analysis for capital and labor accounting.

The following two sections of this report describe these two accounting procedures in detail starting with the Materials and Energy Resource Accounting Model.

2. MATERIALS AND ENERGY RESOURCE ACCOUNTING

One of the goals of this project is to evaluate the total impact of alternative automobile technologies on the materials and energy resources of the nation.

In order to provide a tool to determine the impact of a number of automotive scenarios on the nation's resources and to investigate potential material bottlenecks, a Materials and Energy Resource Accounting Model (ARAM)* was developed. ARAM is composed of several computer programs which accumulate and display materials and energy requirements for each Task Force scenario. Scenario output are stored for later case-by-case comparison with the number of scenarios being limited only by the amount of secondary storage available. The programs are written in FORTRAN and PL/1, and were designed to run on an IBM 360/75. The methodology is similar to that employed by Hittman Associates in their technology assessment of advanced automotive propulsion systems.** The methodology has been extended to provide for the phased introduction of several vehicles into the scenarios.

ARAM accumulates annual requirements for up to 30 major materials used in the domestic production of automobiles. The requirement for each material is transformed into demands for:

(1) Recycled materials

(2) Imported processed materials

(3) Imported raw materials

(4) Domestic raw materials.

---

* The acronym ARAM originally stood for Automobile Resource Accounting Model prior to the development of the capital and labor accounting procedure (INRAM), which of course also applies to automobiles. In current usage, ARAM refers to only the materials and energy part of the overall model.

** Harvey, D.G., and W.R. Menchen, <u>A Technology Assessment of the Transition to Advanced Automotive Propulsion Systems</u>, HIT-541, Hittman Associates, Inc., Columbia, Md., May 1974.

This transformation is performed using national averages, which will be discussed subsequently, for each material in the above demand categories

ARAM also accumulates the energy requirements by form (i.e., coal, natural gas, petroleum, and other or unspecified) where possible for:

(1) Materials production and processing

(2) Auto fabrication

(3) Auto fleet operation.

Much of the data required for ARAM to perform the materials and energy accounting is obtained from other Task Force modeling efforts. Figure 2-1 illustrates the interaction of ARAM and these other modeling efforts. In order to better understand this interaction, the procedural flow and computation methodology incorporated in the ARAM components are described in the following sections.

2.1 PROCEDURAL FLOW FOR MATERIALS AND ENERGY RESOURCE ACCOUNTING

An overview of the procedural flow and interaction of the several data sources and component programs within ARAM is presented in Figure 2-2.

The outputs of the Fleet Accounting Model, the auto family data preprocessor (PPFAM), and the internal data preprocessor (PPINT) are integrated in the auto production and consumer sector preprocessor (PPAPCS).

The fleet model provides the following input data:

(1) Annual fleet operating fuel in gallons by class within family for the following types.

- leaded gas
- unleaded gas
- diesel
- broad cut

(2) Annual fleet size by class within family.

(3) Annual number of autos sold by class within family.

(4) Annual retirements of autos by class within family.

The automobile family data preprocessor (PPFAM) serves the purpose of allowing the flexible generation of scenarios composed of up to six of the automobile families. A <u>family</u> consists of small, medium, and large vehicles having the same technology, fuel economy, emissions, and

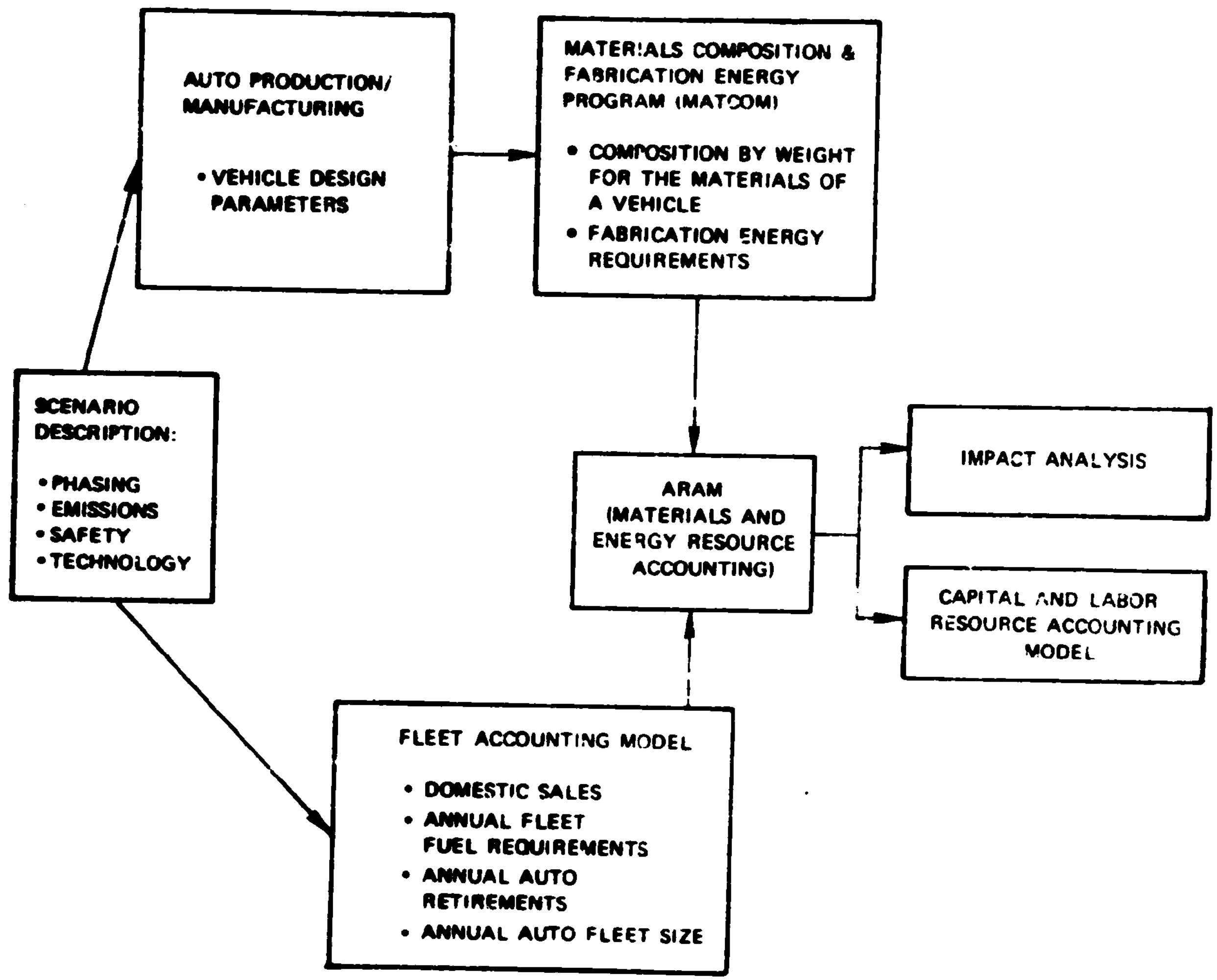


FIGURE 2-1. INTERACTION OF ARAM WITH OTHER TASK FORCE EFFORTS.

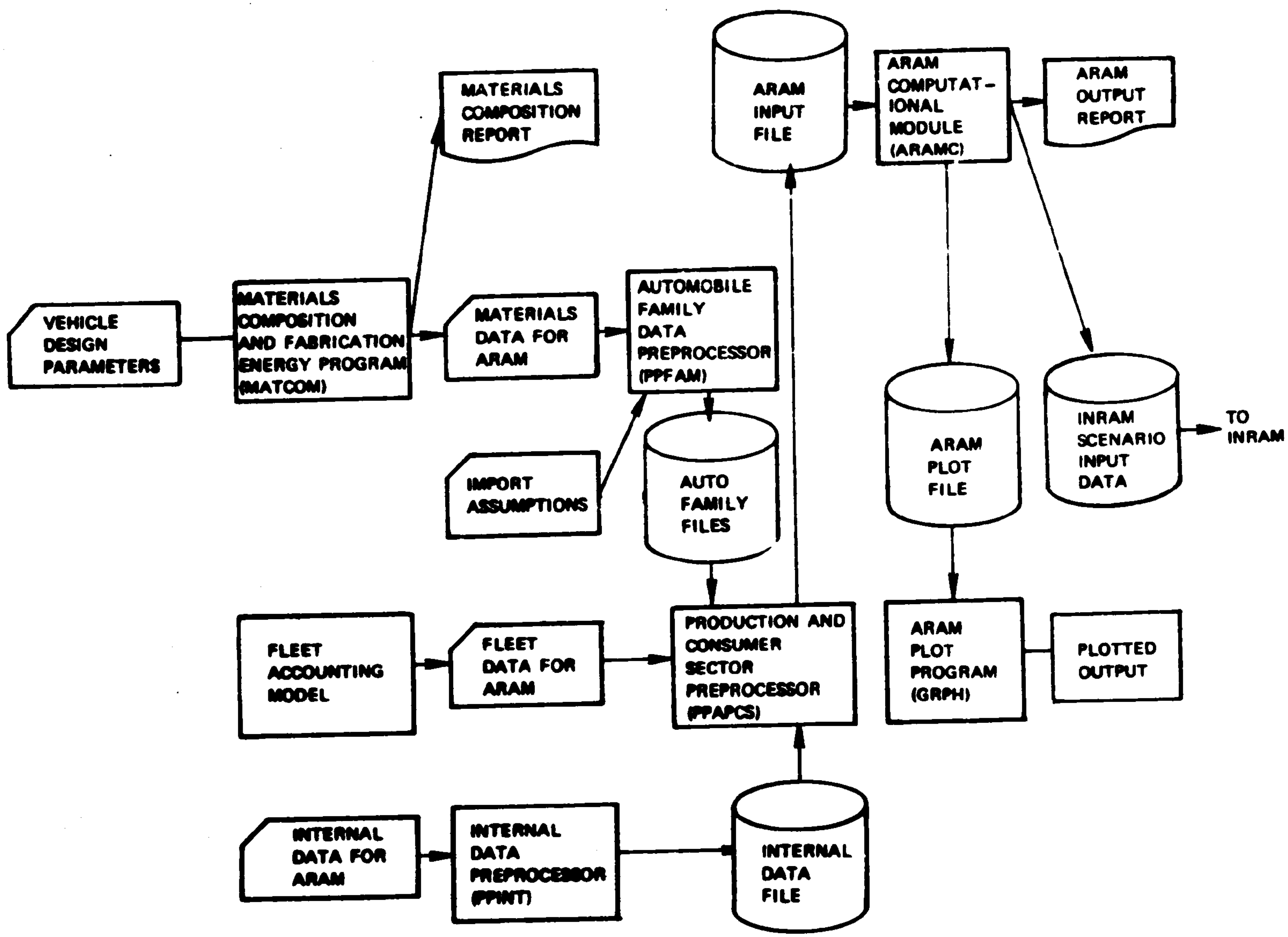


FIGURE 2-2. MATERIALS AND ENERGY RESOURCE ACCOUNTING MODEL.

saftety characteristics. PPFAM receives input data from the materials composition and fabrication energy program (MATCOM) in the form of a weight breakdown by material for the important materials required to produce an auto, and a fabrication energy breakdown by type. PPFAM creates a file for each automobile family containing this information for each class of auto for use by PPAPCS in generating scenarios.

The internal data preprocessor (PPINT) provides information on the recycling and import characteristics of the various materials, the materials waste ratio, and other similar quantities which do not vary from scenario to scenario.

The auto production and consumer sector preprocessor (PPAPCS) then integrates the internally required data (as processed by PPINT) with the fleet data and auto family file data for use by the ARAM computational module (ARAMC). Job control language (JCL) parameters can be specified which determine the families of automobiles (i.e., the family files as created by PPFAM), phased into the scenario, and in what order. PPAPCS and the subsequent computational modules are designed so that with minor modifications they can accumulate data on the materials and energy requirements for the automotive aftermarket as well as vehicle production and operation. Such data are being developed for the Task Force scenarios, but aftermarket accounting is not included as part of this report.

The output of PPAPCS is an integrated sequential disk file ready for use by the ARAM computational module. The result of this sequence of computations is a sequentially improving picture of the automobile scenario. The programs PPINT, PPFAM, and PPAPCS all take inputs on some separate aspect of the scenario, and produce files of outputs (on the disk eventually used by ARAM) which are combined by PPAPCS to produce the total picture.

The ARAM computational module, using the data file generated by PPAPCS, computes annual and total materials and energy requirements for the various Task Force scenarios. This data is output in the form of a printed report, and is also stored in a direct-access disk file for subsequent analysis and plotting. Annual materials usage information is also written into a file for use by the INFORUM preprocessor for capital and labor accounting (see Section 3).

These various ARAM components are now described in further detail with examples of the output given.

2.2 ARAM INTERNAL DATA PREPROCESSOR (PPINT)

The PPINT program reads a deck of cards containing values for the internal ARAM constants, and creates a sequential disk file of the data values. Table 2-1 lists the variable mnemonics with their descriptions. Table 2-2 lists the 1975 values for the first set of Task Force scenarios (run during October and November of 1975). Section 2.3 discusses these values and the sources on which they are based.

The use of a preprocessor allowed the development of the ARAM computational module to be completed without concern for the format and availability of the internally required constants. As new or refined values for these constants became available they were incorporated into the data file using PPINT without requiring any changes in ARAM.

2.3 SOURCES FOR THE ARAM INTERNAL DATA

The ARAM internal data contain information on the energy required for materials processing, the materials waste ratio, the scrap fraction, and import fractions for both processed and raw material imports. The data values shown in Table 2-2 are those used for the first set of Task Force scenarios. The materials list for these scenarios involved the 24 materials shown in the table. The sources of this information and related comments are as follows.

The basic sources for materials processing energy are a report from Chrysler Corporation by Doran K. Samples,* and the study by Berry and Fels of the University of Chicago.** The energy data shown in Table 2-2 are expressed in Btu/lb and include energy for mining, processing, and transportation of the material from the raw form through to the finished product. Energy breakdown is not provided for materials

---

* Chrysler Corporation, "Energy in the Automobile," presentation by D.K. Samples at an energy seminar at the University of Michigan, 1974.

** Berry, R.S. and M.F. Fels, "The Production and Consumption of Automobiles," A Report to the Illinois Institute for Environmental Quality, July 1972, University of Chicago, Chicago, Illinois.

TABLE 2-1. INTERNAL ARAM DATA REQUIREMENTS.

Data Mnemonic	Description
POR_j	A column matrix in which each data item represents the percent of material "j" which is recycled as industrial scrap or lost during the production of an automobile.
SF_{jk}	A two-dimensional matrix in which each data item represents the fraction of material "j" which is domestically produced from old and new scrap in year "k".
IM_{jk}	A two-dimensional matrix in which each data item represents the fraction of material "j" received in processed form from imports in year "k".
RIM_{jk}	A two-dimensional matrix in which each data item represents the fraction of material "j" received in raw material form (e.g., ores) from imports in year "k".
$BTURM_{jl}$	A column matrix in which each data item represents the number of nonelectric Btu (l=1, coal; l=2, natural gas; l=3, petroleum; and l=4 other or unspecified) required for processing one unit of recycled material "j" from energy source "l".
$KWRM_j$	A column matrix in which each data item represents the number of electric kilowatt-hours required for processing one unit of recycled material "j".
$BTUM_{jl}$	A column matrix in which each data item represents the number of nonelectric Btu (l=1, coal; l=2, natural gas; l=3, petroleum; and l=4 other or unspecified) required for processing one unit of material "j" from raw materials from energy source "l".
KWM_j	A column matrix in which each data item represents the number of electric kilowatt-hours required for processing one unit of material "j" from raw materials.

TABLE 2.2. 1975 VALUES OF ARAM INTERNAL DATA FOR THE FIRST SET OF TASK FORCE SCENARIOS.

