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Photovoltaic Subsystem Marketing and Distribution Model: Programming Manual

Final Report

Theodore Barry & Associates
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ABSTRACT

This report provides complete documentation of the M&D computer model. The purpose is to estimate the costs of selling and transporting photovoltaic solar energy products from the manufacturer to the final customer. The model adjusts for the inflation and regional differences in marketing and distribution costs. The model consists of three major components: the marketing submodel, the distribution submodel, and the financial submodel. Information concerning the availability of the FORTRAN computer program can be obtained from the sponsoring organization: Sandia National Laboratories, Photovoltaic Division 9723. This document explains the computer program including the input requirements, output reports, subprograms and operating environment. The program specifications discuss maintaining the validity of the data and potential improvements. An example for a photovoltaic concentrator collector demonstrates the application of the model.

PREFACE

Theodore Barray & Associates (TB&A) was contracted by Sandia National Laboratories to perform a Solar Energy Costing Standards Project. The primary objectives of this study were to:

- Expand the SAMIS manufacturing cost estimating model capabilities to include concentrator technologies and selected balance of system (BOS) components.
- Develop a uniform construction cost accounting structure consistent with PV program requirements and objectives for test and application projects.
- Automate the Marketing and Distribution (M&D) model to estimate the costs of selling and delivering solar energy products to the factory customer.

The results of this have been documented in five reports:

- Photovoltaic Subsystem Production Cost Model (SAMIS) - An overview of the SAMIS model with instructions on input requirements and output reports. (SAND81-7049)
- Photovoltaic Subsystem Marketing and Distribution Model: Programming Manual - A complete listing of all computer documentation necessary to run the program, including a description of the operating environment, program specifications, subprograms, input options, and output reports. (SAND81-7048)
- Photovoltaic Subsystem Marketing and Distribution Model - A description of the M&D model, input options, and output reports, geared towards management. (SAND81-7047)
- Cost Accounting and Reporting System Manual for Photovoltaic Project Management - A uniform construction cost accounting structure for photovoltaic test and application projects including instructions and forms. (SAND81-7046)
- Photovoltaic System Costing Methodology Development - An overview of the entire project, detailing the project background, study objectives, and technical approach, as well as, SAMIS, M&D, and Costing System results. (SAND81-7050)

This document, the marketing and distribution model programming manual, is intended primarily for the individual involved in running the M&D computer code. The report entitled Photovoltaic Subsystem Marketing and Distribution Model (SAND81-7047) provides a more succinct description of the model capabilities without going into the code details. The interpretation of the results of the example calculation is contained in the overall project final report (SAND81-7050).

FOREWORD

This report was prepared for the Photovoltaic Systems Definition Project of Sandia National Laboratories under contract number 46-5760. The project is part of the National Photovoltaics Program sponsored by the U.S. Department of Energy (DOE). The report documents the M&D model to estimate marketing and distribution costs for photovoltaic solar energy products.

The work at Theodore Barry & Associates was performed by many individuals under the supervision of James B. Ayers. Several people worked on the computerization of the model including Robert Bullemer, Valerie Frank, Alex Guttman, and Jeanne Steinhauer. Many other people provided valuable assistance in the formulation of the model which was initiated for the Jet Propulsion Laboratory (JPL) under the direction of Robert Chamberlain with the help of Chet Borden and Robert Aster. Baldwin Klep and Diane Ronnigen of TB&A performed manual calculations and analyzed the model results.

Dr. Gary Jones of Sandia served as technical monitor for the project. Patricia Allen debugged and installed the program on the Sandia computer and made numerous contributions to the reports. Several others at Sandia assisted in the enhancement and documentation of the model.

TB&A extends our sincere appreciation for the courtesy and cooperation from the many individuals from both JPL and Sandia who participated in the development of the M&D computer program.

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I INTRODUCTION

This report documents a computer program of a photovoltaic subsystem marketing and distribution model to support the National Photovoltaics Program of the United States Department of Energy (DOE).

The overall objective of this national program is to promote the development of low cost, reliable, terrestrial photovoltaic (PV) systems, and to stimulate creation of a viable industrial and commercial capability to manufacture and distribute these systems for widespread use in residential, commercial, industrial, agricultural, and governmental applications.

Sandia National Laboratories is actively involved in this program as manager of the DOE Systems Definition Project. Specific goals of this effort are to evaluate alternative applications of PV technology and define the most promising system designs for demonstration experiments.

