UNITED STATES POLYVINYL CHLORIDE

INDUSTRY IMPACT ANALYSIS

A Report to

The Vinyl Chloride and Polyvinyl Chloride Producers Committee

The Society of The Plastics Industry

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Arthur D Little Inc

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I. SUMMARY

The recent discovery of a relatively high concentration of angiosarcoma among workers in a few polyvinyl chloride (PVC) resin plants has led the Occupational Safety and Health Administration (OSHA) to issue emergency exposure standards. More recently, OSHA has proposed to replace the emergency temporary standard of 50 parts per million (ppm) with a permanent acceptable tolerance level which requires that vinyl chloride monomer (VCM) be "non detectable" in regulated (i.e., work) areas.

The companies in the PVC resin industry have stated that they would be unable to meet the newly proposed "non detectable" tolerance standard and its enforcement would force the shutdown of all PVC resin plants in the U.S. Such a shutdown would have a significant adverse impact on production and employment levels and would not be restricted solely to the VCM and PVC industries, but would permeate throughout many sectors of the U.S. economy.

In an attempt to identify the extent and quantify the magnitude of the potential impact of such a shutdown, The Society of The Plastics Industry (SPI) commissioned Arthur D. Little, Inc. (ADL) to undertake an analysis to identify and estimate the loss in employment and domestic production that would be generated by such an event. It was not the purpose of this study to assess whether the proposed permanent "non detectable" standard of OSHA would indeed force an immediate shutdown of all PVC resin plants. At no point in this study did ADL assess the probability of such a shutdown.

Summarizing the conclusions of this report, we find that an immediate shutdown of all PVC resin plants in the U.S. and the subsequent unavailability of PVC resin could result in a loss of 1.7-2.2 million jobs in consuming and related industries and a loss of domestic production value of $65-90 billion annually. Because of the known widespread use of PVC

resins in the U.S., many sectors of the economy would be affected, with the greatest impact occuring in the building and construction and automotive areas. The extent to which materials could be substituted for PVC resin in the immediate term (less than one year) is quite limited and, therefore, would have an insignificant effect upon reducing the potential job and domestic production losses noted above. In addition, the worldwide tightness in supplies of PVC resin precludes the possibility of reducing the above impacts through increased imports of this material.

II. INTRODUCTION

The recent discovery of a relatively high concentration of angiosarcoma, a rare form of liver cancer, among workers in a few polyvinyl chloride (PVC) resin plants has led the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor to issue emergency exposure standards. In its emergency pronouncement, OSHA set a safety tolerance standard of 50 parts per million (ppm) for the vinyl chloride monomer (VCM) content in the atmosphere of the plant work areas. For many of the PVC industry's participants, such a tolerance standard was close to the norm already being experienced and enforced in their plants. This lower level of VCM exposure is well below the initial maximum of 500 ppm set by OSHA when it promulgated its original safety standards for the plastics industry.

More recently, OSHA has proposed to replace the emergency temporary standard of 50 ppm with a permanent acceptable tolerance level which requires that VCM be "non detectable" in regulated (i.e. work) areas. The OSHA proposal as announced would require that the VCM tolerance standard be lowered to 0-1 ppm by October 1974. This standard is in agreement with a recommendation already put forth by the National Institute of Occupational Safety and Health (NIOSH).

The companies in the PVC resin industry have stated that they would be unable to meet the newly proposed "non detectable" tolerance standard announced by OSHA. The industry has concluded that adoption of the proposed permanent standard as currently written would force the shutdown of all PVC resin plants in the U.S. Such a shutdown would have a significant impact on industry and commercial activities, resulting in substantial losses of production and jobs. These losses would not be restricted solely to the VCM and PVC industries but would permeate throughout many sectors of the U.S. economy dependent upon the myriad of products based upon PVC resins.

In an attempt to identify the extent and quantify the magnitude of the potential impact of such a shutdown on the U.S. economy, The Society of The Plastics Industry (SPI) commissioned Arthur D. Little, Inc. (ADL) to undertake an analysis to identify and estimate the loss in employment and domestic production that would be generated by such an event.

III. INDUSTRY IMPACT ANALYSIS

A. Overview of Methodology

The purpose and scope of our task was to identify and estimate the potential economic impact resulting from a complete and immediate shutdown of all PVC resin plants in the U.S.* The impact has been expressed in terms of the potential effect on current domestic production and employment in the U.S. economy. Because of the known widespread use of PVC resins in numerous applications in the U.S. today, the potential for lost production and employment would permeate beyond just the PVC resin, VCM, and their immediate customer markets. Because of the high degree of interdependence among sectors of the economy and lack of adequate substitute materials, production cutbacks in PVC-related markets would lead to further output reductions in a whole host of materials and service supplying industries.

In undertaking our analysis, we focused upon measuring the magnitude of the economic impact resulting from an immediate shutdown of all PVC resin plants in the U.S. With this as our basic focus, our approach included the following:

1. Identification of PVC resin usage by product and end-use application: to best identify the use of PVC resin in the U.S. economy, we defined five end-use applications modules which include:

    a. Building and Construction
    b. Motor Vehicles
    c. Home Furnishings, Household Goods and Apparel
    d. Specialty Products
    e. Miscellaneous Products

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* It was not the purpose of this study to assess whether the proposed permanent "non detectable" standard of OSHA would indeed force an immediate shutdown of all PVC resin plants. At no point in this study did ADL assess the probability of such a shutdown.

Construction of these modules allowed us to identify in a clear and complete fashion the flow and use of PVC resin in the U.S. today. Figures A-1 through A-5 included in Appendix A identify the product and end-use applications of each module.

2. Estimation of resulting economic impact from shutdown of all PVC resin plants: in order to estimate the potential production and job loss from such an event requires an analytical framework that is a balanced, internally consistent and current model of the U.S. economy which identifies the PVC resin industry and defines its relationship to other intermediate and end-use markets. Input/Output econometric models have this capability and ADL uses this type of model in its economic forecasting and regional impact analysis work. The estimates presented in this report are based upon the current relationships that exist within the ADL Input/Output Model. Originally based upon the Input/Output table developed by the U.S. Department of Commerce, Office of Business Economics for 1963, the model has since been revised, expanded, and updated by ADL staff members.

3. Assessment of the extent of PVC resin dependency in each module: in order to accurately estimate the potential impact resulting from an immediate shutdown of PVC resin plants, it was necessary to make explicit assessments of the extent of PVC resin dependency in each end-use application. This estimation was largely necessitated by our use of published Federal Government data which is classified according to Standard Industrial Classification (SIC) definitions.* Since the data available on the intermediate and end-use markets of each module included both vinyl and non-vinyl related products, estimates were made of the proportion that is dependent upon PVC resin. Our analysis at this stage

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* Standard Industrial Classification Manual, Executive Office of the President, Office of Management and Budget, 1967.

indicated that the dependency upon PVC resin varies significantly among the end-use applications. For example, dependency is extremely high in such end-use applications as phonograph records, communications and building wiring, and medical products. On the other hand, PVC resin is not a primary material in paint manufacture.

4. Assessment of the potential for immediate substitution of other raw materials for PVC resin: the resulting economic impact based upon the analysis undertaken in Steps 1-3 had to be reassessed to incorporate the potential for immediate substituion of other raw materials for PVC resin. In an effort to develop our best estimates of this potential, we gathered a team of ADL staff members with considerable experience in the areas of plastics and related markets and the product sectors which a priori offer themselves as possible substitution candidates. We supplemented our own experience with field interviews of selected fabricators and purchasers of PVC-based products.

   In summary, the ADL team concluded that because of the unique nature of PVC resin, it would not be possible to duplicate the exact properties of vinyl plastic products by using substitute raw materials. Even if it were possible, the costs of production and the resulting selling prices of the final products would probably be prohibitive in many cases. Furthermore, it would still take up to an additional three to four years to complete all of the necessary research and development leading to the required changes in product, process, and equipment design, and the actual delivery and installation of new equipment in order to make non-vinyl equivalent products available on a commercial scale necessary to satisfy the demands of industry.

The findings of our analyses undertaken in Steps 3 and 4 above are discussed at greater length in Chapter IV. The following sections of this chapter present a brief overview of the PVC resin industry, background information on I/O models, and a review of the economic impact results.

B. The PVC Resin Industry

1. Introduction

Vinyl-type plastics are among the oldest of the major plastic materials. The first commercial plant to make PVC resin, the basic material for vinyl plastic products, was constructed in 1939. Over time, the vinyl plastics industry was developed largely by the major rubber and chemical companies. The initial vinyl plastics were rather similar to rubber products in that they were very flexible or "rubbery" in nature. Because of this, companies that processed or fabricated rubber compounds into such forms as sheets and tubes (or hose) could use their existing equipment (e.g., calenders and extruders) to process vinyl as well as rubber compounds. Today, about two-thirds of vinyl plastic products are still rubbery (or elastomeric) in nature, but now PVC is also made into rigid end products such as pipe, siding and phonograph records. There are currently 21 separate producers of PVC resin operating 36 plants in the U.S.

PVC resin is a powdery material which is made from vinyl chloride monomer (VCM--a gas under standard conditions of temperature and pressure and a liquid when transported and stored under pressure). PVC resin, as such, cannot be processed but must be made into a vinyl compound which contains several other additives (such as plasticizer, stabilizer, and colorant) in addition to the basic resin, in order to fabricate it into useful product forms. Because they can be compounded to yield a wide range of materials with specific properties, PVC resins are used in more applications than any other type of plastic material.

2. Vinyl Chloride Monomer (VCM)

The VCM industry is made up of nine producers. Four companies (Shell, Dow, PPG, and Allied Chemical) produce VCM for merchant sale only and together they account for over half of the current total VCM capacity. The other five producers make VCM largely or completely for captive use in making PVC resin.

Last year the production of VCM was about 5.3 billion lbs valued at about $292 million (about 5.5¢/lb on average). This year VCM production will likely approximate 5.5 billion lbs but at about 9¢/lb; the 1974 VCM market value will be nearly $500 million. This production required roughly 2.8 billion lbs of ethylene and 3.7 billion lbs of chlorine as raw materials having a combined market value of about $300 million. Total industry capacity is now about 6.4 billion lbs of VCM which should only be sufficient to supply the U.S. demands for about two more years. This assumes that exports which were about 420 million lbs last year, or 8% of domestic production, are decreased substantially. At present, no new VCM capacity is under construction in the United States. Since it takes approximately 2 1/2-3 years to build and start up a VCM plant. decisions on new capacity expansions are needed in the very near future to allow for PVC resin growth beyond 1976. Last year about 88% of all VCM production was used domestically to make PVC resin; another 4% was used domestically for other applications and the remaining 8% was exported. (See Table I).

3. PVC Resin

The term PVC resin is used to describe a family of synthetic polymers in which the vinyl chloride monomer content is over 50% by weight. In practice, the VCM content is usually 85% or more. Resins which are made from VCM only are called homopolymers and those containing other monomers (such as vinyl acetate) are called copolymers. Homopolymers represent about 85% of total PVC resin output.