	Material	Process Energy in Btu/lb (BTURM ℓ=4) (BTUM ℓ=4)	Materials Waste Ratio (POR)	Scrap Fraction (SF)	Processed Material Import Fraction (IM)	Raw Material Import Fraction (RIM)
1	**Cast Iron**	10300.	0.0	0.300	0.0	0.215
2	**Malleable/Nodular Iron**	15500.	0.100	0.300	0.0	0.215
3	**Carbon Steel**	21000.	0.100	0.300	0.220	0.214
4	**Stainless Steel**	34000.	0.100	0.300	0.192	0.445
5	**Alloy Steel**	22300.	0.100	0.300	0.043	0.225
6	**Rolled/Drawn Aluminum**	110000.	0.100	0.0	0.145	0.778
7	**Cast Aluminum**	10000.	0.0	0.180	0.0	0.778
8	**Zinc**	45500.	0.0	0.060	0.286	0.139
9	**Copper**	65700.	0.100	0.210	0.258	0.082
10	**Lead**	22000.	0.0	0.370	0.166	0.069
11	**Body Solder**	22000.	0.0	0.370	0.0	0.069
12	**Platinum (TROY OZ)**	0.	0.0	0.200	0.0	0.800
13	**Palladium (TROY OZ)**	0.	0.0	0.200	0.0	0.800
14	**Glass**	13000.	0.0	0.047	0.0	0.0
15	**Rubber (Tires)**	36900.	0.0	0.262	0.091	0.454
16	**Rubber (Other)**	36900.	0.0	0.262	0.091	0.454
17	**Plastics**	45000.	0.100	0.0	0.042	0.300
18	**Soft Trim/Paper/Composite**	7000.	0.100	0.0	0.0	0.0
19	**Sound Deadeners/Sealers**	27000.	0.0	0.0	0.0	0.300
20	**Paint**	27000.	0.0	0.0	0.0	0.300
21	**Fluid/Lubricants**	27000.	0.0	0.0	0.0	0.300
22	**Ceramics**	0.	0.0	0.0	0.0	0.0
23	**Urethane Foam**	27000.	0.0	0.0	0.0	0.300
24	**Explosives**	0.	0.0	0.0	0.0	0.0

production by fuel type at the present time, although the program can handle this level of detail. Similarly, a breakdown of the energy requirements for recycled versus new materials could be added. This would involve going to a greater level of detail than the Samples study,* and would only be significant if a major variation occurs in recycling practice. The energy accounting is correct for the current level of recycling.

A few comments on process energy are needed with respect to specific materials.

With respect to plastics, the Samples study* states that "the best judgment composite figures for plastics in Chrysler automobiles are 25,000 Btu/lb for process energy and 45,000 Btu/lb for total energy (processing and feedstock energy)." Samples proceeds to use the former figure. The 45,000 figure is more suited to our purposes. Similarly, a feedstock energy of 20,000 Btu/lb is added to the figures for sound deadeners and sealers, fluids, urethane foam, and also paint and protective dip.

Energy figures were not established for platinum, palladium, explosives, and ceramic materials. For the present, it is assumed that their total energy impact in the scenarios is small or has small variations.

The materials waste ratio (POR) is included to account for fabrication losses and waste in the production of autos from the various materials. A 10-percent loss was assumed for certain materials as shown in Table 2-2. For steel, the materials waste ratio was based on salvage market information** that indicates a new scrap ratio (from industrial fabrication losses) of approximately 10 percent. Rolled and stamped aluminum, and other similarly fabricated materials were assumed to have the same fabrication overrun percent as that for steel. For cast and similarly formed materials, there is assumed to be no overrun, since the unused material can be immediately reused by the manufacturer.

---

* Chrysler Corporation, "Energy in the Automobile," presentation by D.K. Samples at an energy seminar at the University of Michigan, 1974.

** Darnay, A. and W.C. Franklin, <u>Salvage Markets for Materials in Solid Wastes</u>, SW-29C, U.S. Government Printing Office, Washington, D.C., 1972.

The scrap fraction (SF) data were obtained from the report of the National Commission on Materials Policy* and represent the fraction of total shipments obtained from recycled materials. The data on recycling of materials vary widely, presumably because of discrepancies concerning what is included (home scrap, industrial (or new) scrap, old scrap). The intent here is to include industrial scrap and old scrap, because they indicate decreases in the actual requirements for production from raw materials when they are recycled. The scrap fraction used in producing autos is assumed to remain constant over the time period under consideration--1975 to 2000—but it can be varied if the scenario requires.

Finally, the figures for the import fraction of processed materials (IM), and the import fraction of raw materials (RIM) were obtained from a Department of Commerce source.** They are expressed as a fraction of total shipments. The values for certain of these materials vary slightly over the time period under consideration.

For both scrap fraction and import fractions, it was necessary to make a few further assumptions for certain of the materials. It was assumed that the imported processed aluminum would be in the rolled and drawn category, with none of it being recycled (in its original form). All of the recycled aluminum is assumed to reduce the raw material needs in the cast aluminum category. Also, rubber for tires and rubber for other uses are treated the same with respect to imports and recycling.

2.4 AUTOMOBILE FAMILY DATA PREPROCESSOR (PPFAM)

The need for a capability to intersperse the different automobile technologies in many different scenarios can create a large data handling requirement. The automobile family data preprocessor (PPFAM) creates a file to serve as a repository for the data for each family, including all three classes which may be used repeatedly in different scenarios. Family data are in general assumed to be functions of time, even though most elements associated with a given family do not normally change. Family data are, therefore, stored by PPFAM in arrays of 26 values—each value corresponding to a year in the period 1975 to 2000.

---

* U.S. National Commission on Materials Policy, Material Needs and the Environment Today and Tomorrow, Final Report, U.S. Government Printing Office, Washington, D.C., June 1973.

** Private communication from Charles M. Ludolf (U.S. Department of Commerce), August 6, 1975.

The principal source of input data to PPFAM is the materials composition and fabrication energy program (MATCOM). The primary data supplied by MATCOM are shown as the first three elements of Table 2-3.

TABLE 2-3. INPUT DATA FOR THE FAMILY DATA PREPROCESSOR.

Data Mnemonic	Description
QMC_{ijm}	The weight of material "j" required to produce an auto of family type "i" and class "m".
BPC_{ilm}	A three-dimensional matrix in which each cell represents the number of Btu of nonelectric energy of type "l" required for the production of a scenario vehicle of family type "i" and class "m".
EPC_{im}	The number of electric kilowatt-hours required for the production of a scenario vehicle of family type "i" and class "m".
AIC_{ikm}	Fraction of total domestic auto sales for vehicles of family type "i" and class "m" which are net imports (including Canadian imports) in year "k".

The first element, QMC, is the weight* of each material required to produce each type of auto as indicated. In the normal case, the materials composition of a given vehicle does not change as a function of time, and MATCOM provides a single list of materials composition data which is used for all years by PPFAM. It is also possible for the user to change the composition of a given vehicle type at up to three points in time, if so desired. This enables the user to regard a minor change in the composition of a family (such as the addition of a catalyst) as a variation rather than a new vehicle type.

---

* The units are arbitrary, and may be selected by the user as long as consistency is observed in defining the internal data parameters BTUM, BTURM, KWM, and KWRM. However, the default weight unit for plot labels is pounds. This may be overridden.

The variables BPC and EPC (also obtained from MATCOM) relate to fabrication energy requirements for the vehicle type as indicated.

In addition to these primary elements, MATCOM supplies PPFAM with family, class, and fuel-type identification parameters. The family identification is used to locate a particular family for storage or retrieval, and the class identification establishes an ordering within the family file. The fuel-type parameter is used by PPFAM to associate a Btu/gal value (BPG) with each family. The Btu/gal value is the heat value of the fuel divided, in turn, by 0.92 to account for refinery efficiency, and 0.98 to account for losses in the distribution system. The heat value associated with gasoline and broadcut fuels (used in certain advanced engines, such as the Stirling) is 125,000 Btu/gal. The heat value associated with diesel fuel is 136,000 Btu/gal.

The last variable, AIC, is a separate card input to PPFAM and represents the net import fraction to be assumed for each vehicle type. This fraction is used later by PPAPCS to connect new-car sales data supplied by the Fleet Accounting Model to domestic auto production as required for resource accounting. Use of this fraction enables the user to exclude net foreign car imports (imports less exports) from the sales data. Since net imports are excluded, ARAM accounts only for those materials and energy used domestically for the production of automobiles for domestic use and for export. This distinction becomes particularly important when the ARAM outputs are used as inputs to capital and labor resource accounting processes as described in Section 3.

2.5 AUTO PRODUCTION AND CONSUMER SECTOR PREPROCESSOR (PPAPCS)

The PPAPCS program generates the integrated input file for the ARAM computational module as illustrated in Figure 2-3. In producing this file, PPAPCS merges data from (1) PPINT, (2) PPFAM, and (3) the Fleet Accounting Model. Tables 2-1, 2-3, and 2-4 list the variable mnemonics and their descriptions for each of these respective sources.

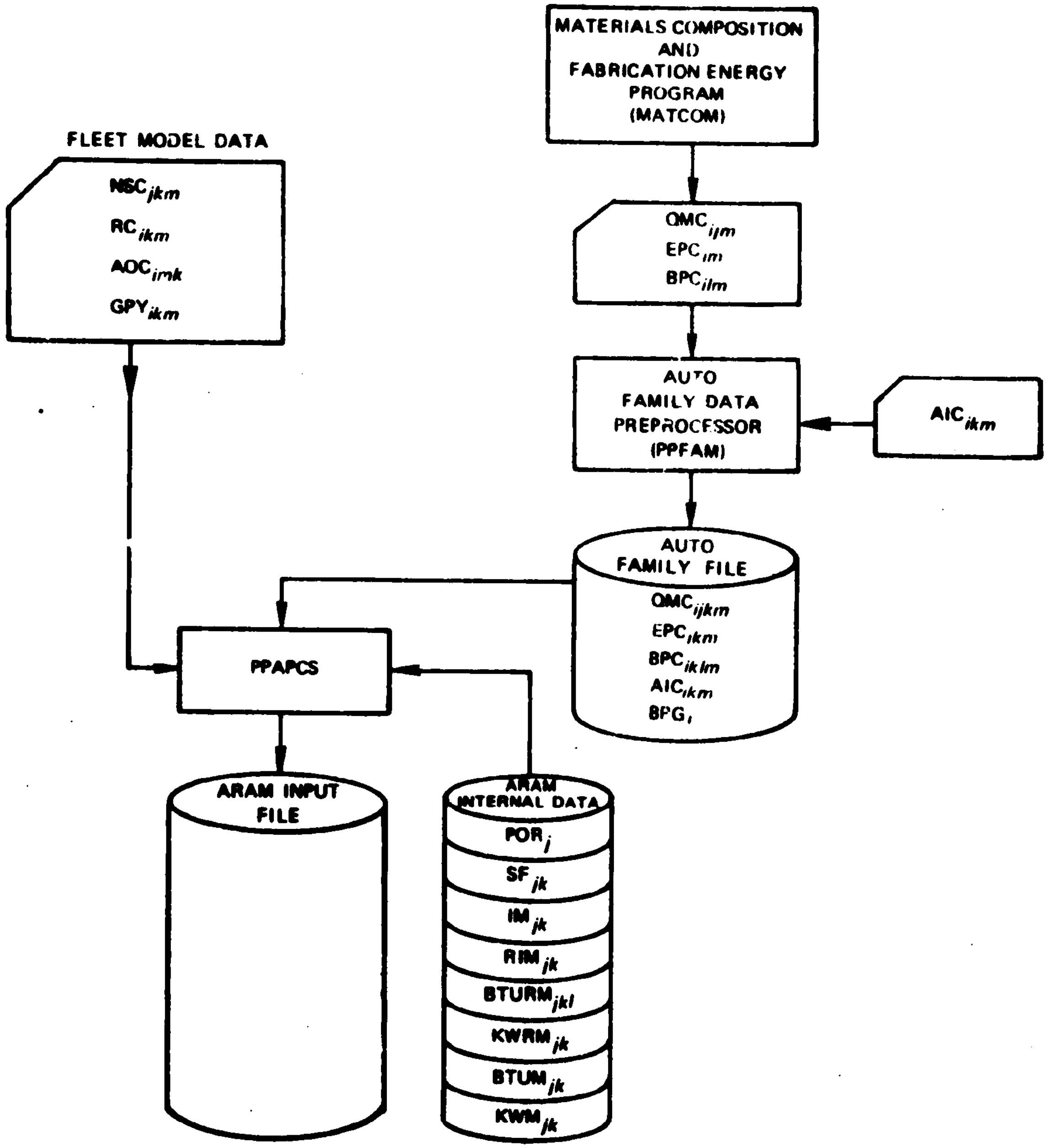


FIGURE 2-3. PPAPCS DEVELOPMENT OF THE ARAM COMPUTATIONAL MODULE INPUT FILE.

TABLE 2-4. DATA FROM THE FLEET ACCOUNTING MODEL.

Data Mnemonic	Description
NSC_{ikm}	The number of automobiles <u>sold</u> of family type "i" and class "m" in year "k".
RC_{ikm}	The number of automobiles of family type "i" and class "m" <u>retired</u> in year "k".
AOC_{ikm}	The number of automobiles of family type "i" and class "m" <u>in operation</u> in year "k".
$GPYC_{ikm}$	The number of gallons of fuel required to operate the entire family fleet of type "i" and class "m" for the year "k".

Once again, the use of a preprocessor allowed the development of the ARAM computational module to proceed without concern for the precise format of the input data. In addition, PPAPCS aggregates certain of the data before creating the ARAM input file. The aggregations performed are either sums or weighted averages over classes within a family. Table 2-5 lists the new variables created and the equations used to generate the data.

2.6 ARAM COMPUTATIONAL MODULE (ARAMC)

The ARAM computational module (ARAMC) accumulates data on the materials and energy for the domestic production and operation of the vehicles in a Task Force scenario. The method by which ARAMC accomplishes the data accumulation is as follows:

(1) The materials required for the production of the automobiles are computed. (Materials required for construction of the auto production facilities are of lesser magnitude, and are not currently accounted for.) The materials required are

then broken down, through the use of national aggregate factors, into imported processed materials, imported raw materials, domestic raw materials, and domestic scrap materials.

(2) The energy requirements for (a) the processing of the materials, (b) the fabrication of the automobiles, and (c) the operation of the automobiles are computed.

(3) The output required for input to the INRAM accounting process is generated.

(4) Summary data for materials and energy requirements are computed for aggregate comparison of scenario runs.

(5) Hardcopy reports are created for presentation of the ARAM results. In addition, a direct access disk file containing the ARAM results is created for plotting purposes.

The above process is executed for each scenario generated by the Task Force.

The equations which have been used in ARAMC for auto-related materials and energy accounting are shown in Tables 2-6 and 2-7. The materials equations apportion the materials requirements by source as indicated. It is worth noting that the energy accounting excludes the energy content of imported processed materials in accordance with the general philosophy of including only domestic energy requirements. Also, the efficiency of converting heat energy to electricity in these equations (EFF) has been assumed to be 40 percent.

The ARAMC produces a yearly report (for the time period 1975 to 2000) for each scenario which includes all input, internal, and computed data. In addition, ARAMC produces a data file containing the annual total materials requirements (by type), sales of autos (in numbers of autos), and operating fuel requirements. This file is used by the PINF (INFORUM preprocessor) program (Section 3.2).

TABLE 2-5. PPAPCS EQUATIONS FOR DATA REDUCTION.

Equation	Description
$R_{ik} = \sum_{m=1}^{3} RC_{ikm}$	Sum of all classes of vehicles of family "i" retired in year "k".
$NS_{ik} = \sum_{m=1}^{3} NSC_{ikm}$	Sum of classes of vehicles of type "i" sold in year "k".
$AO_{ik} = \sum_{m=1}^{3} AOC_{ikm}$	Sum of all classes of vehicles of family "i" in operation in year "k".
$PC_{ikm} = NSC_{ikm} - NS_{ik} * AIC_{ikm}$	Number of autos produced domestically of family "i" and class "m". (set equal to zero if negative)
$P_{ik} = \sum_{m=1}^{3} PC_{ikm}$	Sum of all classes of vehicles of family "i" produced in year "k".
$GPY_{ik} = \sum_{m=1}^{3} GPYC_{ikm}$	Fuel consumption over all classes of vehicles of family "i" in year "k".
$QM_{ijk} = \frac{\sum_{m=1}^{3} (QMC_{ijkm})(PC_{ikm})}{P_{ik}}$	Weighted average of material "j" requirement over all classes of vehicles of family "i" produced in year "k".
$RM_{ijk} = \frac{\sum_{m=1}^{3} (QMC_{ijkm})(RC_{ik})}{R_{ik}}$	Weighted average of material "j" made available for scrap over all classes of vehicles of family "i" through vehicle retirements in year "k".

TABLE 2-6. ARAMC EQUATIONS FOR MATERIALS RESOURCE ACCOUNTING.

Equation	Description
$TMP_{jk} = \sum_i (P_{ik})(QM_{ijk})$	Annual material requirements for domestic auto production.
$TM_{jk} = (1 + POR_j)(TMP_{jk})$	Total annual material requirements for domestic auto production.
$TMS_{jk} = (SF_j)(TM_{jk})$	Total annual material requirements for recycled materials.
$MIR_{jk} = (IM_{jk})(TM_{jk})$	Total annual material requirements for imported processed materials.
$DIRM_{jk} = TM_{jk} - (MIR_{jk} + TMS_{ijk})$	Total annual material requirements for raw materials.
$IRM_{jk} = (TM_{jk})(RIM_{jk})$	Total annual material requirements for imported raw materials.
$DRM_{jk} = DIRM_{jk} - IRM_{jk}$	Total annual material requirements for domestic raw materials.
$XMS_{jk} = \sum_i (R_{ik})(RM_{ijk})$	Total annual material made available for recycling due to auto retirements.