Many companies are currently analyzing system design, prototype fabrication, production planning, installation procedures, maintenance approaches, and life-cycle cost estimates. The installed system price and system operating and maintenance costs are being estimated by each of the system design companies. However, cost estimates are not always comparable due to differences in economic and financial accounting assumptions and because the evaluations have not been made in the context of a complete manufacturing process sequence in an automated factory.

Cost reductions per unit may result from increasing the area, simplifying the design, sharing components, minimizing field labor, automating fabrication, producing large volumes, and reducing labor through learning. The complexity of these assessments for a variety of competing technologies requires sophisticated models capable of simulating an entire industry to evaluate high volume processes and to calculate probable manufacturing costs in the future.

Consequently, the development of a standard cost estimating methodology and performance reporting system is an important part of the DOE Systems Definition Project at Sandia. These standards unify economic and financial accounting assumptions providing comparable cost estimates for the alternative photovoltaic system technologies under development.

These standards include the following economic models which can be applied to analyze performance and to evaluate costs for alternative PV systems.

PHOTOVOLTAIC ECONOMIC MODELS

SAMIS	M&D	PV COST
component manufacturing cost	marketing & distribution cost	on-site installation cost

SAMIS - estimates manufacturing costs for PV system components based on input data describing the component design, manufacturing equipment costs, capacities, and direct requirements for the production processes such as labor, materials, supplies and utilities. These inputs are selected for a complete sequence of manufacturing processes from a standard cost account catalog which contains prices versus quantities. The output reports include a solar product price estimate, income statement, key financial ratios, and an initial capital cost summary. Prices are FOB plant.

M&D - estimates the costs of selling and transporting PV system components from the factory to the site. Three submodels compute marketing expenses, distribution costs, general and administrative expenses, taxes, and profit. Output reports present delivered solar product price estimates, projected income statements, key financial indicators, transportation modes, and warehouse sizes and locations. The model forecasts are adjusted for both inflation and regional differences in marketing and distribution costs.

PV COST - estimates on-site installation costs for all PV system components. The estimating data base contains costs for on-site labor and materials.

This report provides complete documentation of the M&D computer model. Information concerning the availability of the FORTRAN computer program can be obtained from the sponsoring organization: Sandia National Laboratories Photovoltaic Division 4723. The documentation explains the input requirements, output reports, subprograms, and operating environment. The program specifications discuss maintaining validity of the data and potential improvements. An example for a PV concentrator collector demonstrates the use of the model.

II PROGRAM DESCRIPTION

A. Overview of the Model

1. System Schematic - The purpose of the M&D model is to estimate the costs of selling, warehousing, and transporting solar energy products from the factory to the final customer. The user can analyze the implications of alternative distribution channels and transportation modes. The impact of economies of scale can be evaluated with high volume production in national, regional or local factories. The impacts of a diversion of demand from conventional energy sources to solar can be measured in terms of the delivered product price estimate ($/watt).

On the supply side, separate models of marketing, distribution, and finance are combined in a modular representation of the geographic sales territory. Demand for the solar products is not forecast; rather it is treated parametrically via the total megawatt capacity and the average order quantity by customer type. Although this approach ignores the interaction of supply and demand, it does provide information about the economies and productivity of operating alternative distribution systems at various production levels.

As shown in the system schematic Exhibit II-A, the M&D program consists of a main program, a set of four subprograms and twelve subroutines.

Starting with the main program, the user input data is read and run options are established for all of the subprograms. Data is checked for validity and error reports are printed.

Depending on the run options specified as input, the main program calls one or more of the subprograms in the following sequence:

- Marketing Subprogram: MARKET
- Distribution Subprogram: DISTRB
- Finance Subprogram: FINANC.

The marketing and distribution subprograms are independent of one and other although they use some of the same input data. The finance subprogram requires results from either the marketing or distribution subprogram, or both of them.

All input data is read by READ statements in the main program. The values of all standard parameters are initialized by data statements in the block data subprogram. These values, which are used by the other subprograms, are passed through common blocks. All output reports are generated by the marketing, distribution, and finance subprograms.