The total production of PVC resin last year was about 4.5 billion lbs valued at about $650 million (14.5¢/lb). This year production will likely be about 4.6 billion lbs valued at $920 million (20¢/lb, on average). About one-quarter of the total world production of PVC resin is made in the United States. The industry rated capacity of the 21 existing PVC resin producers is now about 5 billion lbs/yr. However, at least one-third of the existing resin producers are expanding their capacity and at least two new producers are entering the market. By the end of 1975 the total PVC resin capacity will

TABLE I

PRODUCTION, PRICE, VALUE, PRODUCERS AND USES OF VINYL CHLORIDE MONOMER

Production, Price, and Market Value

Year	Production (billion lbs)	Average Price (¢/lb)	Market Value ($ million)
1962	1.3	7.5	98
1967	2.4	5.3	127
1972	5.2	4.2	218
1973	5.3	5.5	292
1974	5.5	9.0	495

Producers and Capacity

Producer	Annual Rated Capacity (million lbs) (at August, 1974)
Shell	1,500
Dow	1,200
Goodrich	1,000
PPG	800
Continental Oil	625
Ethyl	420
Monochem (Borden and Uniroyal)	350
Allied Chemical	300
American Chemical (Stauffer and Atlantic Richfield)	170
Total	6,365

End-Use Pattern - 1973

Use	Approximate Percent of Market
PVC Resin	88
Export and Other	12
Total	100

Sources: U.S. Tariff Commission and Arthur D. Little, Inc., estimates.

be about 6.4 billion lbs. This should be sufficient to serve the U.S. market through 1978 (see Table II).

PVC is the most versatile type of synthetic resin produced and is used in more individual end products than any other type of plastic material. It is possible to identify over 25 individual end use product areas for PVC, each of which accounts for between 1 and 29% of the total PVC resin market. By grouping these products into broad market categories it is possible to estimate that over half of all PVC resin is used to make products that are classified as building and construction materials. This includes pipe, conduit, flooring, wire and cable insulation, siding, panels, window frames, wall covering, trim, and gaskets and sealing materials. Home furnishings and household goods taken together represent about 12% of the overall PVC resin usage. This broad grouping of products includes furniture upholstery and decorative laminates (using PVC printed films) for furniture and TV cabinets, table covers and shower curtains, garden hose, appliance components (e.g., hoses and gasketing) and window shades. The end-use market called consumer goods, which also represents roughly 12% of PVC resin use contains items such as phonograph records, footwear (e.g., shoes, boots), toys, dolls and games, apparel and other outerwear, sporting and athletic goods, luggage, handbags and many other products. Packaging materials, such as flexible and rigid film (used for packing fresh and processed meats, produce, cookies and candy as well as non-food products—e.g., blister packs), bottles, and can and closure lining (coating) materials account for about 8% of total PVC resin sales. The transportation equipment industry (mainly motor vehicles) in total represents about 6% of the PVC resin market. The major products include upholstery materials, trim, headliners, wire and cable insulation, floor mats, and external (e.g., landau-type) tops.

The remaining 9% of the domestic PVC resin market is composed of a miscellaneous products category containing hundreds of individual applications. Among the most significant are: medical products (e.g., tubing, blood bags), stationery supplies, book covers and bindings, conveyor belting, credit cards, tools and hardware (e.g., handles), agricultural products (e.g., reservoir liners), and novelties. Table III presents an end-use breakdown of the PVC resin market in 1973.

TABLE II

PRODUCTION, PRICE, VALUE AND PRODUCERS OF POLYVINYL CHLORIDE RESIN

Production, Price, and Market Value

Year	Production (billion lbs)	Average Price (¢/lb)	Market Value ($ million)
1962	1.2	17.6	212
1967	2.1	15.6	327
1972	4.3	13.6	585
1973	4.5	14.5	650
1974	4.6	20.0	920

Producers and Capacity

Producer	Annual Capacity (million lbs) by December, 1975
Goodrich	950
Borden	545
Tenneco	480
Robintech	470
Continental Oil	430
Firestone Tire & Rubber	400
Diamond Shamrock	360
Union Carbide	350
Goodyear	300
Georgia Pacific	220
Others (Air Products, American Chemical, Certain-teed, Ethyl, General Tire, Olin, Pantasote, Shintech, Occidental Petroleum, Stauffer Chemical, Uniroyal, Keysor)	1,895
Total	6,400

Source: U.S. Tariff Commission and Arthur D. Little, Inc., estimates.

TABLE III

END USE BREAKDOWN OF PVC RESIN - 1973

End Use and Product	% of Market (Approximate)	Million Lbs
Building and Construction		
Pipe, conduit and fittings	29	1,345
Flooring	9	440
Wire and Cable Insulation[a]	8	365
Siding, panels	2	90
Wall covering	2	90
Other (window frames, trim, gasketing, sealants, miscellaneous)	2	90
Sub Totals	52	2,420
Home Furnishing and Household Goods		
Furniture (mainly upholstery)	7	320
Shower curtains, table covers, etc.	2	105
Appliance parts (including hoses, gaskets)	1	40
Garden hose	1	35
Other (e.g., window shades)	1	45
Sub Totals	12	545
Consumer Goods		
Phonograph Records	3	145
Footwear (shoes, rainwear)	3	140
Toys, dolls, and games	2	75
Outerwear (e.g., apparel)	2	70
Sporting and Athletic Goods (e.g., balls, bicycle grips, miscellaneous)	1	65
Other (including handbags, wallets, luggage)	1	55
Sub Totals	12	550
Transportation Equipment (mainly motor vehicles)		
Upholstery and Seat Covers	4	180
Wire and Cable Insulation	1	50
Auto Tops, headliners, trim, floor mats, other	1	45
Sub Totals	6	275

TABLE III (Cont'd.)

END USE BREAKDOWN OF PVC RESIN - 1973

End Use and Product	% of Market (Approximate)	Million Lbs
Packaging		
Flexible film (for fresh meats and produce)	3	135
Rigid Sheet (for cookies and candy, unit packs, blister packs)	2	105
Coatings (e.g., can linings, cap liners, gaskets)	1	50
Bottles, other	2	85
Sub Totals	8	375
All Other Uses		
Medical Products (e.g., tubing, blood bags)	1	45
Stationery Supplies	1	35
Agricultural Products (e.g., reservoir liners, tubing)	1	30
Novelties (including advertisement items)	1	30
Conveyor Belting	1	30
Miscellaneous (tools and hardware, credit cards, book binders and covers, other)	4	265
Sub Totals	9	435
Grand Totals	99	4,600 [b]

(a) Includes some wire and cable used in communications equipment.
(b) Domestic use only; excludes exports of about 145 million lbs.

Source: The Society of the Plastics Industry and Arthur D. Little, Inc., estimates.

As a result of this myriad of product and end-use applications, for the purposes of our impact analysis, we have segmented PVC resin usage, and grouped the end-use applications into five distinct modules. The modules and PVC end-use products included in each are given below.

(i) Building and Construction Module: pipe, conduit, floor covering, paint, insulated wire and cable, siding, panels, wall covering and other products (e.g., window frames, trim, gasketing);

(ii) Motor Vehicles Module: upholstery, insulated wire, seat covers, floor mats, dashboards, auto tops (e.g., landau types), and other "soft" component parts such as visors, head lining, and door panel covering, sealants and gaskets;

(iii) Home Furnishings, Household Goods and Apparel Module: upholstery for chairs and sofas, shower curtains, table covers, appliance parts, waterproof outerwear, window shades;

(iv) Specialty Products Module: phonograph records, telephone and telegraph equipment, and lighting and wiring equipment; and

(v) Miscellaneous Products Module: luggage, handbags, toys, sporting and athletic goods, footwear, garden hose, packaging materials, credit cards, medical products (tubing and other), stationery supplies, novelties, conveyor belting, tools and hardware and other.

Each of these modules is presented schematically in Appendix Figures A1 - A5.

There are literally thousands of business firms which fabricate PVC compound (which they make or buy as such) into semifinished and finished products. Such companies, which include nearly all of the PVC resin manufacturers, range in overall size from very large to very small businesses. Many others purchase such semifinished PVC based products and convert them (via cutting, sewing, heat sealing, etc.) into proprietary end products for sale as such to the final consumer. Table IV presents a representative list of major fabricators of PVC resin and compound and the main PVC-based products made by the companies.

TABLE IV

REPRESENTATIVE MAJOR FABRICATORS OF PVC

Company	Main PVC-Based Product(s) Made
Abbott Labs	Medical products (e.g., tubing, blood bags)
Andersen	Window frames
Armstrong Cork	Flooring
American Biltrite Rubber	Flooring, floor mats
Amerace-Esna	Hose, industrial parts
American Can	Can linings
Anaconda	Wire and cable
Avon Sole	Soles and heels
Borden[a][b]	Packaging film, upholstery, wall covering
Bata Shoe	Shoes, other footwear
Belden Manufacturing	Wire and cable
Bemis	Film and coated fabrics
Bird & Son	Siding
Congoleum Nairn (Bath Industries)	Flooring
Columbia Broadcasting System	Phonograph records
Capitol Records	Phonograph records
Certain-teed Products[a]	Pipe, siding
Chemical Products	Plastisols (custom formulated)
Chrysler	Auto upholstery, trim, sealants and gaskets
Clopay	Packaging film, window shades and wall partitions
Continental Can	Can linings
Crane Plastics	Trim, profiles
Dart Industries	Coated fabric, pipe, hose, industrial parts
Dayco	Hose, industrial parts, film
Diamond Shamrock[a]	Film and Coated Fabrics
Dennis Chemical	Plastisols
Essex International	Wire and cable
Evans Products	Trim, decorative laminates

TABLE IV (Cont'd.)

REPRESENTATIVE MAJOR FABRICATORS OF PVC

Company	Main PVC-Based Product(s) Made
Ethyl[(a)(b)]	Pipe, bottles
Fields Plastics	Film and sheet
Firestone Tire & Rubber[(a)]	Film, coated fabrics, hose, industrial parts
Flintkote	Flooring
Ford Motor	Upholstery, trim, sealants
GAF	Flooring, siding
General Cable	Wire and cable
General Electric	Wire and cable
General Mills	Toys, dolls and games
General Motors	Wire and cable
General Tire[(a)]	Film, coated fabrics, hose, industrial parts, sporting and athletic goods
Genesco	Footwear
Genova	Hose, industrial products
Georgia Duck	Conveyor belting
Georgia-Pacific[(a)]	Pipe, decorative laminates
B. F. Goodrich[(a)(b)]	Film, coated fabrics, hose, industrial parts, sporting and athletic goods, and plastisols
Goodyear Tire & Rubber[(a)]	Film, coated fabrics, hose, industrial parts, sporting and athletic goods, flooring, and packaging film
W. R. Grace	Film and coated fabrics, closure linings
Haartz-Mason	Coated fabrics (industrial)
Hooker Chemical (Div. Occidental Petroleum) (a)	Coated fabrics
Hoover	Hose and other appliance parts
Ideal Toy	Dolls, other toys
Indian Head	Pipe
Inmont	Coated fabrics
Johns-Manville	Flooring, siding, trim

TABLE IV (Cont'd.)