TABLE 2-7. ARAMC EQUATIONS FOR ENERGY RESOURCE ACCOUNTING.

Equation	Description
$TEP_k = \sum_i (P_{ik})(EP_i)$	Electric energy requirements for auto fabrication.
$BEP_{kl} = \sum_i (P_{ik})(BP_{ikl})$	Nonelectric (coal, gas, petroleum, unspecified) energy requirements for auto fabrication.
$TKWRS_k = \sum_j (KWRM_j)(TMS_{jk})$ or $= \sum_j TKWR_{jk}$	Electric energy requirements for processing recycled materials used in domestic auto production.
$TBRMS_{kl} = \sum_j (BTURM_{jl})(TMS_{jk})$ or $= \sum_j TBRM_{jkl}$	Nonelectric energy requirements for processing recycled materials used in domestic auto production.
$TKWS_k = \sum_j (KWM_j)(DIRM_{jk})$ or $= \sum_j TKW_{jk}$	Electric energy requirements for processing raw materials used in domestic auto production.
$TBMS_{kl} = \sum_j (BTUM_{kl})(DIRM_{jk})$ or $= \sum_j TBM_{jkl}$	Nonelectric energy requirements for processing raw materials used in domestic auto production.
$FT_{ik} = \sum_i (GPY_{ik})(BPG_i)$	Btu of fuel required to operate vehicle type "i" fleet for year "k".
$TB_k = \sum_i FT_{ik}$	Total annual Btu of fuel required to operate auto fleet.
$TBPE_{kl} = BEP_{kl} + TBRMS_{kl}$ $+ TBMS_{kl}$	Total annual nonelectric energy (Btu) required for auto-related materials processing and auto fabrication.

TABLE 2-7. ARAMC EQUATIONS FOR ENERGY RESOURCE ACCOUNTING (CONT.).

Equation	Description
$TOTBTU_{kl} = BEP_{kl} + TBRMS_{kl} + TBMS_{kl} + \begin{cases} 0 & \text{for } l = 1,2,4 \\ TB_k & \text{for } l = 3 \end{cases}$	Total annual nonelectric energy (Btu) for auto-related materials processing, auto fabrication, and fleet operation.
$TOTKWH_k = TEP_k + TKWRS_k + TKWS_k$	Total annual kilowatt-hours of electricity required for auto-related materials processing and auto fabrication.
$TFE_k = \left(\sum_l BEP_{kl}\right) + (3412)\ TEP_k/EFF$	Total annual auto fabrication energy (Btu).
$TRS_k = \left(\sum_l TBRMS_{kl}\right) + (3412)\ TKWRS_k/EFF$	Total annual energy for processing recycled materials (Btu).
$TS_k = \left(\sum_l TBMS_{kl}\right) + (3412)\ TKWS_k/EFF$	Total annual energy for processing raw materials (Btu).
$TPE_k = \left(\sum_l TOTBTU_{kl}\right) - TB_k + (3412)\ TOTKWH_k/EFF$	Total annual energy (Btu) for auto-related material processing and auto fabrication energy.
$TOTE_k = TPE_k + TB_k$	Total annual energy (Btu) for auto production and operation.

Table 2-8 presents sample output from ARAMC showing cumulative materials and energy requirements for the period 1975 to 2000. This output is also available for each year of the period. The variable names are listed and defined at the bottom of the table. The table shows cumulative materials requirements (in pounds) in the upper part, and cumulative energy requirements (in kWh or Btu as indicated) in the lower part. The column labeled TM shows the total material demand for auto production (including the fabrication waste factor). This is then broken down according to source: recycled material (TMS), imported processed material (MIR), or raw material (DIRM). The raw material is then further broken down by whether it is domestically produced (DRM), or imported (IRM). The energy data is displayed in summary form at the bottom of Table 2-8. The total energy is broken down into energy for vehicle production and energy for operation. The production energy is further broken down into energy for fabrication, and energy for materials processing from recycled sources and raw material sources. The bottom line in the table shows a breakdown of operating energy by family.

Table 2-9 shows a second summary output from ARAMC, this one presenting growth figures for materials use together with scenario energy savings. For materials impact analysis, the table shows both a growth ratio (2000/1975), and annualized growth rates for 5-year intervals between 1975 and 2000. These ratios and rates help the analyst to spot potential bottleneck situations requiring further analysis. For energy impact analysis, the table converts the cumulative energy-use (1975 to 2000) values in Btu to barrels of crude oil equivalent (1 bbl = 5.8×10^6 Btu), and further computes the scenario energy savings in 2000 versus 1975 expressed in barrels per day. The source of the savings (production energy versus operating energy) can also be determined from the table. A negative sign in the savings column implies a net energy loss.

The direct access file generated by the ARAMC, which contains annual material and energy requirements, is used by the ARAM plot program (GRPH).

2.7 ARAM PLOT PROGRAM (GRPH)

Since a large volume of data is computed and tabulated by ARAMC, it was necessary to develop a plotting program which would graphically display this data. The resulting graphical output facilitated the analysis and comparison of the materials and energy requirements of the scenarios.

TABLE 2-8. SUMMARY OUTPUT OF ARAM.

AUTOMOBILE RESOURCE ACCOUNTING MODEL 01/29/76
FORCE VEHICLE GOALS BEYOND 1980
SYSTEMS INTEGRATION PANEL
TRANSPORTATION SYSTEMS CENTER
CAMBRIDGE, MA (CODE 230)

TOTALS FOR YEARS 1975 TO 2000 CASE 0 REFERENCE CASE

OUTPUT -MATERIALS

	MATERIAL	TMP	TMA	TM	TMS	MIR	DIRM	DRM	IRM	XMS
1	CAST IRON	0.9498E 11	0.0	0.9498E 11	0.2848E 11	0.1113E 10	0.6534E 11	0.4187E 11	0.2187E 11	[illegible]
2	MALLEABLE/NODULAR IRON	0.2779E 11	0.0	0.3057E 11	0.9172E 10	0.3588E 09	0.2108E 11	0.1336E 11	0.7687E 10	[illegible]
3	CARBON STEEL	0.4378E 12	0.0	0.4815E 12	0.1445E 12	0.4911E 11	0.2380E 12	0.1170E 12	[illegible] 12	[illegible]
4	STAINLESS STEEL	0.3513E 10	0.0	0.3865E 10	0.1159E 10	0.7656E 09	0.1940E 10	0.1677E 09	0.177[illegible] 10	0.4058E 10
5	ALLOY STEEL	0.2030E 11	0.0	0.2233E 11	0.6699E 10	0.1149E 10	0.1448E 11	0.8318E 10	0.6164E 10	[illegible]
6	ROLLED/EXTRUDED ALUMINUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	CAST ALUMINUM	0.1874E 11	0.0	0.1874E 11	0.3373E 10	0.0	0.1536E 11	0.6381E 09	0.1487E 11	[illegible]
8	ZINC	0.6168E 10	0.0	0.6168E 10	0.3701E 09	0.1947E 10	0.3850E 10	0.2669E 10	[illegible] 10	[illegible]
9	COPPER	0.5777E 10	0.0	0.6355E 10	0.1335E 10	0.1650E 10	0.3370E 10	0.2808E 10	0.5626E 09	[illegible] 10
10	LEAD	0.5231E 10	0.0	0.5231E 10	0.1935E 10	0.9856E 09	0.2810E 10	0.2045E 10	0.365[illegible] 09	[illegible] 10
11	BODY SOLDER	0.1249E 10	0.0	0.1249E 10	0.4622E 09	0.0	0.7870E 09	0.6997E 09	0.8722E 08	[illegible]
12	PLATINUM (TROY OZ)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	PALLADIUM (TROY OZ)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	GLASS	0.1796E 11	0.0	0.1796E 11	0.8440E 09	0.0	0.1711E 11	0.1711E 11	0.0	[illegible]
15	RUBBER (TIRES)	0.2530E 11	0.0	0.2530E 11	0.6627E 10	0.2563E 10	0.1611E 11	0.3818E 10	0.1229E 11	[illegible]
16	RUBBER (OTHER)	0.1967E 11	0.0	0.1967E 11	0.5155E 10	0.1993E 10	0.1253E 11	0.2966E 10	0.9560E 10	[illegible]
17	PLASTICS	0.2178E 11	0.0	0.2396E 11	0.0	0.1984E 10	0.2199E 11	0.1398E 11	0.7999E 10	[illegible]
18	SOFT TRIM/PAPER/COMPOSITE	0.1702E 11	0.0	0.1872E 11	0.0	0.0	0.1872E 11	0.1872E 11	0.0	[illegible]
19	SOUND DEADENERS/SEALERS	0.1351E 11	0.0	0.1351E 11	0.0	0.0	0.1351E 11	0.9455E 10	0.405[illegible] 10	[illegible]
20	PAINT	0.5153E 10	0.0	0.5153E 10	0.0	0.0	0.5153E 10	0.3607E 10	0.1546E 10	[illegible]
21	FLUIDS/LUBRICANTS	0.3833E 11	0.0	0.3833E 11	0.0	0.0	0.3833E 11	0.2683E 11	0.1150E 11	[illegible]
22	CERAMICS	0.5465E 09	0.0	0.5465E 09	0.0	0.0	0.5465E 09	0.5465E 09	0.0	[illegible] 09
23	URETHANE FOAM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	EXPLOSIVES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

OUTPUT -ENERGY

	KWH ELECTRIC	BTU COAL	BTU NAT GAS	BTU PETROLEUM	BTU OTHER	BTU TOTAL
FABRICATION ENERGY:	0.257092 12	0.87832E 15	0.22586E 16	0.27091E 15	0.10899E 16	0.71320E 16
RECYCLING ENERGY:	0.0	0.0	0.0	0.0	0.42987E 16	0.42987E 16
RAW MATERIAL ENERGY:	0.0	0.0	0.0	0.0	0.10943E 17	0.10943E 17
PRODUCTION ENERGY:	0.257092 12	0.87832E 15	0.22586E 16	0.27091E 15	0.16328E 17	0.22370E 17
OPERATING ENERGY:				0.23787E 18		0.23787E 18
TOTAL ENERGY:	0.257092 12	0.87832E 15	0.22586E 16	0.23815E 18	0.16328E 17	0.26024E 18

	FAMILY NO. 1	FAMILY NO. 2	FAMILY NO. 3
OPERATING FUEL (BTU'S)	FT= 0.61287E 17	0.10502E 18	0.7[illegible] 17

TMP – Domestic auto production materials demand.

TMA – Aftermarket materials demand (not currently available).

TM – Total materials demand (including fabrication and production waste factor (POR)).

TMS – Demand for recycled materials.

MIR – Demand for imported processed materials.

DIRM – Demand for raw materials.

DRM – Demand for domestically produced raw materials.

IRM – Demand for imported raw materials.

XMS – Materials made available for scrap through auto retirements.

TABLE 2-9. SCENARIO GROWTH RATES AND ENERGY SAVINGS SUMMARY.

AUTOMOBILE RESOURCE ACCOUNTING MODEL 01/29/76
MOTOR VEHICLE GOALS BEYOND 1980
SYSTEMS INTEGRATION PANEL
TRANSPORTATION SYSTEMS CENTER
CAMBRIDGE, MA (CODE 230)

CASE 0 REFERENCE CASE

OUTPUT -MATERIALS

	MATERIAL	RATIO 2000/1975	RATES (PERCENT) 1975-2000	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000
1	CAST IRON	1.452	1.493	5.432	0.1456	0.7719E-01	1.006	0.8030
2	MALLEABLE/NODULAR IRON	1.452	1.493	5.433	0.1489	0.7721E-01	1.006	0.8029
3	CARBON STEEL	1.452	1.493	5.432	0.1454	0.7746E-01	1.007	0.8024
4	STAINLESS STEEL	1.452	1.493	5.432	0.1456	0.7721E-01	1.006	0.8027
5	ALLOY STEEL	1.452	1.493	5.432	0.1457	0.7717E-01	1.006	0.8029
6	ROLLED/DRAWN ALUMINUM	999.0	999.0	999.0	999.0	999.0	999.0	999.0
7	CAST ALUMINUM	1.452	1.493	5.432	0.1455	0.7708E-01	1.006	0.8023
8	ZINC	1.452	1.493	5.433	0.1454	0.7718E-01	1.006	0.8027
9	COPPER	1.452	1.493	5.433	0.1453	0.7679E-01	1.006	0.8029
10	LEAD	1.452	1.493	5.432	0.1456	0.7748E-01	1.006	0.8025
11	BODY SOLDER	1.452	1.493	5.432	0.1456	0.7731E-01	1.006	0.8030
12	PLATINUM (TROY OZ)	999.0	999.0	999.0	999.0	999.0	999.0	999.0
13	PALLADIUM (TROY OZ)	999.0	999.0	999.0	999.0	999.0	999.0	999.0
14	GLASS	1.452	1.493	5.432	0.1456	0.7719E-01	1.006	0.8027
15	RUBBER (TIRES)	1.452	1.493	5.432	0.1453	0.7717E-01	1.007	0.8026
16	RUBBER (OTHER)	1.452	1.493	5.432	0.1457	0.7727E-01	1.006	0.8027
17	PLASTICS	1.452	1.493	5.432	0.1461	0.7721E-01	1.006	0.8029
18	SOFT TRIM/PAPER/COMPOSITE	1.452	1.493	5.432	0.1456	0.7716E-01	1.006	0.8020
19	SOUND DEADENERS/SEALERS	1.452	1.493	5.432	0.1456	0.7718E-01	1.006	0.8028
20	PAINT	1.452	1.493	5.432	0.1458	0.7708E-01	1.007	0.8026
21	FLUID/LUBRICANTS	1.452	1.493	5.432	0.1459	0.7776E-01	1.006	0.8026
22	CERAMICS	1.452	1.493	5.432	0.1453	0.7725E-01	1.007	0.8025
23	URETHANE FOAM	999.0	999.0	999.0	999.0	999.0	999.0	999.0
24	EXPLOSIVES	999.0	999.0	999.0	999.0	999.0	999.0	999.0

NOTE:INDETERMINATE RATES OR RATIOS HAVE VALUE 999.

OUTPUT -ENERGY

(1975 TO 2000)	TOTAL BTU	TOTAL BBLS	ANNUAL SAVING, 2000 VS 1975 BBLS/DAY
PRODUCTION ENERGY:	0.22370E 17	0.38569E 10	-0.14072E 06
OPERATING ENERGY:	0.23787E 18	0.41013E 11	0.11749E 07
TOTAL ENERGY:	0.26024E 18	0.44870E 11	0.10341E 07

The GRPH program reads a deck of user supplied plotting commands. These commands enable the user to obtain the following graphical output over the years 1975 to 2000.

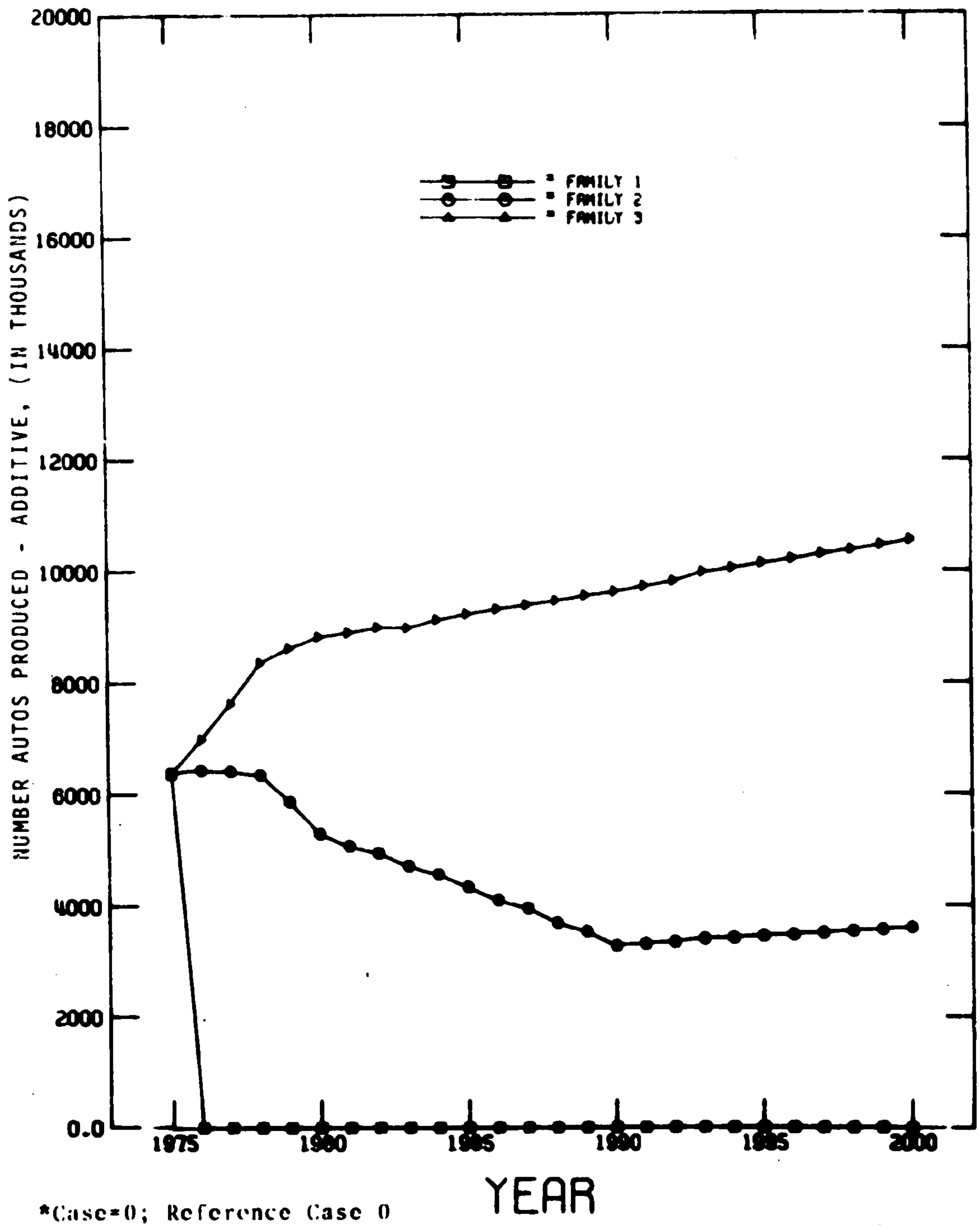
(1) Single-line plots of a specified variable (e.g., carbon steel requirements by year).