INPUT DATA

- Demand for each customer type in each region
- Average order quantity for each customer type
- Average delivery quantity for each customer type
- Price of manufactured product for each customer type
- Manufacturing year, reporting year, weight, volume, factory location
- Warehouse constraint indicator for each region
- Run type indicator (marketing and/or distribution)
- Product type indicator (PCU or collector)

MAIN PROGRAM

- Read input data
- Check validity/print error message
- Call block data subprogram
- Call marketing subprogram
- Call distribution subprogram
- Call finance subprogram

ERROR REPORTS

- Diagnostic error message for input data outside the validation limits by variable name and actual value read

BLOCK DATA SUBPROGRAM

- Logical units specifying location of data for input and output
- Labor cost index for each region
- Utilities cost index for each region
- Facilities cost index for each region
- Construction cost index for each region
- Equipment cost index for each region
- Inflation rates for raw materials, labor cost, chemical cost, commodities, energy, utilities, land cost, facilities, and transportation
- Solar products deflation rate ($/year)
- Annual compensation rate for direct sales personnel
- Requirement coefficient for direct sales support personnel
- Annual compensation rate for indirect sales personnel
- Sales expense rate for each type of customer
- Advertising rate for each type of customer
- Amount of office space per person (square meters)
- Office facilities lease rate ($ of capital cost)
- Office utilities cost rate ($/square meter/year)
- Office maintenance cost rate ($ of capital cost)
- Property tax rate ($ of capital cost)
- Insurance rate ($ of capital cost)
- Base price year
- Indirect staffing requirements matrix (17x17)
- Interregional shipping distance matrix (7x7)
- Intraregional shipping distance matrix (5,7)
- Vehicle load capacity (kilograms/shipment)
- Vehicle distance capacity (kilometers/vehicle/year)
- Annual fixed cost per vehicle ($/vehicle/year)
- Variable operating cost per vehicle ($/kilometer)
- Warehouse order processing cost ($/shipment)
- Warehouse space utilization factor
- Annual inventory carrying charge rate ($ value
- Annual lease rate for equipment ($ capital cost)
- Annual lease rate for warehouse building
- Warehouse utility cost rate ($/square meter/year)
- Warehouse property tax rate ($ capital cost/year)
- Warehouse insurance rate ($ capital cost/year)
- Warehouse maintenance cost rate ($ capital cost)
- Annual compensation for warehouse personnel
- Distribution options matrix for each customer/region
- Finance inventory carrying rate ($ product value)
- Effective income tax rate ($ of income)
- Minimum required rate of return on equity
- Financial leverage ratio (total capital/equity)
- Average inventory turnover time (months)
- Average expense coverage time (months)
- Debt interest rate ($/year)
- Print labels for modes of transportation
- Print labels for geographic regions
- Print labels for marketing and distribution centers
- Print labels for types of customer
- Print labels for distribution alternatives

MARKET SUBPROGRAM

Compute costs of selling solar energy products

- Sales personnel salaries
  - salesman
  - direct support
  - indirect staff
- Office facilities cost
  - rent
  - maintenance
  - utilities
  - other
- Sales Expenses
  - travel
  - entertainment
  - communication
- Advertising Expenses

MARKET SUBPROGRAM REPORTS

MSR-1: Market Demand Distribution
MSR-2: Marketing Expense Summary
MSR-3: Marketing Personnel Summary
MSR-4: Sales Office Facilities
MSR-5: Marketing Price Estimates
MSR-6: Marketing Submodel Parameters

SSI SUBROUTINE

Determine salesman support index SSI as a function of the average order size A in megawatts

MWS SUBROUTINE

Determine salesman productivity in megawatts/year/person as a function of average order size in megawatts per order

KO SUBROUTINE

Determine the office facilities capital cost, KO, as a function of the office size O in square meters

TOTPER SUBROUTINE

Given the direct sales personnel vector DV and the indirect staffing matrix RM compute the total personnel vector TV

MATMUL SUBROUTINE

Compute the total personnel vector TV given the direct personnel vector DV and the inverted matrix I-RM where RM is the 17x17 indirect staffing requirements matrix

INVERT SUBROUTINE

Invert the I-RM matrix where I is the 17x17 identity matrix and RM is the 17x17 indirect staffing matrix

ROWCHK SUBROUTINE

Switch rows in the matrix ENVRTR to assist in the inversion of the indirect staffing requirements matrix

DISTRB SUBPROGRAM

Compute distribution expenses

- salaries and benefits
- transportation costs
- warehouse operating costs
- inventory carrying charges