REPRESENTATIVE MAJOR FABRICATORS OF PVC

Company	Main PVC-Based Product(s) Made
Johnson & Johnson	Tapes, medical supplies (e.g., tape-based)
Johnson Plastic	Hose, industrial products
Kentile	Flooring
Keysor[a]	Phonograph records
Lilly, Eli	Bottles, other packaging products
Mattel	Toys (e.g., dolls)
Minnesota Mining	Tapes
New England Plastic	Profiles
Norton	Tubing (medical, other)
Olin[a]	Pipe
O'Sullivan Rubber	Footwear products (soles and heels), film, coated fabric
Owens-Illinois	Bottles, closure linings
Pantasote[a]	Film and coated fabrics, gasketing
Phelps-Dodge	Wire and cable
Plymouth Rubber	Film and coated fabrics, floor mat
Prevue Products	Footwear (e.g., waterproof)
R & G Sloane Manufacturing	Pipe and fittings
Radio Corp. of America	Phonograph records
Reichhold Chemicals	Custom compounds
Reynolds Metals	Packaging film
Robintech[a]	Pipe, siding
Rubbermaid	Household and automotive products
Rubatex	Hose, industrial parts
A. Schulman	Custom compound
Stauffer Chemical[a][b]	Upholstery, wall covering
Tenneco[a]	Film and sheet
Union Carbide[a]	Film and sheet
Uniroyal[a][b]	Upholstery, wall covering, film

TABLE IV (Cont'd.)

REPRESENTATIVE MAJOR FABRICATORS OF PVC

Company	Main PVC-Based Product(s) Made
Weymouth Art Leather	Coated Fabrics
Western Electric (American Tel. & Tel.)	Wire and cable

(a) Producer of PVC resin

(b) Producer of VCM

Source: Company and trade literature and Arthur D. Little, Inc.

C. Background on Input/Output Models

Input/Output is founded on the simple proposition that what goes into the production process must also come out and eventually finds its way to final consumers or demanders. Thus, one can define an industry's purchases (including materials, services, labor, capital and construction costs, as well as indirect costs such as taxes and profits) as equal to the sales of that industry. In other words, input is equal to output. The I/O accounting scheme is a systematic organization of each industry's purchases from, and sales to, every other industry, plus its sales to the domestic consumer, government, foreign consumer, and the investment and construction markets. Every sale by the selling industry is a purchase from the point of view of the purchasing industry. So each output from one industry can be viewed as a purchase by another. Business transactions among industries are organized in the analytical framework into a square "interindustry" or "flow" matrix, in which sales of each industry are shown along a horizontal row and purchases by each industry are found by reading down a column.

I/O analysis permits the systematic investigation of the interrelationships of producing and consuming industries to final markets and primary inputs; thus, it is particularly useful for analyzing problems of those industries which primarily sell their output to other industries, and it permits the tracing of direct and indirect effects on total demand of changes in final goods markets.

For example, the Input/Output technique allows one to estimate the total impact upon various sectors of the economy of an increase in the demand for passenger cars. This increase in demand will lead to a direct increase in production of the automobile industry. However, there will be further impacts. The automobile industry will demand more upholstery fabrics and the increased production of these fabrics will require more synthetic fibers and more plastics. The use of Input/Output techniques allows one to quantify the magnitudes of the increased production in all affected industries.

In like fashion, the Input/Output methodology can be used to identify the impact of a reduction in the output levels of particular raw materials on the level of production in related final end-use markets. As in the case of PVC resin, the unavailability of this material will lead, for example, to production cutbacks in the automotive industry resulting from a lack of PVC-related products such as electrical wire, upholstery, and assorted component parts. However, cutbacks in automotive production permeate throughout the economy, generating lower demands for materials such as glass, steel, aluminum, rubber, etc. Lower demands in these industries would feedback into reduced outputs of iron ore, bauxite, petrochemicals, energy, etc. Thus, the total resulting economic impact would be far greater than the value of production and number of jobs lost in the automotive industry itself.

The circular flow and general equilibrium concepts of input/output analysis and its emphasis of interindustry relations can be traced back to Francois Quesnay's Tableau Economique. The first empirical application of the input/output model in the modern world dates from 1936 when Professor Wassily Leontief at Harvard University published an input/output system of the U.S. economy. Most recently, Dr. Leontief received the Nobel Prize in Economics, primarily for his work and contributions in the area of input/output analysis.

Even prior to the recognition of Leontief's work by the Nobel committee, a growing number of public and private organizations world-wide had already been using input/output tables and this conceptual technique in economic analysis, planning, and policy applications. In the U.S., the Department of Commerce has published benchmark input/output tables of the U.S. economy for 1947, 1954, 1958, 1963, and 1967; work is now underway on preparing a 1972 table. Recently, the Department of Commerce has announced that it will prepare input/output tables on an annual basis. This decision was based largely upon the growing use of input/output tables by other government agencies and also by private corporations. In the public sector, agencies such as the Bureau of Economic Analysis, Bureau of Labor Statistics, Council of Economic Advisors, and Federal Energy Agency are using input/output tables and techniques in undertaking various analytical planning and policy efforts. The identification of input/output as a powerful tool in economic analysis and development planning and policy making has also greatly influenced many state and regional authorities. Today, more than 20 states and/or regions in the U.S. have constructed input/output models of their economies and work is currently on-going in several others. Internationally, the construction of input/output tables and their applications has increased rapidly. I/O tables now exist for most Western European nations and many African and Far Eastern countries.

In the private sector, domestic and foreign corporations have discovered the strengths of the input/output concept and with the availability of published Government tables and/or tables constructed internally by their staffs, corporations have applied input/output techniques in a whole host of efforts, including:

- economic impact analysis
- short- and long-term economic forecasting
- regional economic development and planning
- marketing and sales analysis
- diversification and acquisition studies

For the reader unfamiliar with input/output, there are several excellent texts which present a discussion of the concept, its mathematical foundation, and its possible areas of applications. Included among these are:

Almon, C., The American Economy to 1975. (New York: Harper and Row, 1966).

Chenery, H., and Clark, P., Interindustry Economics. (New York: John Wiley & Sons, Inc., 1959).

Doofman, R., Samuelson, P., and Solow, R., Linear Programming and Economic Analysis. (New York: McGraw-Hill, 1958).

Miernyk, W., The Elements of Input-Output Analysis. (New York: Random House, 1965).

Richardson, H., Input-Output and Regional Economics. (New York: John Wiley & Sons, 1972).

Yan, C., Introduction to Input-Output Economics. (New York: Holt, Rinehart and Winston, 1969).

During its ten year association with input/output analysis, ADL has applied the technique in many of the above areas. In such efforts, we have combined the expertise of our in-house economists and industry specialists with that of recognized authorities on input/output to many universities. Indeed, Dr. Leontief has (and continues to) served as a consultant to ADL in many of our study efforts applying input/output techniques.

Much effort at ADL over the years has been expended in incorporating up-to-date interindustry relationships into the model in order that it more accurately identify the linkages which exist between sectors of the economy. Use of I/O tables that have not been kept current and thus do not reflect present market relationships would yield misleading estimates of the potential economic impact of a particular event.

A schematic representation of the complete ADL Input/Output model is presented in Figure 1. In the past several years, the model has been applied to several study efforts including:

- an assessment of the regional economic impact generated by the development of deep-water terminals and outer continental shelf drilling operations in the U.S.;

- an assessment of the economic impact resulting from a curtailment in petrochemical supply availability in the U.S.;

- an assessment of the economic impact of alternative federal government fiscal policy strategies; and

- an evaluation of the economic impact of alternative energy conservation programs.

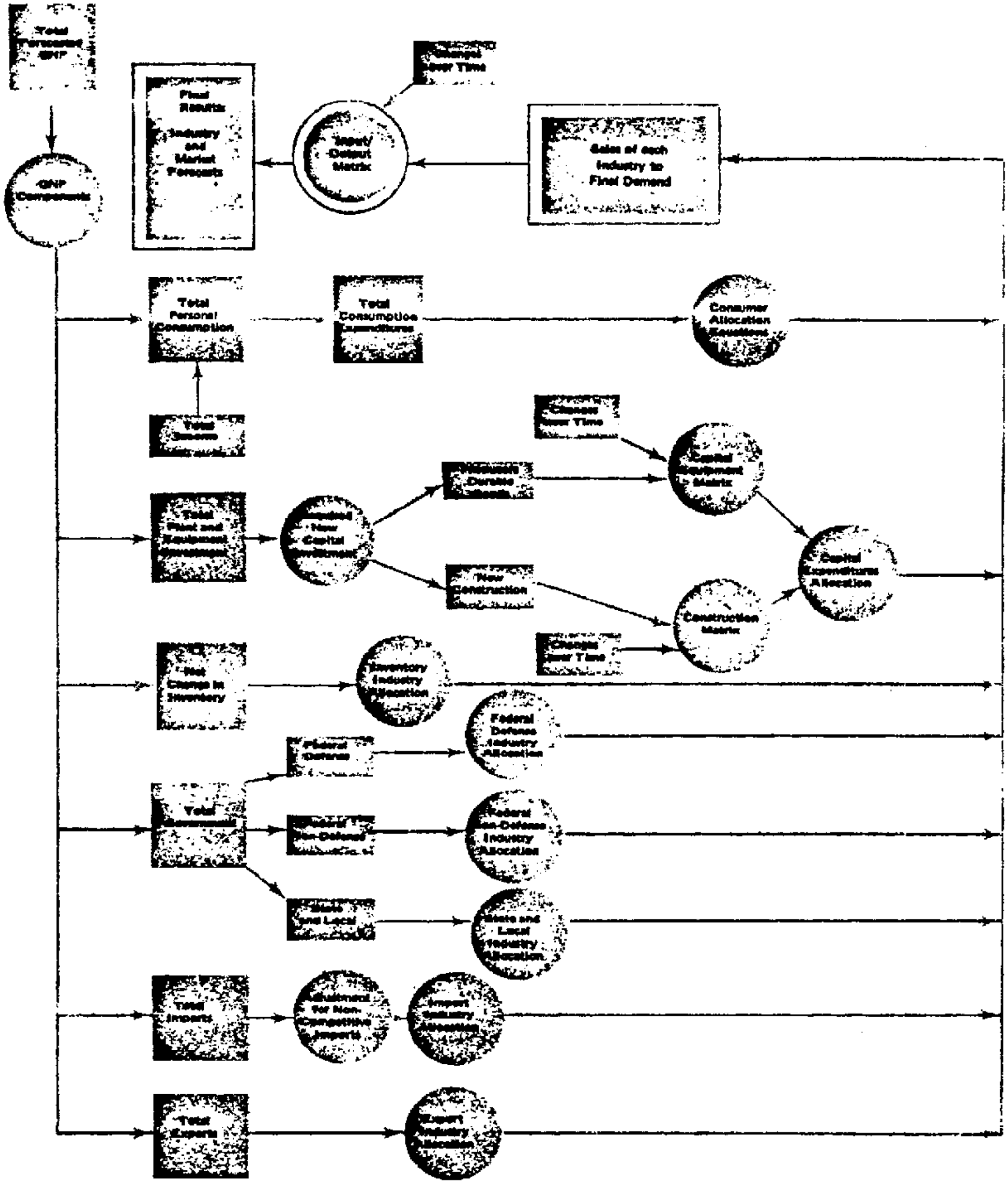

FIGURE 1 FLOW CHART OF ADL MODEL AND COMPONENTS

D. Study Results

The results of our basic impact analysis are summarized in Table V. Using the information on end-use applications of PVC resin collected as part of this effort, the ADL model was then run for each of the five modules to derive estimates of the resulting economic impact should PVC resin become unavailable.