(2) Multiple-line plot, i.e., plots on which up to 12 variables can be graphed (e.g., carbon steel, stainless steel, iron, aluminum).

(3) Multiple-case plots, i.e., plots on which a given variable can be graphed for up to 12 scenarios.

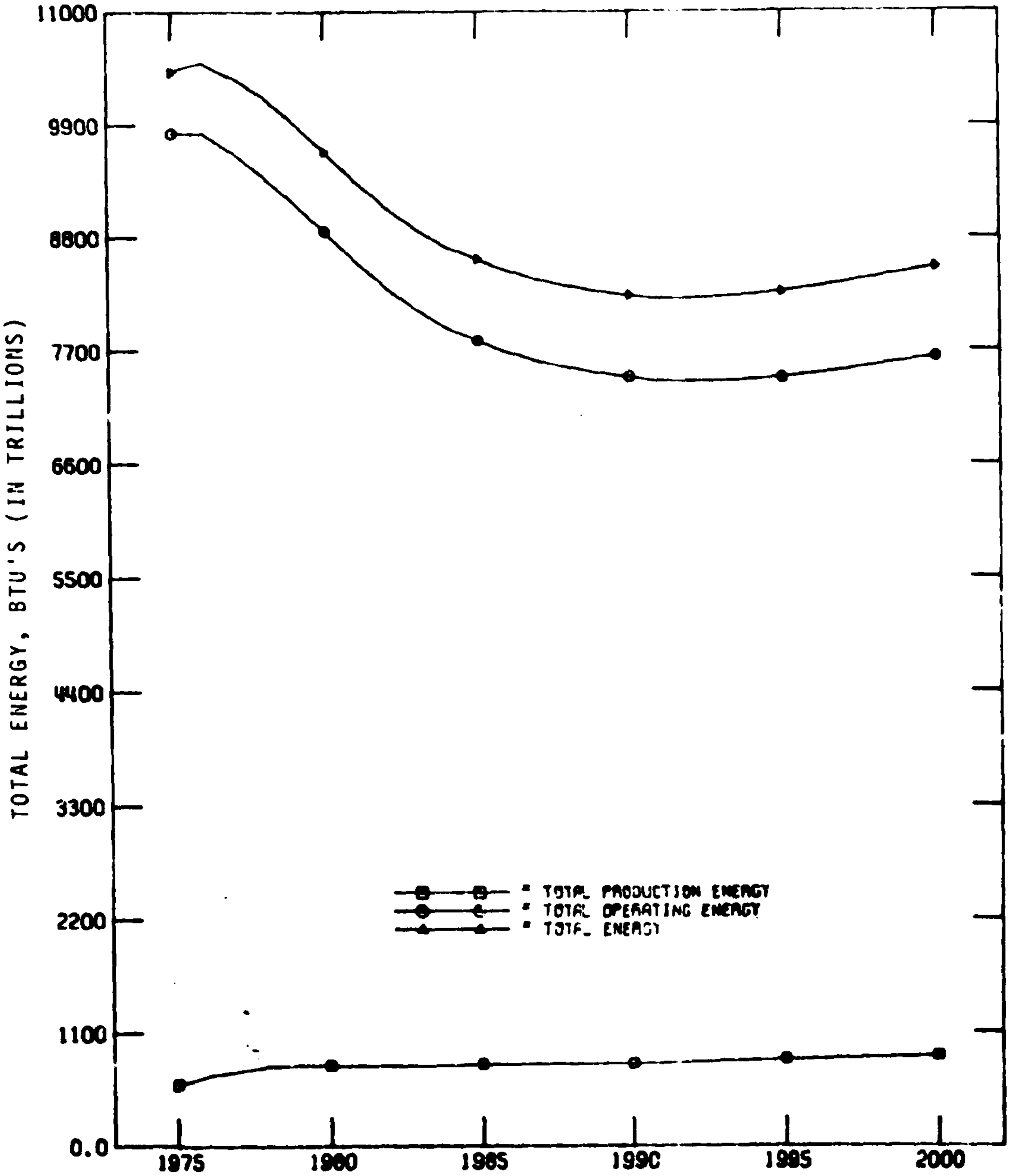
(4) Additive plots, i.e., plots on which the distance between adjacent lines represents the value of the variable.

Once the user commands have been processed, GRPH retrieves the required data from the direct access file created by ARAMC. The data are then scaled according to user-supplied minimum and maximum or automatically. Figures 2-4 through 2-8 illustrate sample graphical output as produced by the ARAM plot program.



*Case=0; Reference Case 0

FIGURE 2-4. NUMBER OF AUTOS PRODUCED (SAMPLE PLOT OF ARAM DATA).*



*NRUN=14 Reference Case 0

FIGURE 2-5. TOTAL ENERGY (SAMPLE PLOT OF ARAM DATA).*

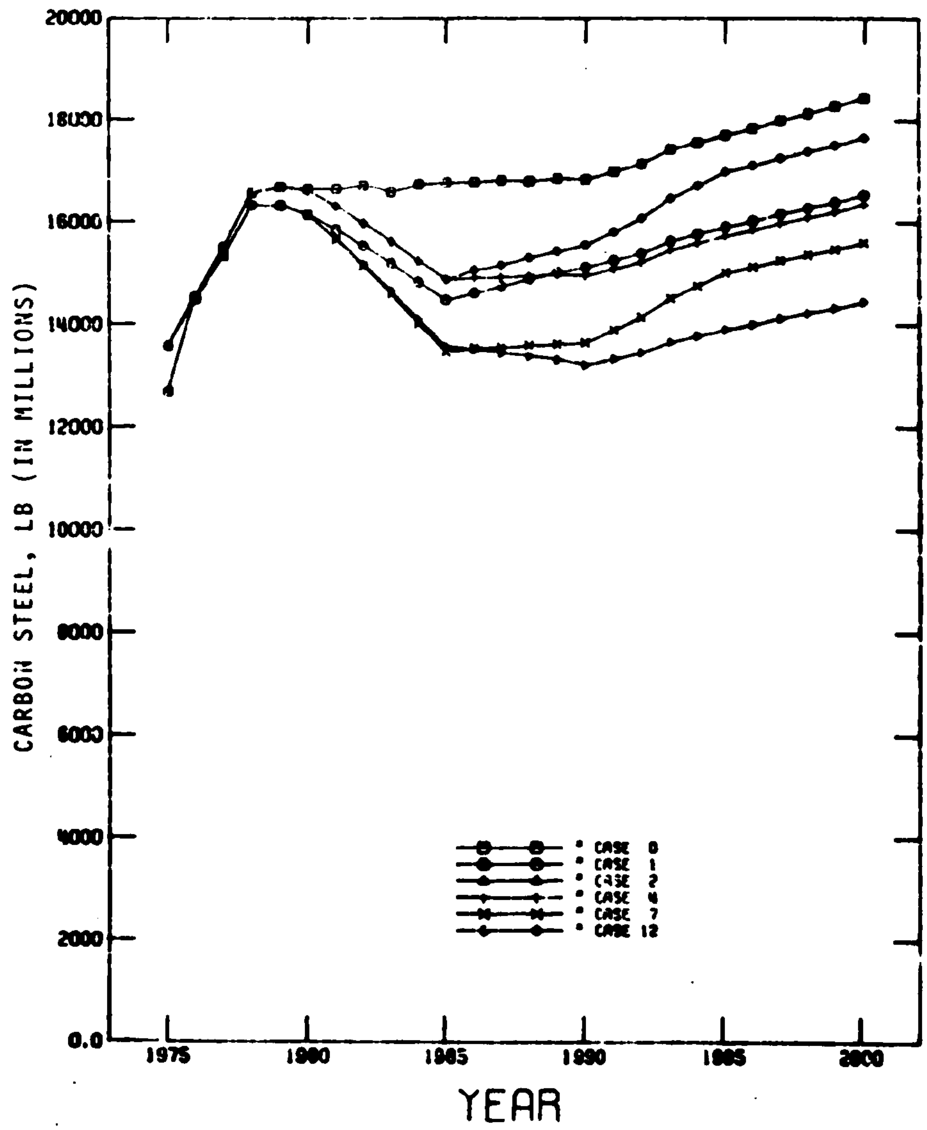


FIGURE 2-6. CARBON STEEL (SAMPLE PLOT OF ARAM DATA).

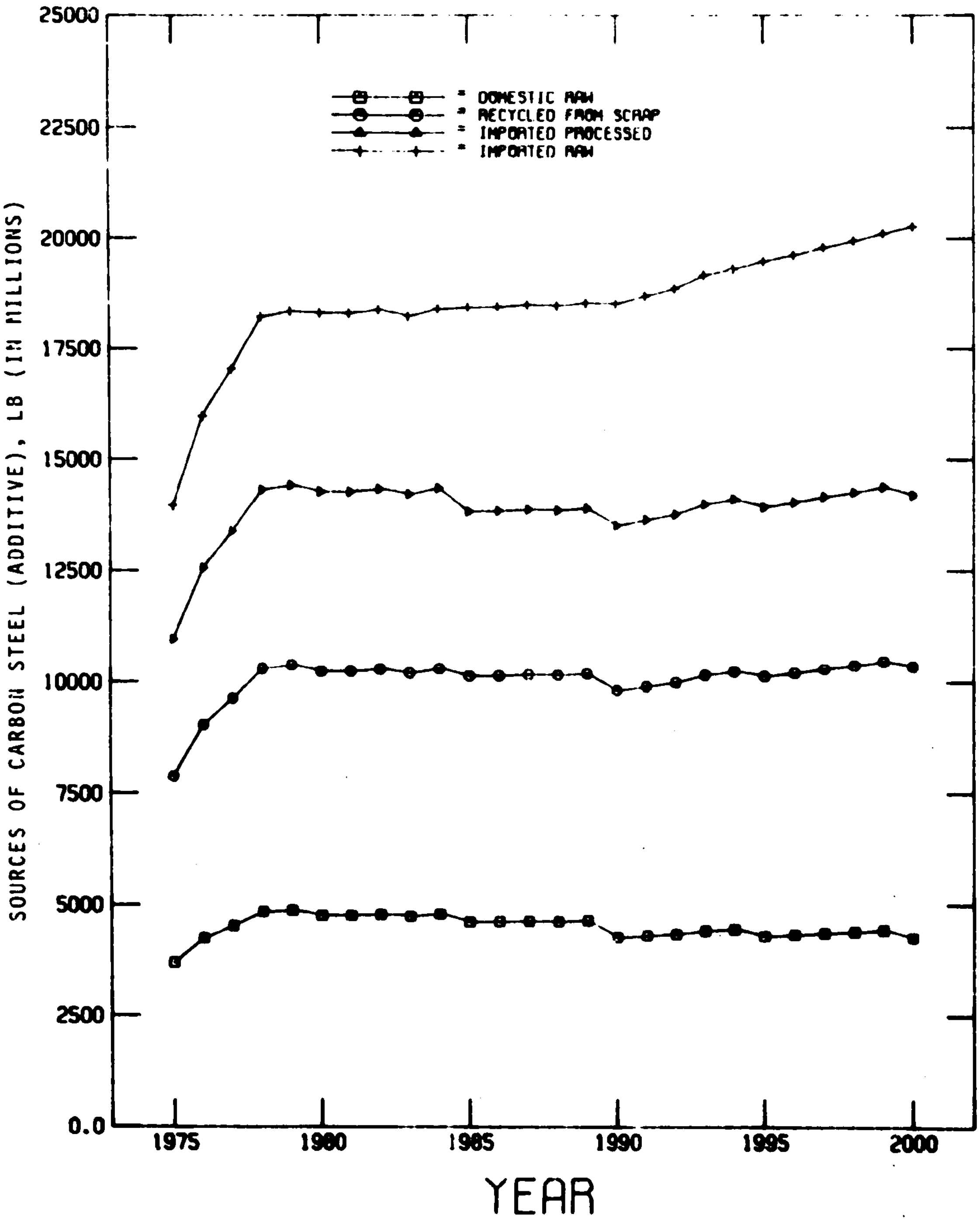


FIGURE 2-7. SOURCES OF CARBON STEEL (SAMPLE PLOT OF ARAM DATA).

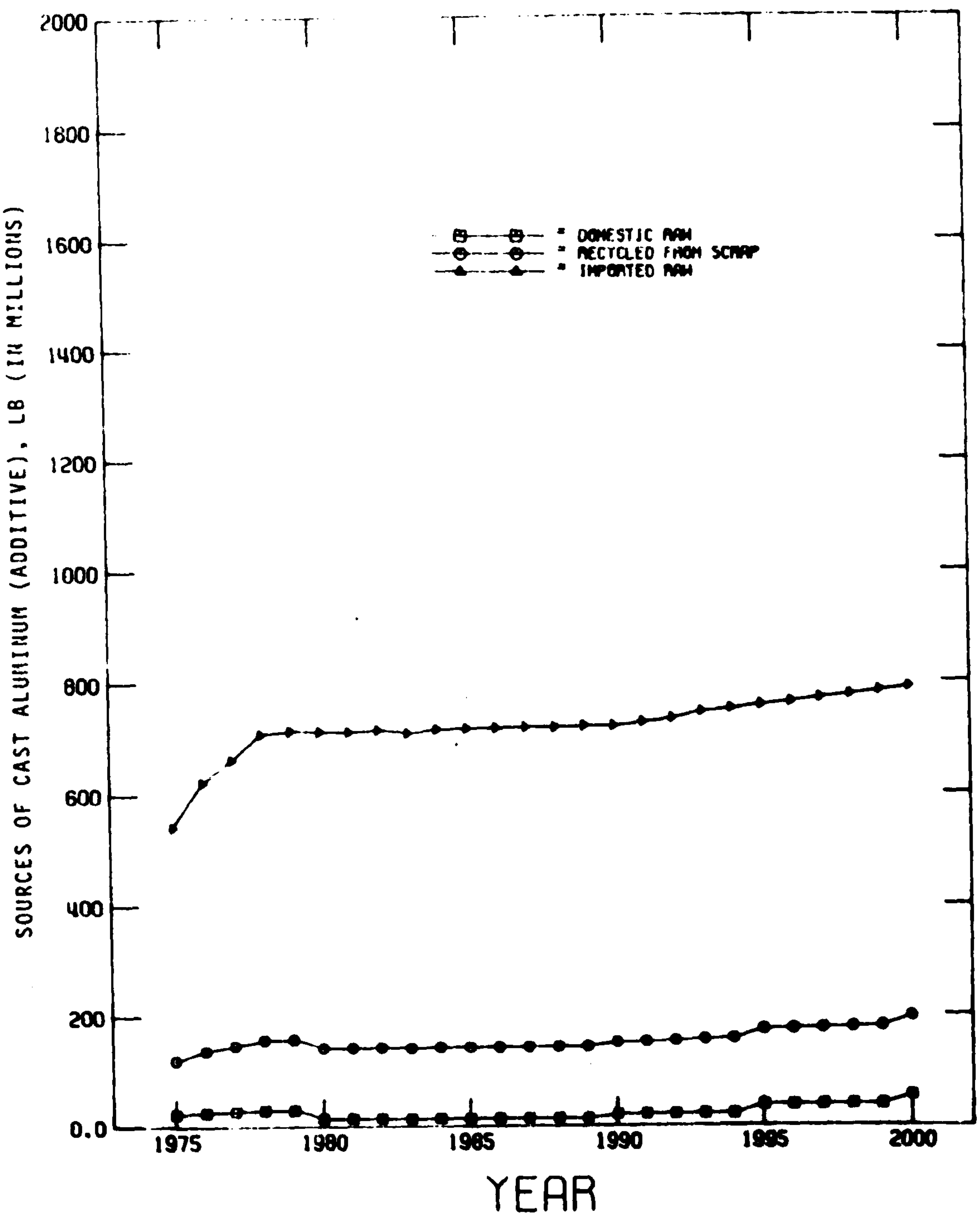


FIGURE 2-8. SOURCES OF CAST ALUMINUM (SAMPLE PLOT OF ARAM DATA).