In brief and in the jargon of input/output economics, the model is run given a new vector of final demands which reflect the unavailability of PVC resin in the end-use markets identified in each module. The matrix-vector multiplication which then follows yields estimates of the resulting impact upon all other sectors of the economy in terms of lost production and employment. Thus, the ADL model (and other current input/output models) can be used to trace through the effects of a lack of PVC resin in the automotive sector and estimate the impact not only upon auto-supplying industries such as steel, aluminum, rubber, glass, etc., but also upon those industries which supply necessary inputs for the production of these auto-related materials.

Tables A-1 through A-5 present a detailed breakdown of the economic impact for each module. Estimates are given for both the direct impact (e.g. automotive sector) and the indirect impact (e.g. all other sectors such as steel, glass, rubber, etc.). As the tables indicate, the magnitude of the economic impact is a function of:

- the size of the end-use industry;
- the extent of PVC dependency;
- the relationship between the end-use market and all other supplying industries. This relationship is an important product of an input-output table.

TABLE V

SUMMARY OF

ECONOMIC IMPACT OF IMMEDIATE
SHUTDOWN OF PVC RESIN OPERATIONS

Industry	Loss in Production (Billion $)	Loss in Employment (MM)
Vinyl Chloride Monomer	0.2	*
PVC Resin	0.6	**
Construction-Related	17.1-34.2	0.6-1.1
Home Furnishings, Household Goods and Apparel-Related	1.4--2.7	0.1
Motor Vehicle-Related	25.3-50.6	0.4-0.9
Specialty Products[1]	10.7-13.9	0.3-0.4
Miscellaneous Products[2]	3.6--5.7	0.1-0.2
TOTAL	$58.9-107.9	1.5-2.7
Inflationary Adjustment	+3.2-5.8	--
Calculated Range	$61-113	1.5-2.7
Most Probable Range[3]	$65-90	1.7-2.2

1. Includes products such as phonograph records, telephone and telegraph equipment, and lighting equipment.
2. Includes products such as luggage, toys, games, sporting goods, bottles, packaging film, credit cards, and medical tubing. Also includes chemical additives (e.g. plasticizer, stabilizers) used to make PVC-based compound and ethylene and chlorine used to make VCM.
3. The most probable range includes adjustments due to rounding, data estimating, and double counting.

* About 1,400 employees.
** About 5,000 employees.

Source: Arthur D. Little, Inc., estimates.

For example, in the automotive module, the input/output model estimates that for every dollar of production in the automotive sector, an additional $1.20 of production is required in all other sectors of the economy. It is not difficult to identify this $1.20 of other production as the demands placed upon producers of steel, aluminum, rubber, iron ore, coal, etc.

Every effort has been made in this analysis to present our best estimates of the potential impact and minimize any upward bias which could result from:

- double-counting - we have eliminated any double-counting which could result from two industry sectors supplying the same final market. For example, the automotive sector can be identified as an end-use market in both the automotive and apparel and home furnishings modules. In this case, the impact upon the sector was determined in the automotive module and not included in the apparel and home furnishings module calculation.

- overestimation of PVC dependency - our estimates of PVC dependency in each module is based upon our knowledge of the industry as defined in SIC terms and the extent of PVC resin usage in the particular industry. In several cases, because of a lack of information or because of the conventions adopted in the SIC codes, the extent of PVC dependency in a particular market was difficult to estimate. In all such cases, a "best estimate" was made with an intentional bias toward the conservative side. Note, for example, the relatively low level of PVC dependency assumed in the building and construction module.

- underestimation of PVC substitution possibilities - as the following chapter will reveal, much effort was expended in assessing the likely use of substitute materials for PVC resins. In analyzing each PVC resin application, we assessed the possibility of using substitutes realizing that present PVC resin users would strive to continue their operations by adopting alternative materials and processes.

As Table V indicates, the magnitude of the potential impact is quite significant, whether measured in terms of lost production or employment. The detailed data which underlies Table V is presented in Appendix A, Tables A-1 to A-5. The adjustment for inflation (Table V) has been included since the basic data used in our analysis has been taken from the 1972 Census of Manufactures. Therefore, in order to update the value of production data to reflect 1973 price levels, an upward adjustment was made based upon the average annual rate of increase in prices since 1972.

On balance, our analysis indicates that the resulting economic impact to the U.S. economy from an immediate shutdown of all PVC resin plants would equal approximately $65-90 billion of lost domestic production, and a reduction in employment of about 1.7-2.2 million. Because of the magnitude of economic activity and extent of PVC-related products usage in the building and construction and automotive sectors, these two segments of our economy would receive the greatest share of the total impact. Unavailability of PVC resin will have production bottleneck effects in these areas in terms of insulated wire and cable, flooring, upholstery, and many other materials.

E. Regional Impacts

In undertaking our analysis, we focused upon estimating the economic impact to the total U.S. nationally. However, as our effort proceeded, it became evident that the resultant economic impact could have a disproportionate effect upon several regions of the country which already have been suffering from depressed economic growth conditions and above-average unemployment rates. Recognizing this, we attempted to identify a small sample of those regions likely to be impacted severely by the shutdown of all PVC resin plants.

This brief analysis proceeded by estimating the percentage of a region's labor force presently employed in PVC-related industries and comparing this percentage with the current rate of unemployment in the area.* The number of employees in PVC-related industries was derived from data in County Business Patterns, 1972. However, in many cases, such information was withheld to avoid disclosure of certain operations and thus, the percentages derived in this brief analysis are in many cases conservative estimates. In addition, the percentages represent a minimum since we have not included employment in those industries indirectly linked to PVC-related markets. Nonetheless, based upon this limited analysis, several local areas were discovered as being likely to receive a severe economic impact. Table VI identifies several such areas and compares their present rates of unemployment with the percentage of PVC-related employment in their labor force.

*PVC-related industries are those identified in each of the modules presented in Appendix Figures A1-A5.

TABLE VI
IMPACT ON SELECTED REGIONS

Area	April 1974 Unemployment Rate	Department of Labor Designation*	Labor Force in PVC-Related Industries
	(%)		(%)
Massachusetts			
Worcester SMSA**	6.4	Substantial	5
New Bedford SMSA	8.9	Persistent	5
California			
Los Angeles SMSA	7.2	Substantial	6
Michigan			
Detroit	9.3	Substantial	20
Grand Rapids	9.1	Substantial	8

* Areas of Substantial Unemployment

A labor area in which the current and anticipated local labor supply substantially exceeds labor requirements is classified as an area of "substantial unemployment." An area is placed in this category when:

(1) Unemployment in the area is equal to 6 percent or more of its work force, discounting seasonal or temporary factors, and

(2) It is anticipated that the rate of unemployment during the next 2 months will remain at 6 percent or more, discounting temporary or seasonal factors.

Areas of Persistent Unemployment

A labor area, or a city of 250,000 or more population, or a county, may be classified as an area of "persistent unemployment" when unemployment during the most recent calendar year has averaged 6 percent or more of the work force, and the rate of unemployment has:

(1) Averaged 6 percent or more and has been at least 50 percent above the national average for 3 of the preceding 4 calendar years, or

(2) Averaged 6 percent or more and has been at least 75 percent above the national average for 2 of the preceding 3 calendar years, or

(3) Averaged 6 percent or more and has been at least 100 percent above the national average for 1 of the preceding 2 calendar years.

** SMSA - Standard Metropolitan Statistical Area.

Even this brief analysis does indicate that an immediate shutdown of all PVC resin plants in the U.S. would generate an economic hardship of large magnitude that would create severe economic dislocations in many local areas.

IV. PVC RESIN DEPENDENCY AND RAW MATERIAL SUBSTITUTION

A. PVC Resin Dependency

By PVC resin dependency we mean: to what extent is an industry or final product market sector dependent today on PVC resin as a raw material? For example, in the case of the phonograph records industry (SIC 3652), the PVC dependency is very high since nearly all phonograph records are based on PVC resin. On the other hand, in the case of the entire finished paint industry (SIC 2851), the PVC resin dependency is very low since the relative amount of PVC resin used is very small in comparison with the total amount of synthetic resin used by that industry.

The question of dependency depends upon the definition of the particular industry sector being considered. For example, the relative PVC resin dependency of all pipe production is quite small since most pipe is made out of metal, concrete and other non-plastic materials. However, if the industry being evaluated is the plastic pipe industry, then the PVC dependency is high since PVC represents about 70% of the total weight of resin used to make plastic pipe.

PVC resin dependency varies widely in the industries and market sectors that are contained in our five modules. In Table VII we have listed the PVC resin dependency for the major industries and end uses of significance to this study. If PVC resin is the major raw material used in a given industry or product sector, the dependency rating (as expressed as an approximate percent of the total resin based raw materials used) is high. Conversely it is given a low dependency rating if PVC is not a primary raw material in that particular industry. It should be noted, however, that even though the PVC resin dependency may be low, as in the motor vehicles industry (since PVC resin represents only about 0.5% of the weight of a typical automobile), if products made from PVC are absolutely necessary in the manufacturing process of that industry, the unavailability of those PVC products could result in a major shutdown of that industry. This would be the case with the original equipment manufacture of motor vehicles, with the

TABLE VII

PVC RESIN DEPENDENCY IN SELECTED INDUSTRIES

Module and Industry	SIC Number	PVC Resin Dependency (%)
Building and Construction		
All pipe, conduit and fittings	--	small
Plastic pipe, conduit and fittings	Part of 3079	70
Flooring (hard surface only)	Part of 3079	90
Wire and cable insulation	Part of 3357	40
All siding	--	small
Wall covering	2644	40
Paint	2851	small
Motor Vehicles		
Upholstery material, trim, external tops, head liner, door covering	--	90
Wire and cable insulation	Part of 3357	50
Sealants and gaskets	--	25
Household Products and Apparel		
Furniture upholstery	--	10
Table covers, shower curtains, place mats	--	75
Garden hose	Part of 3079	50
Outerwear, other apparel	--	small
Raincoats, other waterproof outerwear	2385	10
Curtains and draperies	2391	5
Household tapes	--	50
Baby pants	--	90
Carpet backing (foamed underlay)	--	25
Window shades	--	90
Specialty Products		
Phonograph records	3652	90
Communication wire and cable	Part of 3661	75
Electric lighting & wiring equipment	364	small
Metal cans (e.g., for all beverages)	3411	small
Glass containers (e.g., for baby foods)	3221	small
Conveyor belting	--	25

TABLE VII (Continued)

Module and Industry	SIC Number	PVC Resin Dependency
Miscellaneous Products		
Luggage	3161	50
Handbags and purses	3171	75
Toys and dolls and games	3941, 3942	10
Plastic bottles	Part of 3079	10
Flexible packaging material (film)	Part of 3079	10
Credit cards	--	75
Medical tubing, blood bags	--	90

Source: Arthur D. Little, Inc., estimates.

construction of houses and other buildings (e.g., caused by a lack of PVC insulated building and communication wire and flooring materials) and in the packaging and storage of beer and soft drinks in cans (all have PVC-based linings) and other food products, such as baby foods, in glass jars (all have vinyl gaskets inside the covers).

B. <u>Substitution of Other Raw Materials for PVC Resin</u>

Essentially all major classes of products now made from PVC resin were made on a commercial scale from other raw materials prior to the introduction of PVC resin in the U.S. in 1939. It would seem, therefore, that it should be possible to use substitute raw materials in place of PVC resin. However, because of the <u>unique nature of PVC resin</u> which, when combined with many other raw materials, permits the formulation of hundreds of different compounds with wide ranges of properties (from very soft to very hard materials), and colors, it would not be possible, in fact, to duplicate the exact properties of vinyl plastic products by using substitute raw materials. Even if it were possible from a physical property and decorative point of view to make an "equivalent or acceptable" product derived from non-PVC resin-based materials, the costs of production and the resulting selling prices of the final products would in essentially all instances be greater than those products made from PVC. Such costs and prices would probably be prohibitive in many cases and in effect price the substitute final product "out of the market."

Assuming, however, that (a) the substitute raw materials--some of which are now made in small quantities relative to PVC and in very short supply (including a very low level of inventory) and are likely to remain in "tight" supply for at least 2-3 years (such as other plastics, rubbers, metals, paper, textile products, and glass)--will be available in sufficient quantity when needed, and (b) the physical capacity to produce the additional non-vinyl chloride based end products is also in-place and operating when required (which is most unlikely), it would still take up to an additional three years to complete all of the necessary research and development leading to the required changes in product, process, and equipment design and the actual delivery and installation of new equipment in order to make such non-vinyl equivalent products on a commercial scale necessary to satisfy the demands of industry. This latter stage of the manufacturing process (after the product and process design changes have been made) could in itself take up to two years for many of these "new" products. Based solely on technological factors, those substitute products which would take the longest lead time to develop are those that are critical products particularly for the construction industry and motor vehicle industries. Such products include: insulated communication, building and automotive wire and cable, pipe, flooring, and automotive upholstery and related soft trim materials.

A discussion of the PVC substitution issues according to several of the major PVC product lines is presented below.

1. Pipe, Conduit and Fittings

This is by far the largest single PVC market accounting for about 29% of current total PVC resin consumption in this country. Over two-thirds of all plastic pipe and fittings is based on PVC with ABS and polyethylene plastic each representing about 15%. Most of the other 5% is accounted for by rubber-modified styrene type resins. Roughly 65% of all PVC pipe is used in pressure applications such as for use in chemical processing plants. In these applications PVC is used for its chemical and corrosion resistance, its non-flammable properties, its rigidity and ease of installation as well as its relatively low price. Polyethylene is also used in some of these pressure pipe markets (e.g., gas distribution) but does not compete directly with PVC in most applications. ABS resin is not used in these particular pipe markets mainly because of its higher price and lack of chemical and flame resistance. ABS, however, is a major competitive plastic for PVC in DWV (drain, waste and vent) pipe for home construction and also competes with PVC in electrical and communication conduit and sewer pipe. It is possible that ABS plastic, in particular, could be substituted in 20-25% of the PVC pipe market; however, this would increase the total ABS resin market by roughly one-third and the resin would not be available in this quantity for this market for at least 2-3 years. Conceivably some of the PVC pipe markets could be satisfied from a property point of view by metal pipe. However, the metal pipe industry is itself operating at capacity and likewise could not supply the replaced PVC pipe market in less than two years.

2. Upholstery Material (coated fabrics)

(a) Automotive

Most motor vehicles today use vinyl-coated fabrics as the primary upholstery material; the backing material (fabric) is still largely cotton, but in the future, synthetic fiber based materials will be used to a greater extent. The vinyl coating is applied either by calendering or plastisol casting operations. Calendering is by far the major method of fabrication used for these products; only about 15% of automotive upholstery coated fabrics are made by the casting (or knife coating) process. The casting process is generally more expensive than calendering because (1) it uses more costly PVC (plastisol) compounds, and (2) production-line speeds are much lower than for calendering lines--30-50 yds/min. vs. 70-100 yds/min. The casting process is used primarily for low-volume, short-run operations.

In addition to PVC-coated fabrics, some motor vehicles are still made using conventional uncoated textile upholstery fabrics such as those based on nylon and polyester blends; however, today, these all-textile fabrics represent only a small percentage of the market. Even assuming that the nylon and polyester fibers were available in ample supply, the textile products industry would still need at least two years to install the necessary equipment to manufacture such quantities of upholstery fabrics from synthetic fibers as required by the auto producers.

In the absence of PVC, the preferred approach would be to substitute another synthetic resin such as polyurethane. However, polyurethane-based coated fabrics are not easily calendered as are the PVC based products. Coated polyurethane fabrics made by the casting process are now used in the apparel and furniture upholstery markets, where they are considered "deluxe" products. Also, polyurethane coated fabrics are now being used selectively in the automotive industry in Europe, and they are presently being tested by the U.S. auto makers.

According to our industry contacts, polyurethane-coated fabrics should have adequate properties to essentially meet the performance required of them in this application. Polyurethanes, in general, lack good UV stability; but now some materials are available that can meet this requirement. In some property aspects, polyurethanes are superior to PVC. For example, they have better abrasion resistance; consequently, thinner coatings can be used to produce equivalent properties when compared to PVC.

If polyurethanes are coated onto fabrics by the casting process, a research and design period of about one year would be required to meet the needs of the motor vehicle industry. However, casting is not the process used by most of the coated fabrics industry and several new facilities using different equipment would have to be constructed. For example, the urethane casting process requires significant drying facilities such as ovens, because the polyurethanes are applied as a solution from which the solvent must be removed (this is not the case with PVC plastisol casting). Disregarding polyurethane material shortages which are significant, 18-24 months would be needed to install the necessary casting facilities to "handle" this market. Moreover, because the production rate for the casting process is considerably slower than the calendering process, relatively more casting facilities would be needed in place of the existing PVC calendering facilities to meet demand. Thus, from a technology viewpoint only, the casting-process approach could be a reality in about 2-3 years.

On the other hand, if the polyurethanes were processed by the calendering process, then the research and design period itself would last as much as two years. While a few polyurethanes are available today that can be calendered, more research will be needed to develop the specific polyurethanes needed by the motor-vehicle industry. Therefore, if the calendering process were selected as the preferred approach, then the polyurethane substitute coated fabric could be at least four years away from commercialization. This approach might be preferred because, as mentioned above, most present fabricators of PVC-coated fabrics use calendering equipment. However, most industry respondents agree that polyurethanes designed for calendering would process at a slower production rate than PVC. Also, because the price of urethane compounds is about four times that of PVC compound, the price of urethane-based coated fabric would be substantially higher than PVC-coated fabrics.

Chlorinated polyethylene (CPE) is another possible substitute material, although at present its absolute output and availability is very limited. This product has the advantage that it can be calendered in much the same manner as the present calender-grade PVC, and some fabricators have already worked with this resin. In their opinion, the product is close to meeting existing PVC specifications for automotive upholstery. However, CPE does not have the necessary low-temperature flexibility needed by the motor vehicle manufacturers. Furthermore, it is more difficult to calender than the PVC compounds; some have estimated that the production rate would be slowed by as much as 20% compared to PVC. Still another possible substitute for PVC in this application is ethylene-vinyl acetate copolymer (EVA). This product also can be calendered but, again, it lacks the necessary low-temperature flexibility. Because EVA, in contrast to PVC and CPE, lacks inherent flame resistance, it has to be especially formulated to meet this requirement. Thus, substituting EVA or CPE would mean some sacrificing of performance. Furthermore, these substitute products would still require about three years to reach commercialization; again, assuming the raw materials were available.

Fabricators and motor vehicle manufacturers are also developing new methods for manufacturing motor vehicle seats--methods that would not require coated fabrics. For example, one promising approach is the manufacture of one-piece molded seats using foamed polyurethanes with an external skin; the boating industry is currently using products of this type. However, this approach will require considerably more research and development time than the approaches described above in terms of replacing PVC-based automotive upholstery fabrics.

(b) Furniture

Today, polyurethane coated fabrics are used commercially as furniture upholstery material. However, it is still a small part of the market compared to PVC-coated fabrics. At the present time, most of these coated fabrics are made by the solution casting process. As mentioned above, a series of relatively new urethane polymers have become available that can be calendered. In either case, the preferred substitute for PVC in this application is the polyurethane family of polymers, whether the manufacturer's existing facilities include casting or calendering equipment. The product design period for the changeover in this market should be no more than one year, and following that the modification of the existing equipment and the installation of some new equipment also should take place within one additional year. Thus, the time lag for PVC substitution in this application would be about two years, assuming that the polyurethane materials were then available. Manufacturers of PVC based furniture upholstery, like automotive upholstery, have also considered other substitute materials. For example, ethylene-vinyl acetate polymer is another candidate material. Though it can be calendered and formulated to meet most property requirements, it lacks low-temperature flexibility. Chlorinated polyethylene has been used, but it would have similar deficiencies.

3. Flooring

Nearly all of the hard surface (resilient) flooring products made today are based on PVC resin. The production of asphalt tile (made in only a limited color range) has been largely supplanted by vinyl-asbestos type and the output of linoleum and felt-back enameled "rugs" has decreased considerably relative to the past. In fact, many of the plants that used to make these latter products have been converted to PVC-based flooring products or dismantled entirely.

Because of the unusual ability of PVC resin to be made in a variety of colors (including pastels), surface finishes ("shiny" or dull), degrees of hardness, and the fact that PVC possesses excellent chemical and flame resistance, it would essentially be impossible to duplicate the same line of vinyl flooring products now on the market by using other synthetic or natural polymers. New facilities would have to be built to produce much larger quantities of linoleum and asphalt tile if the consumer would indeed "go back" to using these inferior products. It is more likely that most of the hard surface plastic flooring market would be replaced by soft carpeting rather than with these "outmoded" resilient flooring materials.

4. Wire and Cable

(a) Building Wire

This wire carries a maximum voltage of 600 volts; typically, manufacturers sell 110, 220, and 440-voltage wire to industrial, residential, and commercial users. In this market, a PVC compound is most often used as the insulation material.

PVC was originally selected as the preferred material for this application because of its low cost (which derives in part from its "easy" processability), excellent flame resistance, good low-temperature flexibility and colorability (e.g., for coding) in addition to desirable electrical insulation properties. If PVC were no longer available, a major constraint that would inhibit the introduction of a substitute material would be the existing building codes. Although most of the codes involve performance specifications, they essentially restrict the material to PVC, because they specify performance requirements that only PVC can meet, such as flame resistance and flexibility.