3. CAPITAL AND LABOR RESOURCE ACCOUNTING

To evaluate the capital, labor, and industrial impacts of the Task Force scenarios, a Capital and Labor Resource Accounting Model (INRAM) employing input-output analysis was developed. The input-output methodolog was selected since (1) it employs a forecasting tool already in existe e, and (2) permits the analysis of technological changes on detail industries.

Other methodologies, such as the family-tree approach or dynamic programming, could have been employed for analyzing the economic impacts. However, these alternative approaches would have required the development of a large and sophisticated data base—a task involving significant time and effort. After weighing these considerations and the time constraints imposed by the Task Force schedule, the input-output approach appeared the most attractive.

Input-output analysis is based on data collected through the various economic censuses, and requires such information as follows:

(1) Purchases/sales of production goods and services between industries.

(2) Purchases/sales of capital equipment by industries.

(3) Purchases of structures.

(4) Sales to final demand by industry.

(5) Employment (in jobs) by industry.

Due to the level of industry detail required to observe possible industry bottlenecks, the INFORUM input-output* model developed at the University of Maryland was selected to perform the economic analysis. An additional advantage of using the INFORUM model is that forecasts of other industry data (e.g., imports, exports, shipments) are produced as a

* Almon, C. et al., 1985: Interindustry Forecasts of the American Economy, Lexington Books, Lexington, Mass., 1974.

byproduct of the capital and labor analysis, and often prove useful in their own right. The INFORUM model is designed to run on a UNIVAC 1106 with an EXEC 8 operating system.

Figure 3-1 presents the interaction of the Capital and Labor Resource Accounting Model (INRAM) with other Task Force efforts.

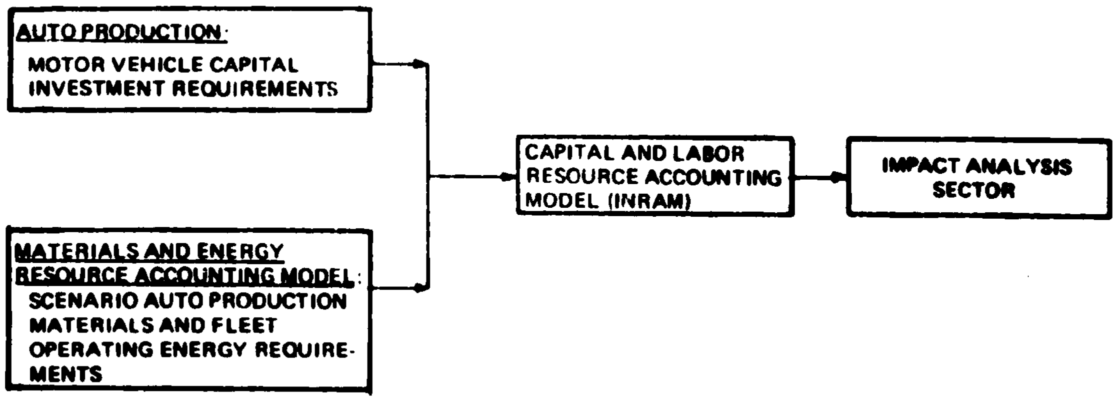


FIGURE 3-1. INTERACTION OF CAPITAL AND LABOR RESOURCE ACCOUNTING MODEL, WITH OTHER TASK FORCE EFFORTS.

3.1 PROCEDURAL FLOW FOR CAPITAL AND LABOR RESOURCE ACCOUNTING

The Capital and Labor Resource Accounting Model evaluates capital, labor, and industrial impacts for each scenario. Scenario output data are stored on tape for later case-by-case analysis. Figure 3-2 illustrates the procedure through which this is accomplished.

The file created by ARAM for use by INRAM contains the following data:

(1) Annual requirements for up to 30 materials used in domestic auto production.

(2) Annual number of autos produced domestically.

(3) Annual new car sales.

(4) Annual fleet operating energy.

The INFORUM preprocessor (PINF) uses this information together with data on motor vehicle capital investment (which was made available for Task Force scenarios by the manufacturing assessment group) to alter selected interindustry and final demand coefficients. The output of PINF is a deck

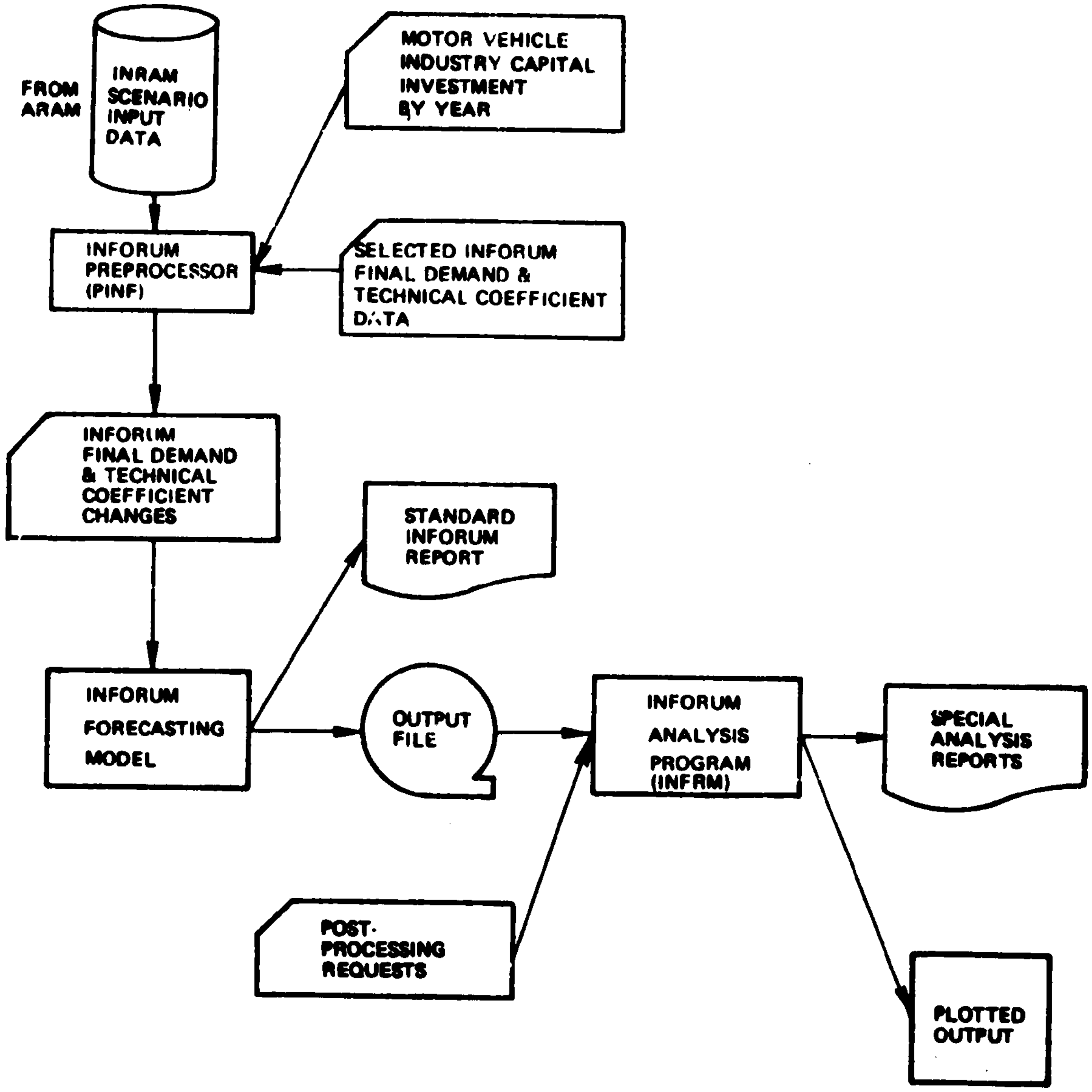


FIGURE 3-2. CAPITAL AND LABOR RESOURCE ACCOUNTING MODEL.

of cards which contains these new coefficients in the format required by INFORUM. These coefficients reflect the altered economic and technological environment induced by a given scenario.

The INFORUM model is then executed to obtain the capital, labor, and industrial impacts of the new environment which appear in a series of tabulations. These print files are also copied onto a tape for subsequent processing by the INFORUM postprocessor (INFRM).

The INFORUM print file (converted to IBM format by the CNVRT program, not shown in Figure 3-2) is processed by the INFRM program to obtain aggregated industry differences, discounted and deflated industry investments, differences from the Reference Case for each scenario, and a number of other useful summary outputs.

The output from INFORUM and INFRM (in either tabular or graphical form) is then available for impact analysis by the user. A detailed description of these programs follows.

3.2 INFORUM PREPROCESSOR (PINF)

The data file created by ARAM is used by the PINF to modify the INFORUM final demand and inter industry flow coefficients. This modification is performed to reflect a more realistic economic and technological environment due to different Task Force scenarios.

At present, 14 coefficients in the INFORUM input-output matrices have been selected for modification to reflect the technological and economic conditions of Task Force scenarios. These coefficients are identified in Table 3-1. Tables 3-2 through 3-6 present the equations which are used to modify the coefficients. These equations are currently being validated on historical data, and consequently may be modified in future program versions.

The equations presented in the following tables can generally be interpreted as follows:

The new coefficient in year "k" is equal to the base year coefficient multiplied by the sum of:

(1) The proportional increase (or decrease) over the base year in the inter-industry or final demand activity of that fraction (R) of the activity pertaining to new auto production.

(2) The fraction of the activity pertaining to non-auto production (1-R). (In the case of the equations of Tables 3-3 through 3-6 it is assumed that the whole coefficient pertains to personal autos, i.e., R = 1.)

Table 3-7 lists the temporary values assigned to the variable R as required by the equation in Table 3-2. These values were estimated using data from the 1972 Census of Manufactures.

The output of PINF is a set of cards in the format required by INFORUM.

TABLE 3-1. INFORUM COEFFICIENTS WHICH ARE MODIFIED TO REFLECT SCENARIO CONDITIONS.

INFORUM Producing Industry	INFORUM Consuming Industry
1. Steel (91)	Metal Stampings (106)
2. Aluminum (95)	Metal Stampings (106)
3. Steel (91)	Motor Vehicles (145)
4. Aluminum (95)	Motor Vehicles (145)
5. Copper (92)	Motor Vehicles (145)
6. Glass (86)	Motor Vehicles (145)
7. Tires & Inner Tubes (80)	Motor Vehicles (145)
8. Other Rubber (81)	Motor Vehicles (145)
9. Plastic (82)	Motor Vehicles (145)
10. Paint (74)	Motor Vehicles (145)

Additional INFORUM parameters to be modified:

- **Personal Consumption Expenditures for**

11. • **Motor Vehicles (145)**

12. • **Petroleum (76)**

13. - **Motor Vehicle (70) Equipment Investment**

14. - **Motor Vehicle (145) Imports**

TABLE 3-2. GENERAL EQUATION FOR TECHNICAL COEFFICIENT CHANGE (COEFFICENTS 1 THROUGH 10, INCLUSIVE.)

$$A^k_{i,j} = A^{75}_{i,j} * \left\{ R_{i,j} * \left[\frac{TM^k_{i,j}/P^k}{TM^{75}_{i,j}/P^{75}} \right] + \left[1 - R_{i,j} \right] \right\}$$

where

$A^k_{i,j}$	-	Input-output coefficient in year "k" for the interaction between the "i^{th}" producing industry and the "j^{th}" consuming industry.
$A^{75}_{i,j}$	-	Base year ('75) value of the coefficient.
$R_{i,j}$	-	Fraction of output in industry "j" which is used in the production of new autos.
$TM^k_{i,j}$	-	Material in physical units (e.g., tons, pounds, etc.) used in industry "j" as produced in industry "i" for the <u>annual</u> production of autos in <u>year</u> "k".
P^k	-	Number of autos produced in year "k".
$TM^{75}_{i,j}$	-	Base year (k = 75) value of material in physical units consumed by industry "j" as produced by industry "i" for the production of new autos.
P^{75}	-	Base year (k = 75) number of autos produced.

TABLE 3-3. EQUATION FOR MODIFYING PERSONAL CONSUMPTION EXPENDITURE (PCE) FOR NEW AUTOS.

$$PCE^{k}_{145} = \left(PCE^{75}_{145} - IMP^{75}_{145}\right) * \left(\frac{P^{k}}{P^{75}}\right) + \left(IMP^{75}\right)\left(\frac{TI^{k}}{TI^{75}}\right)$$

where

$\left(PCE^{75}_{145} - IMP^{75}_{145}\right)$	-	Base year value of PCE spent on domestically produced autos (i.e., total PCE less imports - IMP--values in millions of dollars as per INFORUM).
P^{k}	-	Number of domestically produced and consumed autos in year "k".
P^{75}	-	Base year value of number of domestically produced and consumed autos.
IMP^{75}	-	Base year value of autos imported (value in millions of dollars as per INFORUM).
TI^{k}	-	Number of autos imported in year "k".
TI^{75}	-	Base year number of autos imported.

TABLE 3-4. EQUATION FOR MODIFYING PERSONAL CONSUMPTION EXPENDITURE (PCE) FOR PETROLEUM.

$$PCE^{k}_{76} = PCE^{75}_{76} * \left[\frac{TB^{k}}{TB^{75}}\right]$$

where

PCE^{k}_{76}	-	Personal consumption expenditure (PCE) for petroleum in year "*k*".
PCE^{75}_{76}	-	PCE for petroleum in base year (*k* = 75).
TB^{k}	-	Petroleum in Btu required for the operation of the auto fleet in year "*k*"
TB^{75}	-	Petroleum in Btu required for the operation of the auto fleet in the base year.

TABLE 3-5. EQUATION FOR MODIFYING PRODUCER'S DURABLE EQUIPMENT INVESTMENT (PDE) MADE BY THE MOTOR VEHICLES INDUSTRY.

$$PDE^{k}_{70} = PDE^{75}_{70} * \left[\frac{C^{k}}{C^{75}}\right]$$

where

PDE^{k}_{70}	-	Equipment investment (PDE) by the motor vehicles industry in year "*k*".
PDE^{75}_{70}	-	Base year PDE by the motor vehicles industry.
C^{k}	-	Capital expenditure made by the motor vehicles industry in year "*k*".
C^{75}	-	Capital expenditures made by the motor vehicles industry in base year.

TABLE 3-6 EQUATION FOR MODIFYING MOTOR VEHICLE IMPORTS.

$$IMP^{k}_{145} = IMP^{75}_{145} * \left[\frac{TI^{k}}{TI^{75}}\right]$$

where

IMP^{k}_{145}	-	The value in millions of dollars of motor vehicle imports (IMP) in year "k".
IMP^{75}_{145}	-	The base year value in millions of dollars (as per INFORUM) of motor vehicle imports.
TI^{k}_{145}	-	Number of autos imported in year "k".
TI^{75}_{145}	-	Number of autos imported in base year.

TABLE 3-7. PRELIMINARY MARKET SHARES FRACTIONAL VALUES.

Coefficient In Table 3-2	Mnemonic	Value
1	$R_{91,106}$	0.64
2	$R_{95,106}$	0.64
3	$R_{91,145}$	0.70
4	$R_{95,145}$	0.70
5	$R_{92,145}$	0.70
6	$R_{86,145}$	0.70
7	$R_{80,145}$	0.70
8	$R_{81,145}$	0.70
9	$R_{82,145}$	0.70
10	$R_{74,145}$	0.70

3.3 INFORUM

INFORUM is a model which enables one to forecast economic conditions to 1985 (a modification in progress at the University of Maryland will allow forecasting to 1990 or 2000). Using input-output matrices and certain exogenously supplied data, INFORUM forecasts the distribution of sales of 200 industries to their respective buyers. Figure 3-3 illustrates the input output matrix organization used in INFORUM.* Each of these matrices will be briefly described below in order to demonstrate its use in evaluating the distribution of capital and labor impacts among the industry sectors due to a scenario.