The "easiest" substitute approach would be to use polyethylene plastics. Although this material lacks the inherent flame resistance of PVC, the industry believes that given sufficient time it could be formulated to meet this requirement. However, polyethylene does not satisfy the operating temperatures required in many building-wire applications. Although "flame-resistant" polyethylene could be used in most homes, it would probably be unsatisfactory in many industrial, commercial, and institutional applications where relatively high service temperatures are required. Polyethylene is also less flexible than PVC, a major disadvantage in household wiring; one approach might be to use thinner coatings to get improved flexibility; however, this might result in unsatisfactory insulation value.

Another PVC substitution approach would be to use EP (ethylene-propylene) rubber (EPR) with an outer coating of HYPALON (chlorosulfonated polyethylene) or neoprene. By itself, EPR is too soft for many applications and does not have the required flame resistance; therefore, the HYPALON or neoprene coating would be required. These materials would impart the necessary flame resistance. Another approach would be to use HYPALON or neoprene only, disregarding the much higher cost and the lack of availability. Although neoprene would be satisfactory in many building wire applications, it lacks the necessary abrasion resistance required in several non-building construction applications. Another potential substitute material is cross-linked polyethylene (XPE), a thermosetting material. Again, it would have to be formulated to meet the flame resistance requirements; otherwise, it would have all of the other necessary properties, including the relatively high-service-temperature property. XPE, however, is a rigid material which would limit its use significantly in this market.

Assuming that the constraint of the building codes was removed and that sufficient amounts of the substitute materials were available (again essentially impossible from a physical capacity viewpoint), the redesigning of the substitute product would take up to two years, depending upon which substitute materials were selected. But even if the "easiest" approach were taken, e.g., using polyethylene, the existing extruding equipment would have to be modified (e.g., new and different screws would be needed). If a thermoset material, such as HYPALON, were selected, then considerable new auxiliary equipment and facilities also would be required. Therefore, depending upon which material was selected, the total time needed to commercialize substitute building wire products would be from two to four years.

(b) Automotive Wire and Cable

The average passenger car uses about ten pounds of PVC compound as insulating material for wire and cable; although small in terms of weight percent, this is a very necessary product that is used in motor vehicle production. According to the industry, the best substitute material would be polyethylene. Ordinary polyethylene has an operating temperature somewhat lower than PVC; therefore, in most instances, the auto industry would rather use crosslinked polyethylene which is used in some automotive wire applications today. Whereas PVC has a rated operating temperature of 105°C, the crosslinked variety of polyethylene has an operating temperature of 150°C. Although polyethylene itself will not meet the existing flame-resistance requirements, polyethylene can be satisfactorily formulated to meet these requirements. However, substituting polyethylene would mean giving up other performance requirements such as flexibility.

Because crosslinked polyethylene wire is a commercial product today, the redesign period would be relatively short--perhaps about six months--if crosslinked polyethylene were used as a substitute. However, this material is processed differently than is PVC, and the need for additional equipment and space would introduce an additional time lag of 12-24 months. While the existing PVC extruders could be used in the fabricating operation, the processors would have to change the extruder screw but, more significantly, they would have to add new curing lines. Curing of crosslinking polyethylene requires heat and, therefore, more space and obviously more steam would be needed than is the case with PVC products. Furthermore, substituting cross-linked polyethylene would also reduce productivity--perhaps by as much as one-third. Consequently, additional extruding equipment also would be needed. In summary, substituting XPE for PVC in automotive wire applications would require about two years.

(c) Communication Wire

Flexible PVC compound is widely used as the wire insulation and jacket material for communication wire. This insulation is primarily used inside buildings--commercial, industrial, and residential. As a consequence, this insulation material must meet local building codes. PVC is the preferred material in this application because of its overall cost/performance characteristics, its relatively high-temperature resistance, and its good flexibility and colorability. Perhaps most importantly because it is used inside buildings, it is preferred because it meets the necessary flame-resistance requirements. In some applications where PVC is used currently, the industry could substitute polyethylene, if it were formulated to meet the flame-resistance requirement. On the other hand, neoprene could probably meet all of the existing requirements met by PVC insulation today, even though neoprene's electrical properties are slightly inferior to those of PVC.

HYPALON also can be considered a good substitute material. But HYPALON and neoprene rubbers are thermoset materials that would require new processing equipment. A thermoplastic material would be preferred. For example, chlorinated polyethylene might be used, if it were available in the quantities needed to satisfy this large market. The best approach would be to substitute appropriately formulated polyethylene for many of the current applications that use PVC and use neoprene as the substitute material for those applications that cannot be served by polyethylene alone.

Again, disregarding the constraint introduced by the need to change the existing building code requirements, extensive research and development would be needed to develop the substitute insulation material for communication wire. The specifications for materials used in this application are very stringent. Thus, R&D required to develop a neoprene substitute product would probably involve at least a two-year period. Moreover, as mentioned above, neoprene would require different processing equipment. Therefore, another two years would be needed to install the new facilities and build the additional space to manufacture the neoprene-insulated wire. The design and development period for the polyethylene substitute material would be somewhat shorter. Consequently, the time lag for substituting PVC in this application would be from three to four years.

5. Packaging

(a) Meat Wrapping

At the present time, flexible PVC is essentially the only wrapping film used for fresh meat. In the past, cellophane was used; consequently, cellophane is a potential substitute material. However, the manufacturing process required to make cellophane film is completely different from that used to fabricate PVC film. New facilities might be needed to manufacture the additional cellophane film, because at the present time most cellophane manufacturing facilities are relatively antiquated. Two to three years would be needed to construct these facilities.

Cellophane would meet most of the existing performance requirements; however, it is not as flexible as PVC. Other substitutes for PVC in this application might be polyethylene and ethylene-vinyl acetate resins. However, these alternatives are not very acceptable, because they are inferior to PVC with respect to clarity and oxygen transmission properties.

(b) Can Coatings

Most metal cans have an internal coating to protect the contents of the can from metal contamination. In some instances, these coatings also protect the metal from corrosion. In food canning applications, a variety of coatings are used, including vinyl chloride based copolymers. Other coating materials used for these purposes include oleo resins, phenolics, and epoxy resins; also some polybutadiene resins are used in beverage cans.

Polyvinyl chloride based resins have been used primarily because of their flexibility--a property that is important in the manufacture of two-piece metal cans that are "deep drawn." The industry could use epoxy resins as a substitute product in this application, because it would require a minimum of new equipment. The epoxy coating could be used in beverage and food cans. However, the use of epoxy resins, will slow production somewhat for it is more difficult to spray; most two-piece cans are sprayed while three-piece cans are coated by a roll coating process. The epoxy resins also may introduce a flavor problem. From this point of view, polybutadiene coatings would likely be preferred for beverage containers because they impart little or no taste. Assuming that epoxy resins were commercially available, the time required for the changeover would be minimal--less than one year.

PVC coatings are also used in the manufacture of some composite (paper-foil) cans used for foods. Here, it is typically used as a slip coating on aluminum foil. It also provides heat sealability. In this case, the industry has substitute products under development and, if PVC were not available, these products could be introduced within 6-12 months.

(c) Crowns and Closures

Most beverage crowns use a PVC plastisol compound as an insert to provide the necessary seal to keep the content of the bottle fresh for long periods of time. The use of cork, the original product, for this application represents no more than 10% of this market now; cork, which is imported, is very difficult to obtain and is expensive. The new convenience "roll-on" closures for beverage bottles also use a plastisol compound as the liner material. Although cork is a substitute material for this application, realistically, it is not preferred. The use of a cork liner requires very different equipment than that which is used to apply the plastisol liners. At the present time, substitute products are under development, and one manufacturer has developed a new ethylene-based elastomer material. This product is currently in use in Europe. However, to utilize this new material, new equipment would be required and installation of this equipment would introduce a time lag of about one year.

Plastisol materials are also widely used as liners for the wide-mouth jar closures. For example, most vacuum-packed food jars use plastisol liners. In this case, the best substitute product would be a rubber latex material. Usually a natural or an SBR rubber is used. However, for the most part, these products would not meet the existing performance requirements. Although rubber does have adequate sealing capabilities in many applications, there are some applications where it does not. Also, in some of the high temperature processes required during the bottling of food, rubber is not as good as plastisol. In addition, rubber often has "cut through" problems and can introduce taste problems.

However, some rubber latices are presently used in this application, and therefore, a changeover to this substitute material could be carried out with a minimum of research and development time. (Sealing products in these applications, of course, must meet FDA requirements.) The equipment required to manufacture closure liners based on rubber latex is different than that required for the manufacture of plastisol liners. Consequently, about one to two years would be required to obtain the necessary equipment in-place. Furthermore, the process that uses rubber latex is considerably slower than that used for plastisol. Therefore, the production rate would be cut substantially.

In the case of non-vacuum closures, substitution will be much easier. Here, plastisol is not used as widely, and rubber or coated paper inserts can provide satisfactoty performance. Table VIII presents a summary of the primary substitution materials for PVC resin and the time required to substitute them in the different major end uses.

TABLE VIII

SUBSTITUTION ASPECTS OF FABRICATED VINYL PRODUCTS

PVC Based Product	Primary Substitute Raw Material Candidates	Total Time Required for Substitution[a] (years)
Pipe	ABS, Polyethylene Metal	1-2
Conduit	ABS, Polyethylene Metal	1-2
Flooring		
Tile	Coumarone-indene resin, SBR	2-3
Yard Goods	Linseed oil (for linoleum)	3-4
Upholstery Material (Coated fabrics)	Polyurethane, CPE	
Automotive		2-3
Furniture		1-2
Wire Insulation	Polyethylene, Neoprene, HYPALON, EP Rubber	2-4
Phonograph Records	Polystyrene	3-4
Siding	Wood, metal (steel, aluminum)	1-2
Packaging Materials		
Flexible Film	Cellophane	1-2
Rigid Film	Cellulosic resin, polystyrene, nitrile resin	1-2
Bottles	Nitrile resin, glass	1-2
Cap liners	Cork, rubber	1-2
Can linings	Epoxy resin	1-2
Medical Tubing	Rubber (e.g., thermoplastic elastomer)	1-2

(a) Assumes that (1) sufficient quantities of substitute raw materials would be available when required by market demand; (2) production facilities are in place and operating at time required.

Source: Arthur D. Little, Inc., estimates.

APPENDIX A

FIGURE A-1

BUILDING/CONSTRUCTION MODULE

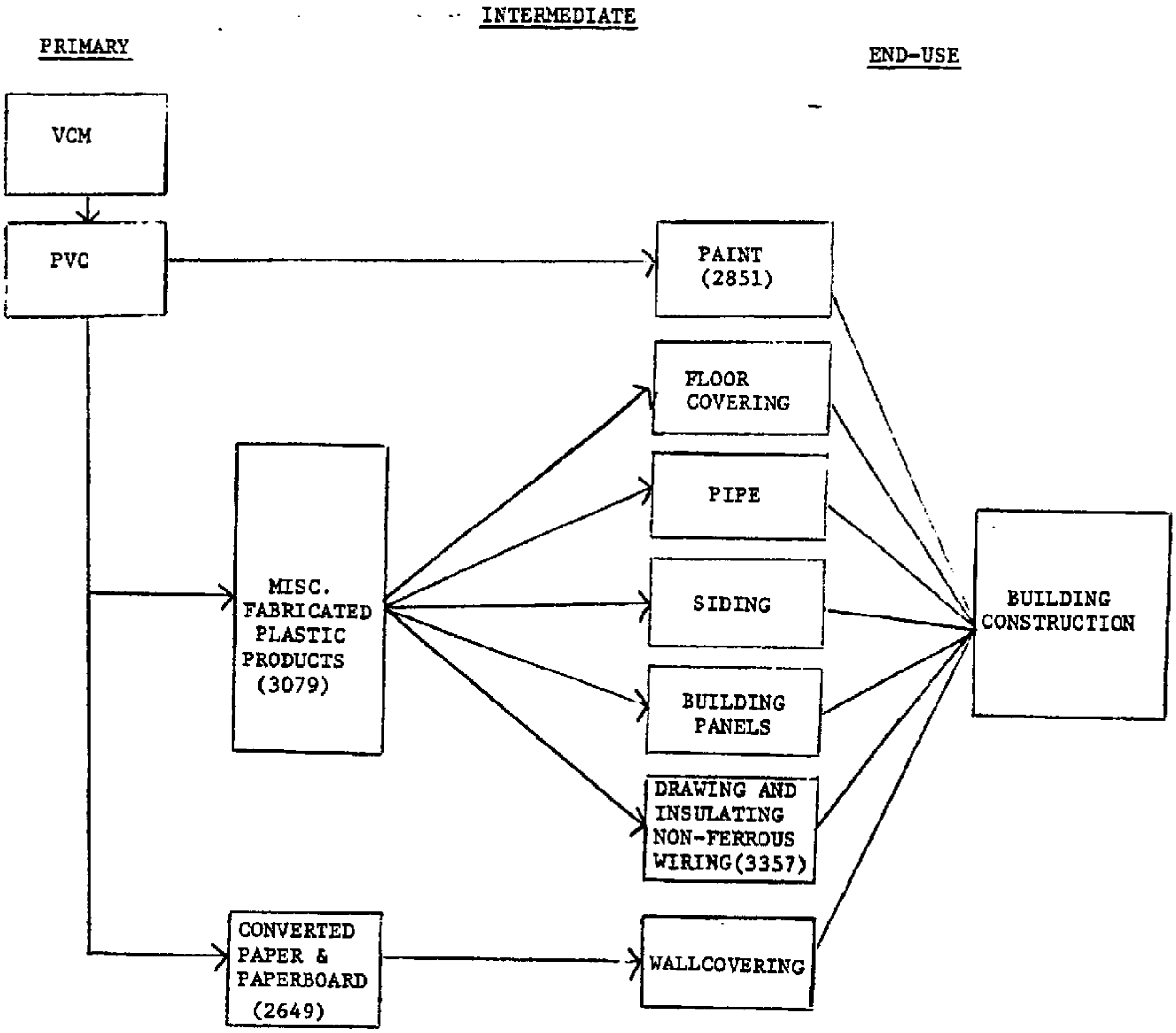

FIGURE A-2

HOME FURNISHINGS AND HOUSEHOLD GOODS AND APPAREL MODULE

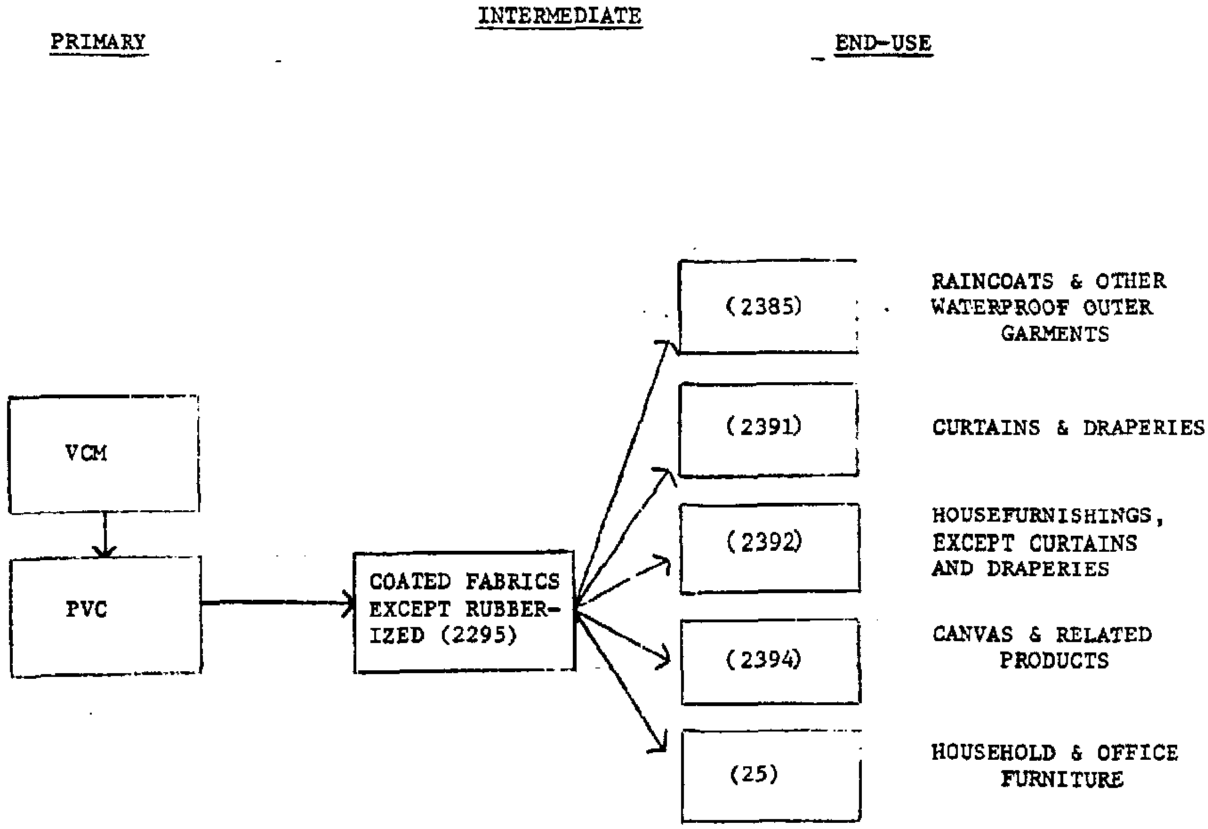

FIGURE A-3

MOTOR VEHICLES MODULE

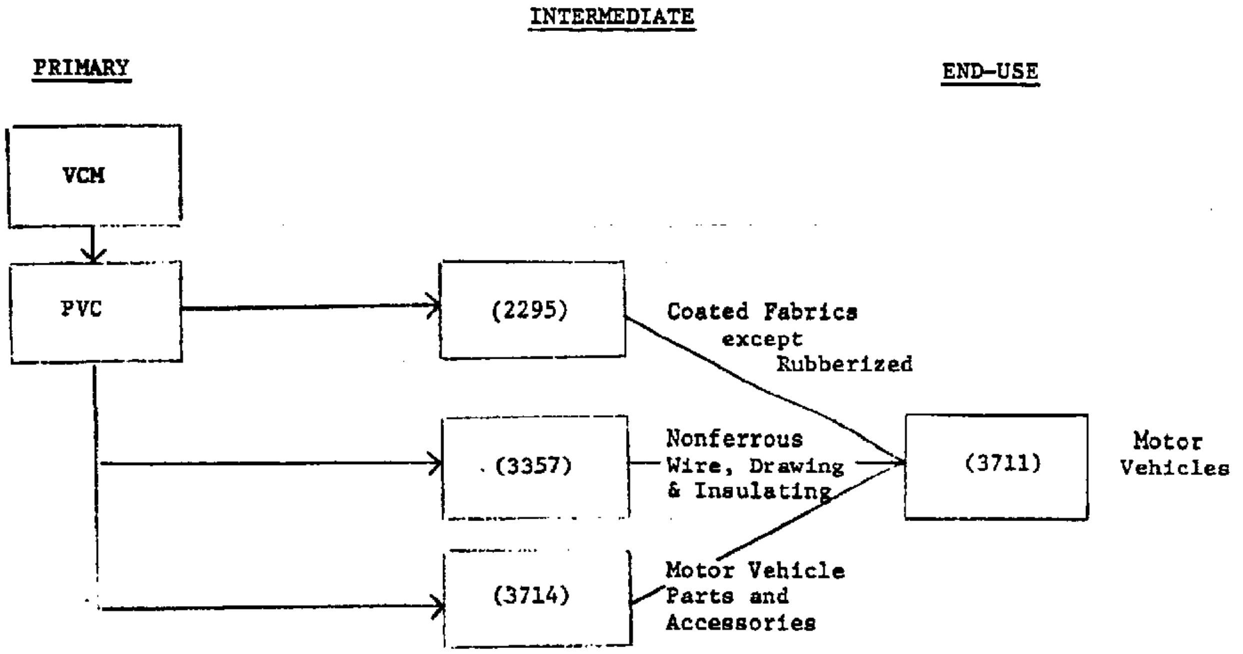

FIGURE A-4

SPECIALTY PRODUCTS MODULE

PRIMARY	INTERMEDIATE	END-USE

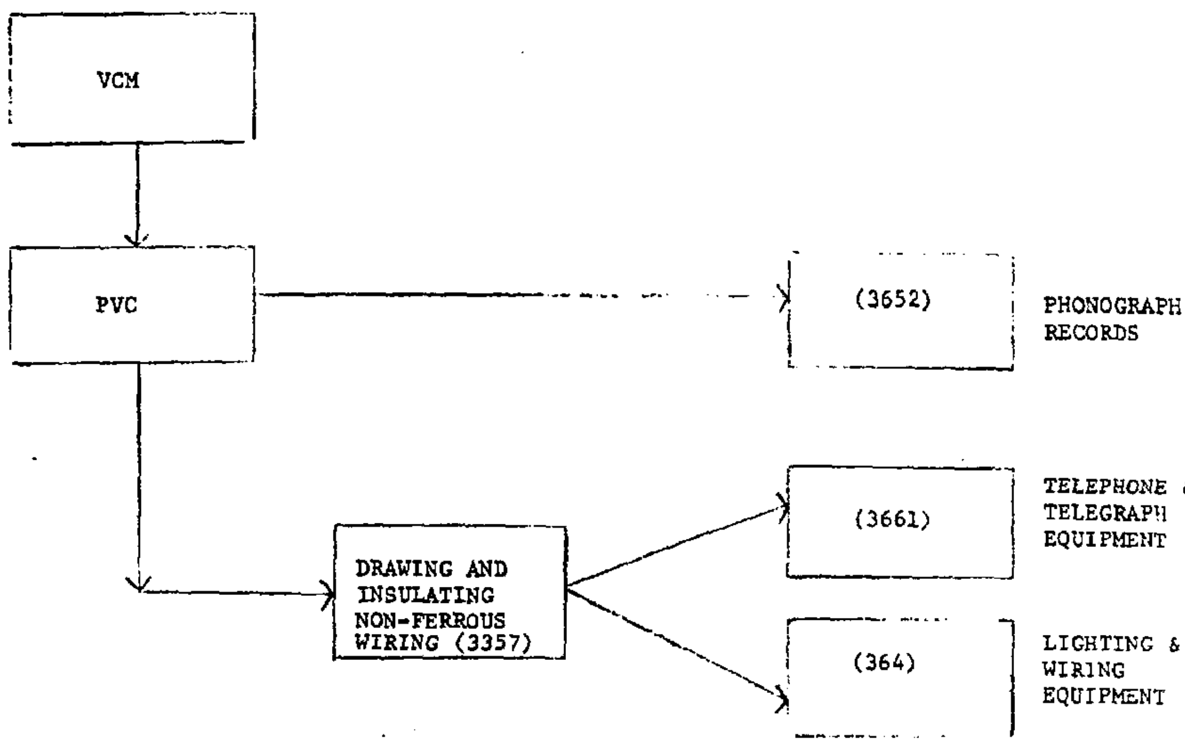

FIGURE A-5

MISCELLANEOUS PRODUCTS MODULE

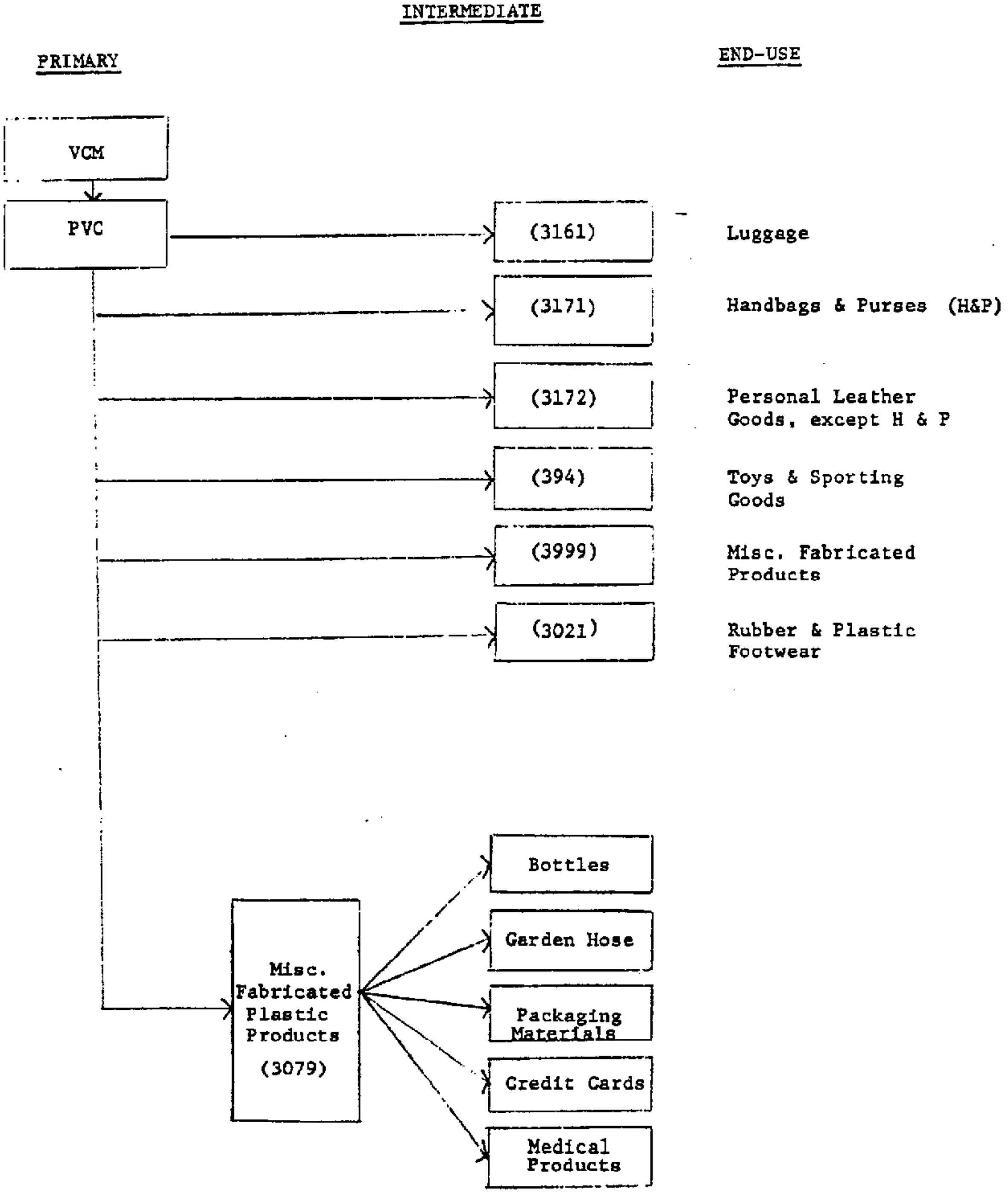

TABLE A-1

Building/Construction Module

Industry	1972 Value of Shipments (MM$)	1972 Employment (000)	Estimated PVC Dependency	Direct Loss in Shipments (MM$)	Direct Loss in Employment (000)	Impact on All Other Industries Loss in Shipments (MM$)	Impact on All Other Industries Loss in Employment (000)
Primary							
VCM							
PVC							
Intermediate							
Paint (2851)	3856	68					
Misc. Fabricated Plastic Products (3079)	9155	303					
Floor Covering							
Pipe, Conduit & Fittings							
Siding							
Building Panels							
Drawing and Insulating Non-Ferrous Wiring (3357)	4177	65					
Wall Covering	79	3					
End-Use							
Building/Construction	95000	3521	10%-20%*	9500-19000	352-704	7600-15200	190-380
TOTAL				$9500-19000	352-704	$7600-15200	190-380

TOTAL Modular Impact	Production (Billion $)	Employment (Million)
Direct	$9.5-19.0	0.4-0.7
All Other	7.6-15.2	0.2-0.4
	$17.1-34.2	0.6-1.1

* This estimate of PVC dependency represents a "best conservative" estimate based upon our work effort. The dependency could be greater given the high level of importance of such PVC-related items as building wire, pipe, and floor covering in many segments of the building/construction industry.

Source: 1972 Census of Manufactures and ADL estimates.

TABLE A-2

Home Furnishings, Household Goods and Apparel Module

Industry	1972 Value of Shipments (MM$)	1972 Employment (000)	Estimated PVC Dependency	Direct Loss in Shipments (MM$)	Direct Loss in Employment (000)	Impact on All Other Industries Loss in Shipments (MM$)	Impact on All Other Industries Loss in Employment (000)
Primary							
VCM							
PVC							
Intermediate							
Coated Fabrics except[a] Rubberized (2295)	792	17					
End-Use							
Raincoats & Other Waterproof Outer Garments (2385)	288	14	5%-10%	14-28	0.1	13-25	*
Curtains & Draperies (2391)	745	33	5%-10%	37-74	0.1-0.3	33-66	*
Housefurnishings (2392)	1372	48	5%-10%	68-137	0.2-0.5	61-123	*
Canvas & Related Products (2394)	245	11	5%-10%	12-24	0.1	11-22	*
Furniture (25)	11231	460	5%-10%	561-1123	23.0-46.0	533-1066	13-27
TOTAL				692-1386	23.5-47.0	651-1302	13-27

TOTAL Modular Impact	Production (Billion $)	Employment (Million)
Direct	0.7-1.4	0.1
All Other	0.7-1.3	*
	1.4-2.7	0.6-1.1

(a) e.g., furniture upholstery material.

* Less than 50,000.

Source: 1972 Census of Manufactures and ADL estimates.

TABLE A-3

Motor Vehicle Module