BUYER / SELLER		GNP - COMPONENTS						
	200 PRODUCTS BOUGHT FOR USE IN PRODUCTION	90 CAPITAL EQUIPMENT BUYERS	28 TYPES OF STRUCTURE PURCHASED	9 GOVERNMENT CATEGORIES	4 OTHER FINAL DEMAND CATEGORIES			
200 PRODUCTS PRODUCED AND SOLD	A MATRIX SALES TO INTERMEDIATE USE	B MATRIX SALES TO CAPITAL EQUIPMENT INVESTMENT	C MATRIX SALES TO CONSTRUC- TION INVESTMENT	G MATRIX SALES TO FEDERAL AND STATE & LOCAL GOVERNMENT	PLUS EXPORTS	LESS IMPORTS	INVENTORY CHANGE	PERSONAL CONSUMPTION
	EMPLOYMENT (90 INDUSTRIES)							

Taken from Almon* and used with permission from the publisher.

FIGURE 3.3. INFORUM INPUT-OUTPUT MATRIX ORGANIZATION FOR DISTRIBUTION OF SALES OF 200 PRODUCTS TO TYPE OF BUYER.

---

* **Almon, C. et al., 1985: <u>Interindustry Forecasts of the American Economy</u>, Lexington Books, Lexington, Mass., 1974.**

3.3.1 A Matrix

The A matrix represents the inter-industry flows of products. Specifically the cells in this matrix are coefficients representing the dollars of input required of a "seller" (row) industry in order to produce a dollar of output for the "buyer" (column) industry. The sum of the coefficients in any column, including the value added or marginal coefficients, equals one.

In other words, the A matrix represents the technology of a given buyer industry by indicating the inputs (in dollars) required of other industries in order for the buyer industry to produce $1 of its output. As such, it is the coefficients in this matrix which are modified to reflect the different material compositions or technologies of the scenario autos (first 10 items of Table 3-1).

3.3.2 B Matrix

The B matrix represents the purchases by 90 industries (which are aggregates of the 200 seller industries) of capital equipment from the seller industries. A cell in this matrix represents the dollars of purchases of producers' durable equipment from a seller industry by one of the buyer industries per dollar investment of the buyer industry.

INFORUM generates the capital investment required for producers' durables using capital investment equations (which can be overridden) which link capital spending to total industry output. This implies that when an industry's output increases, the capital investment would also increase.

Currently, none of the B matrix coefficients are modified in connection with the scenarios. Instead the total equipment investment for one of the 90 capital equipment buyers (motor vehicles) is exogenously input to reflect (1) an accelerated scenario implementation strategy, or (2) significant retooling or reinvestment for the industry. This total is then apportioned to the cells of the column by INFORUM.

3.3.3 C Matrix

The C Matrix represents the purchases from the 200 seller industries by 28 aggregate construction industries. The 28 industries are aggregated from the 200 basic industries by the type of structures required.

A column in this matrix represents the purchases required from the 200 seller industries to generate a dollar of construction for a specific structure type (representing one of the 28 aggregated industries).

INFORUM generates the capital investment required for structures based on a set of structures equations. Therefore, as output increases, capital investment in structures will increase. At present, none of the C matrix coefficients or column totals is modified.

3.3.4 G Matrix

The G matrix represents nine sectors of government purchases of products from the 200 seller industries. These nine sectors represent a part of the final demand. A column in this matrix represents purchases from 200 seller industries by a classification of government expenditures, e.g., state, local, Department of Defense, NASA, etc. A cell in this matrix represents purchases of products from a single seller industry by a classification of government expenditures.

There is currently no recognized need to modify any of these final demand values.

3.3.5 Other Final Demand Vectors

There are four additional final demand vectors in INFORUM as shown in Figure 3-3. These vectors are exports, imports, inventory change, and personal consumption expenditures. Each of these vectors represents purchases of products from the 200 seller industries by the specific form of final demand.

Currently, there is no recognized need to modify any of the values in the export and inventory change forms of final demand. The cells in the import column represent, among others, the imports of crude petroleum, natural gas, petroleum refinery products, and motor vehicles. Only motor vehicle imports are currently modified to correspond to Task Force assumptions.

The personal consumption expenditure (PCE) column represents consumer purchases of products from the 200 seller industries, not all of which are sellers to PCE. Purchases in this column are based on INFORUM projections of personal disposable income. The cells in this final demand column representing consumer purchases of gasoline, and motor vehicles are modified to reflect (1) decreased gasoline purchases due to higher fuel economy of advanced (scenario) automobiles, and (2) assumed future motor vehicle sales levels.

3.3.6 Exogenous Assumptions

The general user of the INFORUM model can make modifications to any of the matrices or vectors previously listed (the PINF program makes only those changes indicated in the previous section). These modifications would reflect the user's view of technology for a given industry or set of economic assumptions.. In addition to making such modifications, the general user can override the exogenous assumptions of INFORUM. These assumptions pertain to:

(1) Disposable per capita income

(2) Population

(3) Long-term investment rate

(4) Rent/construction cost index

(5) Households

(6) Investment tax credit

(7) Average foreign currency price

(8) Labor force

(9) Civilian unemployment rate.

None of these exogenous assumptions is varied from case to case in the present implementation.

3.3.7 Outputs

The output generated by INFORUM is a series of tabulations in 1972 constant dollars as follows:

(1) GNP summary

(2) Personal consumption expenditures for 200 industries (PCE)

(3) Competitive imports in domestic port prices (IMP)

(4) Durable equipment investment by producers (PDE)

(5) Purchases of structures by type (STR)

(6) Number of persons employed by industry (EMP)

(7) Product shipments in producer prices by industry (SHP)

(8) Productivity (output per employed person)

(9) A selected set of buyer/seller tabulations for user specified industries.

Each of the nine tabulations contains the respective information for a series of user-selected years between 1972 and 1985. The print files as listed above (with the exception of the last) are copied onto a tape for subsequent processing by the INFORUM postprocessor (INFRM).

Table 3-8 presents a sample of INFORUM output (the GNP Summary) for an example case. Other portions of the INFORUM output contain industry detail related to these summary numbers.

3.4 INFORUM POSTPROCESSOR (INFRM)

Although the INFORUM model produces a wealth of detail relating to capital and labor requirements for the various scenarios, much of the specific data required for impact assessment can only be obtained by further processing of the INFORUM output. The capital information may be needed on a discounted basis for cost-benefit calculations, and INFORUM 1972 constant dollars may need to be converted to constant dollars for some other base year. For both capital and labor, it is desirable to be able to calculate absolute and percentage differences between the various cases. It is further desirable to be able to express capital and labor requirements on a cumulative basis. To be able to make user-defined aggregations of the basic industries for summary purposes is also helpful. Finally, a plotting capability is needed for rapid evaluation of scenario results and for data presentation. The key to these various capabilities is the INFORUM postprocessor (INFRM).

The INFRM program reads a series of user-defined commands which indicate (1) the INFORUM scenarios which are to be processed, (2) the INFORUM tables which are to be processed, and the industry aggregations to be performed for each of these tables, and (3) the plots to be produced. After processing these commands, the required INFORUM print files are processed. The following output can be obtained for the scenarios selected:

(1) Capital investment in producers' durable equipment by year (actual, and deflated and discounted) for 90 industries.

TABLE 3-8. SAMPLE INFORUM OUTPUT.

INFORUM SUMMARY OF NATIONAL ACCOUNTS AND FINAL DEMAND — DATE 102875 — PAGE 5

JUNE FORECAST - OIL DELTA — GNP SUMMARY (BILLIONS OF 1972$)

	1972	1975	1976	1978	1980	1981	1982	1983	1984	1985
GROSS NATIONAL PRODUCT	1158.00	1187.58	1264.55	1347.70	1427.29	1456.50	1482.39	1513.98	1546.15	1578.09
PERSONAL CONSUMPTION EXPENDITURES	729.02	739.66	793.89	840.15	895.65	917.00	938.35	959.89	980.97	1002.14
DURABLE GOODS	118.44	112.73	113.87	126.21	136.76	137.07	140.44	143.14	146.77	148.45
NONDURABLE GOODS	299.67	296.74	330.51	346.15	363.91	370.82	377.52	384.36	390.97	397.57
SERVICES	310.91	325.60	342.43	364.50	392.18	404.24	416.02	427.70	439.22	450.77
GROSS PRIVATE DOMESTIC INVESTMENT	179.33	166.07	187.17	221.51	232.69	235.13	233.96	236.37	240.09	244.96
STRUCTURES	95.09	79.84	87.42	101.71	105.51	106.46	107.02	108.20	109.66	111.05
RESIDENTIAL	53.81	36.37	40.32	51.15	53.42	54.32	54.84	55.40	55.82	56.47
PRODUCERS' DURABLE EQUIPMENT	75.71	86.00	94.52	109.61	117.81	120.78	120.56	123.26	127.13	130.56
AGRICULTURE	5.55	6.52	6.60	7.13	6.34	6.84	6.67	6.86	7.31	7.12
MINING	2.56	3.08	3.22	3.74	4.15	4.22	4.21	4.31	4.47	4.59
CONSTRUCTION	3.23	3.35	3.50	4.48	5.11	5.07	4.72	4.63	4.81	4.90
NONDURABLE GOODS	8.70	10.67	11.53	13.24	14.00	14.31	14.15	14.48	14.89	15.28
DURABLE GOODS	9.51	11.96	12.61	15.15	16.89	16.87	15.97	16.11	16.63	17.06
TRANSPORTATION	5.35	6.22	7.07	8.72	9.31	9.68	10.00	10.34	10.78	11.22
COMMUNICATION	8.59	9.82	11.34	13.21	14.29	14.87	15.25	15.75	16.33	16.94
UTILITIES	7.66	9.12	9.80	11.54	12.46	12.89	13.18	13.53	13.94	14.37
TRADE	9.52	11.33	12.32	13.78	15.81	16.46	16.25	16.70	17.27	17.65
FINANCE AND SERVICES	7.84	8.02	9.77	10.88	11.71	11.72	11.75	11.87	12.06	12.28
INVENTORY CHANGE	8.70	-.90	15.80	10.75	9.39	8.51	6.38	7.53	7.56	8.09
EXPORTS OF GOODS AND SERVICES	72.42	80.91	86.02	95.84	105.38	110.26	115.19	120.34	125.57	131.02
MERCHANDISE	42.04	49.61	52.58	58.44	64.06	66.96	69.91	73.05	76.15	79.54
MARGINS AND SCRAP	6.23	7.26	7.67	8.47	9.25	9.65	10.05	10.49	10.92	11.38
TRAVEL	2.71	3.74	4.01	4.37	4.60	4.72	4.83	4.95	5.06	5.18
PASSENGER FARES, OTH TRANSPORT	4.32	4.07	4.32	4.58	5.08	5.20	5.19	5.22	5.37	6.22
OTHER PRIVATE SERVICES	2.16	1.37	1.42	1.52	1.61	1.66	1.71	1.76	1.82	1.87
INVESTMENT INCOME	13.13	13.79	14.87	17.13	19.42	20.58	21.74	22.91	24.09	25.27
GOVERNMENT	2.38	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
IMPORTS OF GOODS AND SERVICES	-78.43	-75.34	-81.12	-87.18	-94.22	-97.38	-100.58	-104.28	-108.32	-112.44
MERCHANDISE	-55.68	-47.88	-52.22	-55.61	-59.78	-61.71	-63.58	-65.91	-68.70	-71.58
NON-COMPETITIVE MERCHANDISE	-3.35	-3.50	-3.79	-4.34	-4.34	-4.46	-4.59	-4.73	-4.87	-5.02
MARGINS AND SCRAP	6.50	5.50	6.01	6.42	6.92	7.15	7.37	7.65	7.99	8.33
TRAVEL	-4.66	-4.38	-4.60	-4.93	-5.47	-5.62	-5.76	-5.91	-6.05	-6.19
PASSENGER FARES, OTH TRANSPORT	-5.02	-4.84	-5.08	-5.46	-5.88	-6.09	-6.30	-6.54	-6.80	-7.06
OTHER PRIVATE SERVICES	-.79	-.46	-.49	-.51	-.54	-.55	-.57	-.58	-.60	-.62
INVESTMENT INCOME	-3.38	-4.85	-5.42	-6.59	-7.80	-8.82	-9.05	-9.69	-10.33	-10.99
GOVERNMENT	-8.21	-8.30	-8.32	-8.36	-8.40	-8.42	-8.44	-8.46	-8.48	-8.50
FOREIGN LONG-TERM CAPITAL TO U.S.	5.34	5.85	5.95	6.15	6.35	6.45	6.55	6.65	6.75	6.85
U.S. LONG-TERM CAPITAL ABROAD	-5.49	-7.00	-7.09	-7.13	-7.21	-7.26	-7.30	-7.34	-7.38	-7.43
U.S. GOVT. LONG-TERM CAPITAL FLOWS	-1.34	-1.34	-1.34	-1.34	-1.34	-1.34	-1.34	-1.34	-1.34	-1.34
GOVERNMENT PURCHASES	255.66	261.45	267.44	276.34	286.33	290.13	294.20	298.44	302.80	307.53
PUBLIC CONSTRUCTION	31.94	33.34	34.34	35.60	36.46	37.43	37.98	38.52	39.06	39.59
NATIONAL DEFENSE	72.69	64.73	64.93	65.34	65.74	65.87	66.00	66.13	66.26	66.39
NON-DEFENSE FEDERAL	27.11	25.21	30.00	31.57	33.15	34.35	35.55	36.76	37.96	39.17
STATE AND LOCAL	124.26	135.18	139.33	144.70	151.90	153.07	156.11	158.54	161.09	164.00
EDUCATION	57.68	61.87	63.62	66.28	67.03	67.17	67.85	68.12	68.43	69.90
PRODUCTIVITY (\$1000 PER EMPLOYEE)	13.73	13.89	14.29	14.49	14.81	14.93	15.07	15.24	15.41	15.57
PRIVATE SECTOR	14.97	14.78	15.64	15.78	16.24	16.38	16.56	16.78	16.97	17.20

TABLE 3-8. SAMPLE INFORUM OUTPUT. (CONT.).

I.N.F.O.R.U.M. SUMMARY OF NATIONAL ACCOUNTS AND FINAL DEMAND — DATE 102975 — PAGE 5

JUNE FORECAST - OIL QUOTA — GNP SUMMARY (BILLIONS OF 1972$)

	1972	1975	1976	1978	1980	1981	1982	1983	1984	1985
EMPLOYED PERSONS (MILLIONS)	84.14	85.75	88.28	93.11	96.15	97.36	98.16	99.11	100.11	101.10
PRIVATE INDUSTRY	68.63	69.56	71.80	76.22	78.73	79.78	80.42	81.18	81.99	82.74
CIVILIAN GOVERNMENT	13.65	13.94	14.24	14.67	15.22	15.38	15.56	15.76	15.97	16.21
DEFENSE	1.08	.90	.90	.90	.90	.90	.90	.90	.90	.90
MILITARY	2.40	2.25	2.24	2.22	2.20	2.19	2.19	2.17	2.16	2.15
AGGREGATE PRICE FORECASTS										
WHOLESALE PRICE INDEX (1967=100)	119.10	173.90	185.37	201.77	207.79	208.98	209.25	208.95	208.43	207.81
GROSS NATIONAL PRODUCT	146.20	199.39	219.05	240.63	249.06	252.02	252.60	252.65	252.41	252.00
PERSONAL CONSUMPTION EXPEND.	138.20	186.76	200.55	225.15	234.06	236.31	237.08	237.35	237.39	[illegible]
DURABLE GOODS	112.90	150.30	176.25	198.16	209.55	211.68	212.78	212.87	212.33	211.60
NONDURABLE GOODS	136.10	197.38	205.31	220.87	225.09	226.26	226.02	226.12	225.80	225.38
SERVICES	153.00	190.65	215.42	247.21	258.60	261.62	262.67	263.35	263.79	263.94
GROSS PRIVATE FIXED INVESTMENT	149.80	200.07	219.21	244.91	254.07	255.60	255.52	254.75	253.53	252.15
BUSINESS STRUCTURES	172.60	246.48	266.61	294.87	301.23	302.18	301.02	299.55	297.88	295.98
PRODUCERS DURABLE EQUIPMENT	126.50	174.96	192.79	218.29	229.35	231.22	231.71	231.27	230.22	229.05
RESIDENTIAL CONSTRUCTION	157.40	212.37	229.00	250.39	256.29	257.29	256.72	255.78	254.64	253.33
EXPORTS	138.00	193.53	209.91	229.19	237.07	238.39	238.59	238.19	237.43	236.52
GOVERNMENT	170.60	253.77	274.85	303.69	313.72	315.77	315.80	315.42	314.55	313.48
FEDERAL	171.90	234.59	257.26	284.39	294.40	296.24	296.21	295.67	294.71	293.56
STATE AND LOCAL	103.70	262.97	285.43	314.94	325.92	328.33	328.06	328.67	328.07	327.27
PUBLIC CONSTRUCTION	177.30	251.75	280.67	310.05	322.11	323.05	322.33	321.12	319.53	317.67
EXOGENOUS ASSUMPTIONS										
CONSUMPTION										
DISPOSABLE PER CAPITA INCOME $58	2779.00	2845.00	2915.00	3030.00	3105.00	3210.00	3251.00	3285.00	3315.00	3345.00
POPULATION - SERIES E (MILLIONS)	209.30	213.90	216.00	220.00	224.16	225.90	228.00	231.10	233.98	235.78
SCHOOL AGE POPULATION	59.60	58.32	57.97	56.32	54.62	54.01	53.61	53.35	53.27	53.46
PLANT AND EQUIPMENT INVESTMENT										
LONG-TERM INTEREST RATE	.04	.03	.09	.25	.05	.05	.05	.05	.05	.05
SHORT-TERM INTEREST RATE	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
RENT/CONSTRUCTION COST INDEX	.76	.60	.69	.69	.69	.69	.69	.69	.69	.69
HOUSEHOLDS (MILLIONS)	66.67	72.00	71.55	74.99	77.30	78.60	80.06	81.99	82.83	84.21
INVESTMENT TAX CREDIT	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07
FOREIGN TRADE										
AVERAGE FOREIGN CURRENCY PRICE	1.00	1.00	1.10	1.12	1.11	1.11	1.10	1.10	1.10	1.09
EMPLOYMENT										
LABOR FORCE (MILLIONS)	88.99	93.77	95.39	98.59	101.01	102.99	104.17	105.38	106.53	107.71
CIVILIAN UNEMPLOYMENT RATE	5.60	8.77	7.62	5.30	5.68	5.60	5.49	6.05	6.15	6.26

NUMBERS HAVE BEEN SCALED TO 1972 PUBLISHED LEVELS AND MAY NOT ADD TO TOTALS

(2) Reports on the following quantities for user-defined aggregations of the individual industries with options as listed (abbreviations defined under <u>Outputs</u> in Section 3.3).

a) PCE, IMP, SHP — actual; deflated

b) PDE, STR — actual; deflated; discounted; deflated and discounted; cumulative for any of the above

c) EMP

(3) User-defined aggregations of the individual industries for a numerical difference from a user-defined reference case for the tables and options listed above.