Industry	1972 Value of Shipments (MM$)	1972 Employment (000)	Estimated PVC Dependency	Direct Loss in Shipments (MM$)	Direct Loss in Employment (000)	Impact on All Other Industries Loss in Shipments (MM$)	Impact on All Other Industries Loss in Employment (000)
Primary							
VCM							
PVC							
Intermediate							
Coated Fabrics (2295)[a]	792	17					
Nonferrous Wire Drawing and Insulating (3357)	4177	65					
Motor Vehicle Parts and Accessories (3714)	18554	401					
End-Use							
Motor Vehicles (3711)	45979	359	25%-50%	11494-22988	90-180	13793-27585	345-689
TOTAL				11494-22988	90-180	13793-27585	345-689

TOTAL Modular Impact	Production (Billion $)	Employment (Million)
Direct	11.5-23.0	0.1-0.2
All Other	13.8-27.6	0.3-0.7
	25.3-50.6	0.4-0.9

(a) e.g., upholstery materials.

Source: 1972 Census of Manufactures and ADL estimates.

TABLE A-4

Specialty Products Module

Industry	1972 Value of Shipments (MM$)	1972 Employment (000)	Estimated PVC Dependency	Direct Loss in Shipments (MM$)	Direct Loss in Employment (000)	Impact on All Other Industries Loss in Shipments (MM$)	Impact on All Other Industries Loss in Employment (000)
Primary							
VCM							
PVC							
Intermediate							
Drawing and Insulating Non-Ferrous Wiring (3357)	4177	65					
End-Use							
Phonograph Records (3652)	472	18	80%-90%	378-425	14-16	340-382	8-9
Telephone & Telegraph Equipment (3661)	4301	138	65%-75%	2796-3228	90-104	2237-2582	56-64
Lighting & Wiring Equipment (364)	5466	168	50%-75%	2733-4100	84-126	2186-3280	55-82
TOTAL				5907-7753	188-246	4763-6244	119-155

TOTAL Modular Impact	Production (Billion $)	Employment (Million)
Direct	5.9-7.7	0.2-0.2
All Other	4.8-6.2	0.1-0.2
	10.7-13.9	0.3-0.4

Source: 1972 Census of Manufactures and ADL estimates.

TABLE A-5

Miscellaneous Products Module

Industry	1972 Value of Shipments (MM$)	1972 Employment (000)	Estimated PVC Dependency	Direct Loss in Shipments (MM$)	Direct Loss in Employment (000)	Impact on All Other Industries Loss in Shipments (MM$)	Impact on All Other Industries Loss in Employment (000)
Primary							
VCM							
PVC							
End-Use							
Luggage (3161)	345	16	50%-75%	172-258	8-12	206-310	5-8
Handbags & Purses (3171)	313	21	50%-75%	156-234	11-15	187-280	5-7
Personal Leather Goods, except H&P (3172)	274	13	50%-75%	137-205	6-10	164-246	4-6
Toys & Sporting Goods (394)	2800	100	30%-40%	840-1120	30-40	756-1008	19-25
Misc. Fabricated Products (3999)	1244	56	5%-10%	62-124	3-6	56-111	1-3
Rubber & Plastic Footwear (3021)	563	29	5%-10%	28-56	2-3	25-50	1-1
Misc. Plastic Products (3079)	9155	303	5%-10%	450-915	15-30	410-823	10-20
Bottles							
Garden Hose							
Packaging Materials (including coatings)							
Credit Cards							
Medical Products							
TOTAL				1845-2912	75-116	1804-2828	45-70

TOTAL Modular Impact	Production (Billion $)	Employment (Million)
Direct	1.8-2.9	0.1-0.1
All Other	1.8-2.8	* -0.1
	$3.6-5.7	0.1-0.2

* Less than 50,000.

Source: 1972 Census of Manufactures and ADL estimates.