(4) User-defined aggregations of the individual industries for a percent difference from a user-defined reference case. for the reports listed in (2), actual values only.

Figure 3-4 illustrates the flow, data requirements, and output of INFRM as previously described. The CNVRT program shown in this figure simply converts the UNIVAC print file produced by INFORUM to an IBM compatible file for use with INFRM.

Table 3-9 presents a sample of INFRM tabular output. INFRM also produces graphical output, samples of which are shown in Figures 3-5 through 3-7.

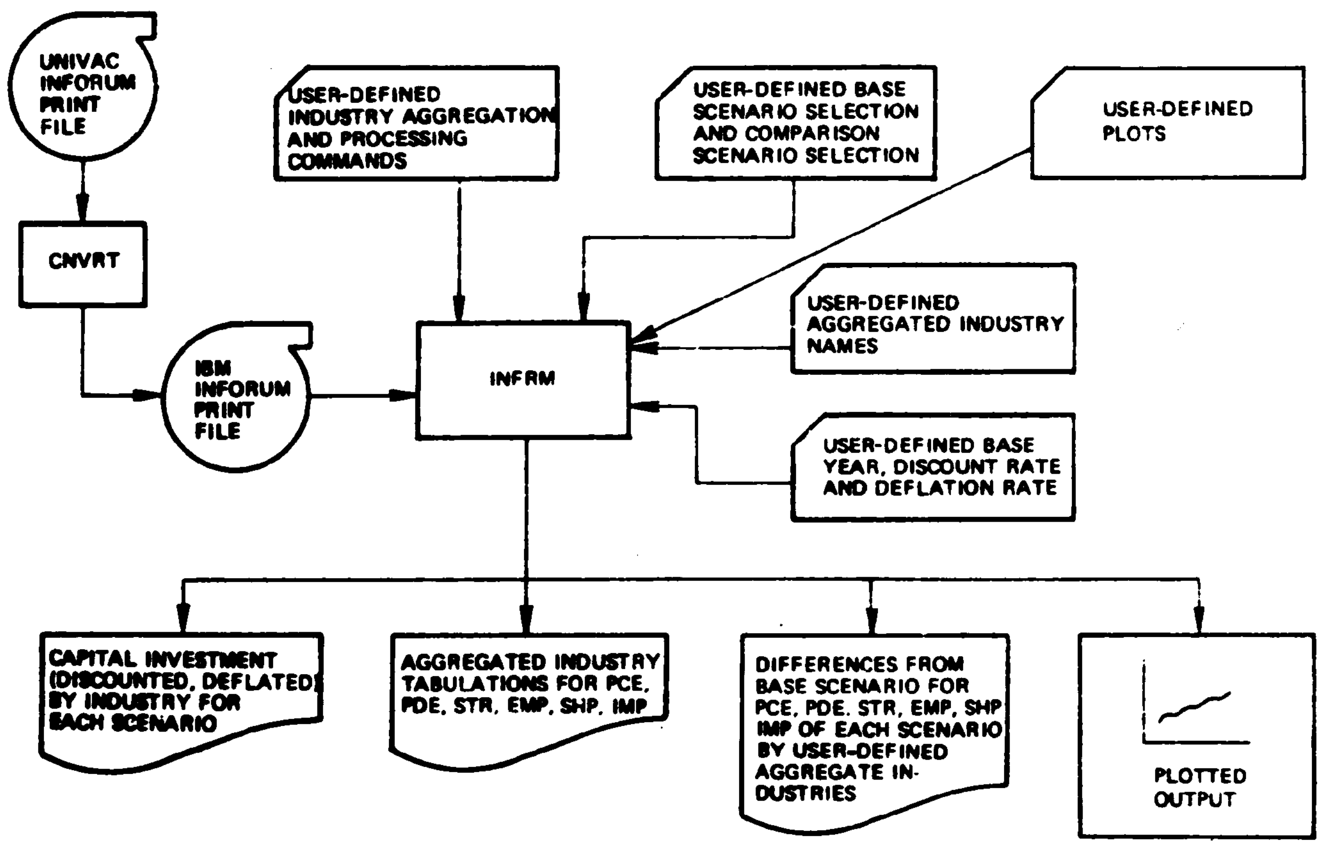


FIGURE 3-4. FLOW OF INFORUM POSTPROCESSOR (INFRM).

TABLE 3-9. SAMPLE INFRM OUTPUT.

DURABLE EQUIPMENT INVESTMENT BY PRODUCER [illegible]
(MILLIONS OF 1974 DOLLARS--DISCOUNTED TO 1975)

	1972	1975	1976	197-	19[illegible]	1981	1982	1983	1984	1985
2 MINING	0	2311	2365	2346	2338	2323	2175	2094	2067	2011
3 PETROLEUM AND GAS	0	1275	1191	1263	1279	1163	1086	1067	1014	975
4 CONSTRUCTION(NEW AND OL	0	3953	3651	4346	4449	4164	3655	3391	3313	313[illegible]
21 HSHLD TEXTILES & UPHOLS	0	135	137	124	134	137	121	119	114	113
27 PAPERBOARD. EX.CONTAINE	0	1729	1673	1709	1650	1624	1491	1467	1414	1347
31 INDUSTRIAL CHEMICALS	0	2357	2097	2135	2196	2042	1925	1879	1835	17[illegible]
34 PLASTICS AND SYNTHETICS	0	1167	1059	1270	1124	111[illegible]	1075	1024	903	9[illegible]
37 PAINTS & ALLIED PRODUCT	0	77	73	72	72	74	63	[illegible]	[illegible]	[illegible]
38 PETROLEUM REFINING	0	784	737	656	632	634	615	542	547	55[illegible]
39 TIRES AND TUBES	0	344	349	381	372	325	306	300	289	27[illegible]
40 RUBBER PROD. EX. TIRES	0	167	164	165	161	145	126	119	114	11[illegible]
41 PLASTIC PRODUCTS	0	459	524	627	598	572	549	532	521	51[illegible]
44 GLASS AND GLASS PRODUCT	0	362	331	384	336	326	316	303	294	290
45 STONE AND CLAY PRODUCTS	0	971	887	1019	959	923	753	69[illegible]	635	6[illegible]
46 IRON AND STEEL	0	2366	2459	2753	2592	2255	1993	1933	1864	1747
47 NON-FERROUS METALS	0	1175	990	111[illegible]	1067	993	871	768	746	757
51 STAMPINGS	0	483	420	[illegible]	405	373	381	319	290	24[illegible]
52 HARDWARE,PLATING,WIRE P	0	424	496	532	527	464	425	310	306	341
53 ENGINE AND TURBINES	0	203	179	232	223	224	212	200	197	195
55 CONST,MINE,MATRL HANDL	0	266	276	337	352	363	295	279	27[illegible]	2[illegible]
56 METALWORKING MACHINERY	0	311	295	361	292	272	260	235	24[illegible]	2[illegible]1
57 SPECIAL INDUSTRIAL MACH	0	154	185	176	151	143	133	122	12[illegible]	115
58 GENERAL INDUSTRIAL MACH	0	302	295	344	334	301	279	255	254	24[illegible]
59 MISC. MACHINERY AND SHO	0	151	132	132	119	114	109	10[illegible]	99	94
61 SERVICE INDUSTRY MACH.	0	149	137	145	149	153	135	132	13[illegible]	125
65 ELEC. LIGHTING & WIRING	0	139	144	149	163	147	129	126	12[illegible]	11[illegible]
69 BATTERIES,X-RAY EQ.,ETC	0	112	99	129	111	103	97	9[illegible]	95	[illegible]
73 MOTOR VEHICLES	0	1534	1561	1762	1653	1593	1532	1466	1387	13[illegible]
90 RAILROADS	0	2257	2415	2491	2192	2082	1970	1881	1825	174[illegible]
91 TRUCKING	0	931	977	1025	965	935	902	877	850	83[illegible]
92 OTHER TRANSPORT	0	629	397	802	662	620	592	529	470	444
94 WHOLESALE & RETAIL TRAD	0	139[illegible]	13545	13475	1376[illegible]	13514	125[illegible]	[illegible]	[illegible]	[illegible]
95 COMMUNICATION	0	11364	12391	12855	12395	12157	11764	11457	[illegible]	[illegible]
96 FINANCE AND SERVICES	0	9381	10737	10642	10191	9624	91[illegible]	8678	[illegible]	[illegible]
97 ELECTRIC UTILITIES	0	9616	9643	10115	9835	957[illegible]	9229	[illegible]	[illegible]	[illegible]
98 NAT. GAS, WATER AND SE	0	1213	1095	1177	1039	1012	942	[illegible]	[illegible]	[illegible]
0 ALL OTHER	0	25473	26035	26399	24293	237[illegible]	223[illegible]	[illegible]	[illegible]	[illegible]
0 TOTAL	0	97536	106683	104119	[illegible]	961[illegible]	90[illegible]	[illegible]	84787	[illegible]

NOTE:

1972 TO 1974 DOLLAR CONVERSION FACTOR OF 1.165 APPLIED TO ABOVE DATA
ANNUAL CONTINUOUS DISCOUNT RATE OF .1600 APPLIED TO ABOVE DATA FOLLOWING YEAR 1975

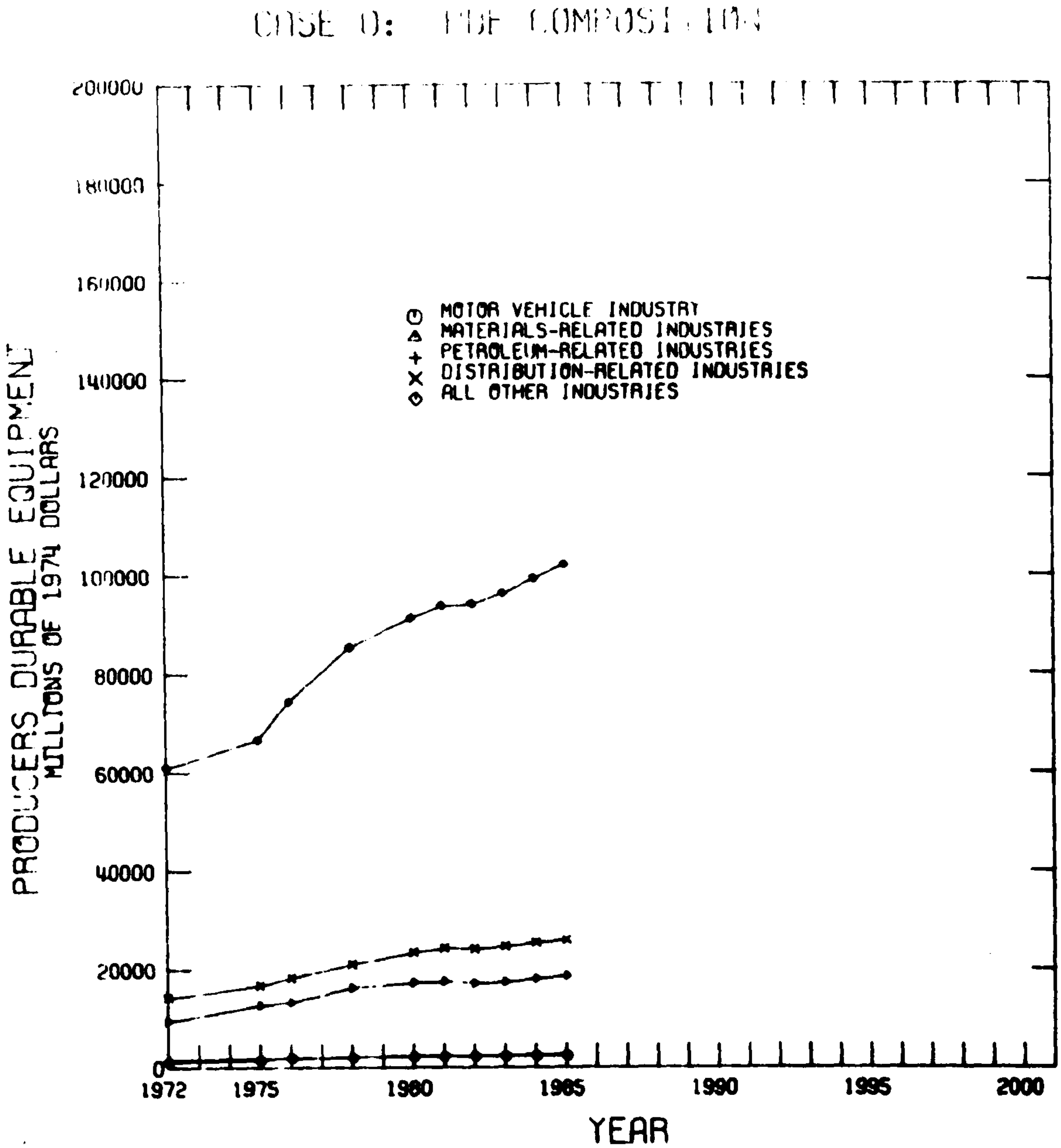


FIGURE 3-5. PDE COMPOSITION BY INDUSTRY (SAMPLE INFRM PLOT).

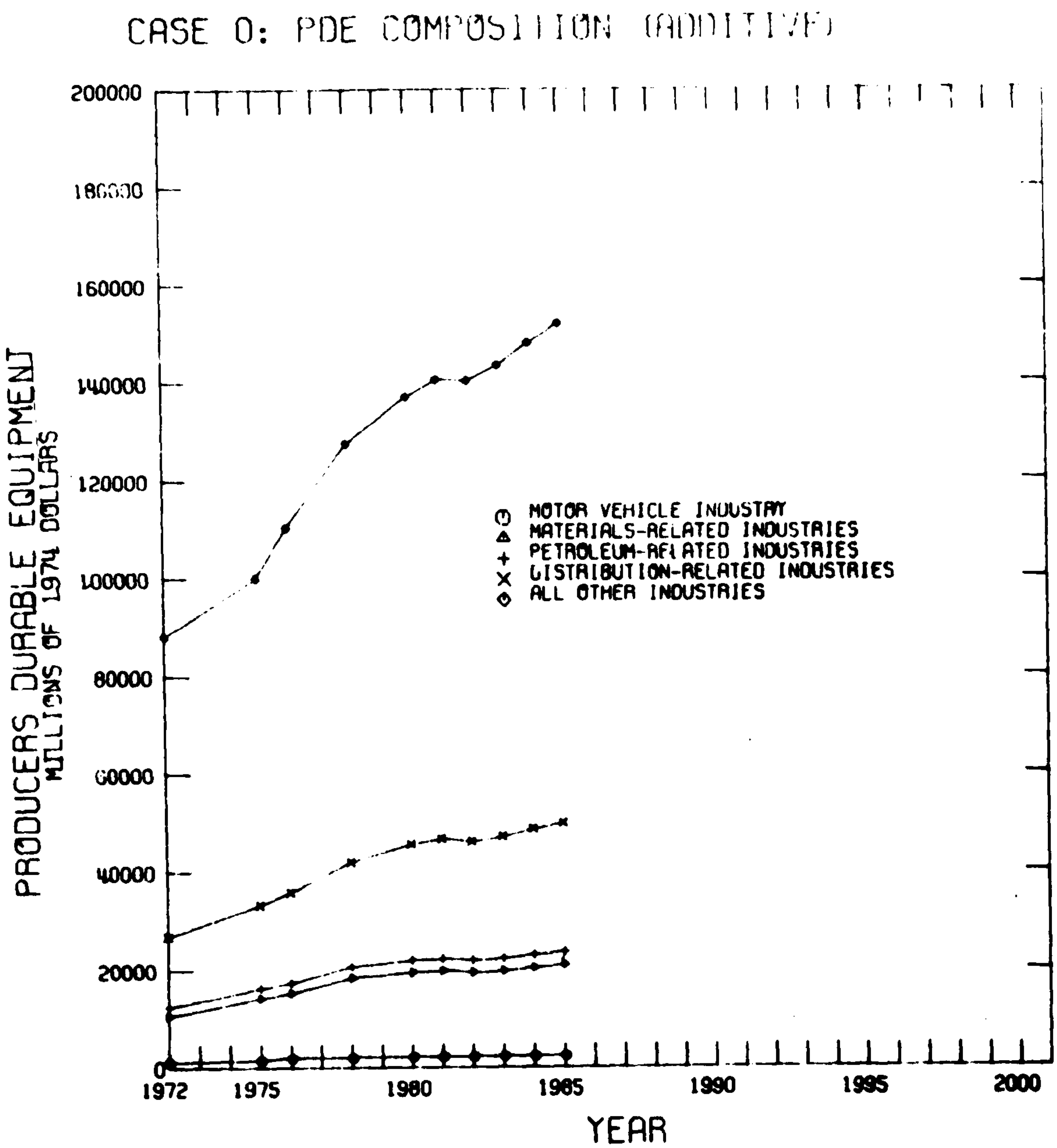


FIGURE 3-6. PDE COMPOSITION BY INDUSTRY (ADDITIVE) (SAMPLE INFRM PLOT).

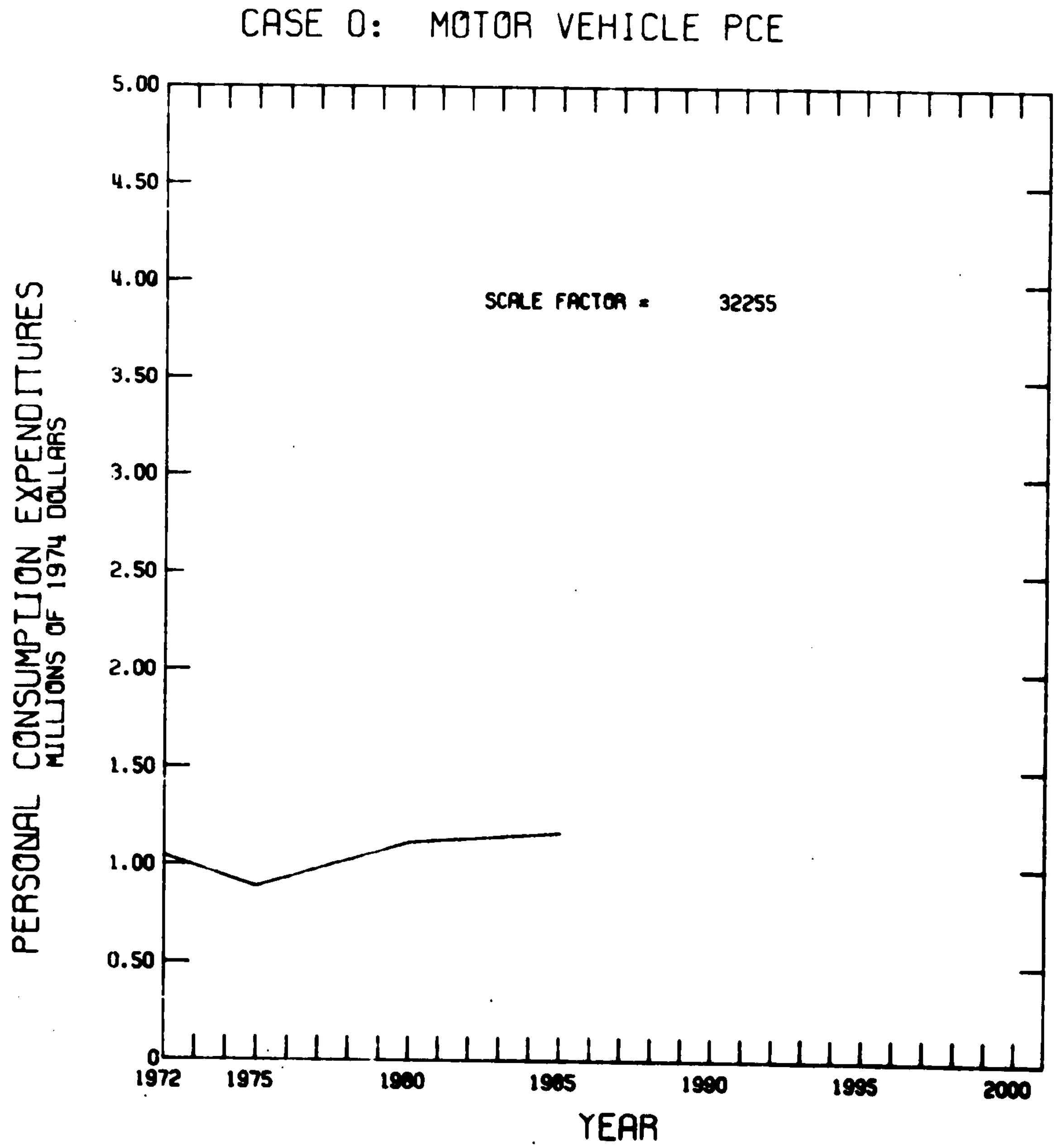


FIGURE 3-7. MOTOR VEHICLE PERSONAL CONSUMPTION EXPENDITURES (SCALED) (SAMPLE INFRM PLOT).

4. SUMMARY AND RECOMMENDATIONS

A Resource Accounting Model has been developed as described in Sections 3 and 4 of this document. The following discussion summarizes the current status of the model and presents recommendations for further improvements and suggestions for its use.

4.1 SUMMARY

As indicated in the preceding sections of this report:

(1) The methodology adopted has allowed tabular and graphical display of resource requirements or impacts (materials, energy, capital, and labor) associated with advanced automobile scenarios.

(2) The materials resource sources (domestic sources versus imports; primary versus secondary) can be traced for future years using ARAM and the effects of various assumptions can be displayed.

(3) The energy impacts (materials processing, fabrication, fleet operation) can also be tracked and evaluated for future years using ARAM.

(4) The capital, labor, and other industrial impacts throughout the economy can be traced using INRAM, and the direct and indirect effects associated with changes in motor vehicle technology can be displayed and understood.

Experience with using the model for evaluating Task Force scenarios suggests further that:

(5) The methodology adopted can be used in a qualitative sense to determine potential bottleneck or problem situations for which a more detailed analysis is desirable.

(6) The Resource Accounting Model is easy to use and economical to run.

Item (5) bridges into the area of impact evaluation, and thus goes beyond the scope of the work undertaken in the present effort. Nevertheless, the point is an important one and deserves further comment.

Using the Resource Accounting Model, it was possible to verify that the anticipated impacts were in some cases small or insignificant, or well within current growth capabilities. In other cases, the growth in the use of a key material during a period of years could be identified as a possible problem, and a detailed cost study undertaken. A similar screening to identify possible problem areas was carried out for capital and labor impacts.

Thus, the Resource Accounting Model can be used to identify or isolate problem areas. This is an advantage in that impact evaluation (in a cost-benefit sense) in the resource area is difficult, controversial, and laced with various value judgments. The Model provides a basis for evaluation where necessary, but also helps by indicating where such evaluation is not necessary.

Item (6) is significant in that ease of use and run-time efficiency enable the analyst to study a greater number of scenarios with differing assumptions in order to explore a broad range of alternative futures. Further data on usage characteristics and run-time efficiency are found in Volume 2.

4.2 RECOMMENDATIONS

The following specific recommendations are offered for improving or extending the Resource Accounting Model.

(1) Improvements are recommended in the handling of the automotive aftermarket

Input materials data are particularly critical here, as only minor modifications are needed for data entry into the model. The model already contains provisions for data storage, printout, and plotting.

(2) Extensions are recommended for the hardling of energy system alternatives.

These extensions would be primarily in the input-output area and would consist of adding a syncrude sector to the model and improving certain of the energy sector coefficients. Capital investment for energy system alternatives should be reviewed for consistency with other studies of the energy sector.

(3) The input-output forecasting model should be extended to 2000.

This would enable capital and labor impacts to be assessed over the entire target time frame.

(4) The development of quantitative tools for impact evaluation is recommended to assist in scenario comparison and selection.

Although difficult, there is plainly a need to incorporate the resource accounting process into a framework for assessing costs and benefits. The frame work should enable an explicit valuation of resource conservation, import impacts, strategic considerations, resource costs, and the like. This is particularly important when resource issues are found to be critical in the scenario evaluation process, and when large numbers of scenarios are to be reviewed

APPENDIX A

MATERIALS COMPOSITION AND FABRICATION ENERGY PROGRAM

As a prerequisite for tracking the materials and energy required to produce the autos described in a Task Force scenario, it is necessary to transform the technical description of a vehicle family into domestic auto production requirements for materials and fabrication energy on a per-vehicle basis. This is currently accomplished using the materials composition and fabrication energy program (MATCOM), which operates on the DECSYSTEM-10 at TSC. MATCOM generates a report for each vehicle family and class and also punches data on cards in the proper input format for PIEAM, thus entering it into the resource accounting process. MATCOM is not considered part of the Resource Accounting Model at present, and hence is described only briefly in this appendix.

MATCOM currently calculates per-vehicle materials requirements (except for platinum and palladium) based on a given curb weight and a set of percentages. Different sets of percentages are used to apply to each of the vehicle-structure and engine combinations. A previously used computational procedure for calculating materials changes for increased levels of crashworthiness is no longer part of the program. Per-vehicle materials data for platinum and palladium (expressed in troy ounces) are input directly instead of being calculated as a percent of curb weight. Platinum and palladium are used as part of the catalytic converter in some vehicle designs.

Example materials data inputs to MATCOM are shown in Tables A-1 and A-2. Table A-1 shows percentage data for a list of 24 materials as used in vehicle scenarios analyzed for an early version of the Task Force report. Table A-2 shows example assumptions used for platinum and palladium for various catalyst technologies.

TABLE A-1. MATERIALS COMPOSITION PERCENTAGE SETS.

Material	Basic and Weight Conscious	Innovative with Catalyst	Innovative without Catalyst	Stirling
1. Cast Iron	12.16	10.51	10.54	5.45
2. Malleable & Nodular	3.56	3.61	3.62	3.60
3. Plain Carbon Steel	56.07	54.71	54.92	57.84
4. Stainless Steel	0.45	0.69	0.46	2.13
5. Alloy Steel	2.60	2.60	2.60	2.60
6. Rolled Aluminum	0.00	1.11	1.11	0.99
7. Cast Aluminum	2.40	4.04	4.05	4.36
8. Zinc	0.79	0.80	0.80	0.81
9. Copper	0.74	0.30	0.30	0.33
10. Lead	0.67	0.68	0.68	0.68
11. Body Solder	0.16	0.16	0.16	0.15
12. Platinum	0.00	0.00	0.00	0.00
13. Palladium	0.00	0.00	0.00	0.00
14. Glass	2.30	2.32	2.33	2.33
15. Rubber for Tires	3.24	2.58	2.59	3.23
16. Rubber not for Tires	2.52	2.07	2.07	2.60
17. Plastics	2.79	4.15	4.16	2.84
18. Soft Trim	2.18	2.21	2.21	2.20
19. Sound Deadeners	1.73	1.75	1.75	1.75
20. Paint	0.66	0.67	0.67	0.66
21. Fluids and Lubricants	4.91	4.97	4.98	4.97
22. Ceramics	0.07	0.07	0.00	0.48
23. Urethane Foam	0.00	0.00	0.00	0.00
24. Explosive	0.00	0.00	0.00	0.00

TABLE A-2. PLATINUM AND PALLADIUM ASSUMPTIONS.

Catalyst Technology	Amount per Vehicle (Troy oz)	
	Platinum	Palladium
Oxidation catalyst	0.056	0.024
3-way catalyst	0.112	0.048

MATCOM also calculates fabrication energy by type based on the curb weight of the vehicle. Each energy component is assumed proportional to vehicle curb weight, as indicated in Table A-3. The constants of proportionality are based on data obtained from the Chrysler Corporation,* and may not be representative of other manufacturers. Total fabrication energy is obtained by expressing the electrical component in Btu of input heat energy (40-percent conversion efficiency is assumed) and adding it to the other Btu components. Although each of the fabrication energy components is punched out on cards for use in resource accounting, only the total fabrication energy is shown in the program's printed output.

TABLE A-3. FABRICATION ENERGY COMPONENT EQUATIONS.

Component	Unit	Equation
Electricity	kW-h	EPC = 0.3293*TW
Coal	Btu	BPC1 = 1125*TW
Natural gas	Btu	BPC2 = 2893*TW
Petroleum	Btu	BPC3 = 347*TW
Other	Btu	BPC4 = 1396*TW
Total fabrication energy	Btu	TE = EPC*3413/0.40 + 5761*TW

Note: TW = vehicle curb weigh. in pounds

A typical MATCOM output table is shown in Table A-4. In this table, the word "type" refers to the computational method used to calculate the material weights. At present, the calculation procedure is to use straight percentages only (except for platinum and palladium), and this is referred to as a type 1 procedure. Type 1 is the only procedure currently available. The sum of the input percentages is printed at the top of the table after the word "sigma".

---

* Chrysler Corporation, "Energy in the Automobile", presentation by D.K. Samples at an Energy Seminar at the University of Michigan, 1974.

TABLE A-4. MATCOM OUTPUT.

FAMILY: A   CLASS: SMALL   FUEL: GAS
TYPE: 1   CURB WT:2500.LBS.   SIGMA$100.00
FABRICATION ENERGY: 22916901.BTU PER VEHICLE
STRAIGHT PERCENTAGES ONLY

MATERIAL	WT(LBS.)	% OF CURB WT	DELTA WT (LBS VS. TYPE 1)
CAST IRON	304.000	12.16	0.000
MALLEABLE & NODULAR	89.000	3.56	0.000
PLAIN CARBON STEEL	1401.750	56.07	0.000
STAINLESS STEEL	11.250	0.45	0.000
ALLOY STEEL	65.000	2.60	0.000
ROLLED ALUMINUM	0.000	0.00	0.000
CAST ALUMINUM	60.000	2.40	0.000
ZINC	19.750	0.79	0.000
COPPER	18.500	0.74	0.000
LEAD	16.750	0.67	0.000
BODY SOLDER	4.000	0.16	0.000
PLATINUM	0.000*	0.00	0.000
PALLADIUM	0.000*	0.00	0.000
GLASS	57.500	2.30	0.000
RUBBER FOR TIRES	81.000	3.24	0.000
RUBBER NOT TIRES	63.000	2.52	0.000
PLASTICS	69.750	2.79	0.000
SOFT TRIM	54.500	2.18	0.000
SOUND DEADENERS	43.250	1.73	0.000
PAINT	16.500	0.66	0.000
FLUIDS & LUB.	122.750	4.91	0.000
CERAMICS	1.750	0.07	0.000
URETHANE FOAM	0.000	0.00	0.000
EXPLOSIVE	0.000	0.00	0.000

(* WEIGHTS ARE IN TROY OUNCES RATHER THAN LBS)

APPENDIX B

REPORT OF INVENTIONS

After a diligent review of the work performed under this contract, no innovation, discovery, improvement, or invention was made. There are, however, several advances in this type of analysis. These developments are of interest and should be noted.

The phased introduction of new vehicles into the existing automobile fleet provides a more realistic impact assessment than a single calculation assuming total fleet implementation.

The time-phased capital and labor impacts are generated within industry sectors comprising an Input-Output model. This methodology, with some understanding of the assumptions in the model, can furnish the flexibility further to disaggregate or alter the pattern of assumed economic impacts.

The material and energy requirements are also disaggregated according to the sources of the raw materials and fuels, separating domestic from imported, and allowing changes to be investigated in the level of recycling.

115Copies