Compute network configuration

- warehouse locations/sizes
- inventory levels
- distribution alternatives
- transportation model

DISTRB SUBPROGRAM REPORTS

DSR-1: Customer Demand Distribution
DSR-2: Distribution Expense Summary
DSR-3: Distribution Network Configuration
DSR-4: Warehouse Facilities
DSR-5: Alternative Distribution Costs
DSR-6: Economic Warehousing Order Quantity
DSR-7: Distribution Price Estimates
DSR-8: Distribution Submodel Parameters

PEOPLE SUBROUTINE

Determine total warehouse personnel (PEOPLE) as a function of the warehouse size F in square meters

KE SUBROUTINE

Determine the equipment capital cost KE as a function of the warehouse size F in square meters

KB SUBROUTINE

Determine the building and land capital cost KB as a function of the warehouse size F in square meters

P SUBROUTINE

Determine the warehouse personnel cost P as a function of the warehouse size F in square meters.

C SUBROUTINE

Determine the interregional transportation cost C as a function of the average shipment weight Q in kilograms and the shipping distance S in kilometers; compute the shipping cost per 100 kilograms

FINANC SUBPROGRAM

Compute projected income statements

- revenues
- cost of goods sold
- gross profit
- R&D expenses
- income taxes
- profit

Compute solar product price estimates

- by customer type
- by geographic region

Compute key financial indicators

- markup by customer
- profit margin

FINANC SUBPROGRAM REPORTS

FSR-1: Consolidated Income Statement
FSR-2: Schedule A - Distribution Expenses
FSR-3: Schedule B - Marketing Expenses
FSR-4: Regional Income Statements
FSR-5: Delivered Price Estimates
FSR-6: Delivered Price Estimates
FSR-7: Key Financial Indicators
FSR-8: General R&D Model Parameters

The major inputs to the model are the manufacturing cost of the solar products and the demand distribution by customer type and geographic region. Output reports present delivered solar product price estimates, projected income statements, key financial indicators, transportation modes, warehouse sizes and locations. Three submodels compute marketing, distribution and fianancial parameters.

The marketing submodel computes the cost of selling solar products. These costs include:

- Sales personnel salaries
- Office facilities cost
- Sales expenses
  - travel and entertainment
  - communications
  - office supplies
- Advertising expenses.

It is assumed that these costs vary for different types of customers, and the model computes the costs by type of customer. Customers are described by their average order quantity. The model allows for up to three classes of customers, although fewer can be specified. For example, small (residential), intermediate (commercial), and large (utilities). In the example case presented in this report for photovoltaic concentrator collectors, the average residential customer purchases photovoltaic solar systems in orders of 5 kilowatts, commercial 500 kilowatts and utilities 5 megawatts.

The user inputs total sales by customer, total sales by region, and average sales per unit. From these, the model calculates costs. The model, restricted to the supply side, does not attempt to measure the impact on demand in a region from lower prices in that region. However, the user can measure the impact on costs of increased or reduced volume through iterations using different input data.

The distribution submodel computes the cost of transporting, warehousing, and delivering the solar arrays from the factory to the final customers. The country is divided into seven distribution regions. For each region, there are two distribution alternatives for each type of customer:

- Direct shipments from the factory to the customer

- Transshipments from the factory through a regional warehouse to the customer.

The model computes the alternative which minimizes the total annual distribution cost. In a given region, some types of customers may be supplied directly from the factory and others from a regional warehouse. There will not necessarily be a warehouse in every region, unless it is calculated to be economical to have one.

If there is a warehouse, the model computes the optimal warehouse size which balances the number of shipments required with the cost of operating the warehouse, thereby minimizing the cost of the delivered solar products.

The financial submodel of the firm consists of the equations used to compute sales revenues, taxes, and profits based on the marketing and distribution expenses. The model parameters are expressed in standard financial statement terms to facilitate preparation of projected income statements for each region.

The inputs include demand distribution by region, the annual distribution expense by region, the annual marketing expense by region, the manufacturing cost of goods sold, and the manufacturing year.

Several financial parameters are used, including the minimum required rate of return on equity, financial leverage ratio, effective income tax rate, and the risk coverage period.

The model specifies the working capital required for inventories and a cash reserve to cover fixed expenses. Profits are computed to earn the minimum required return on equity. Product prices are derived from the required revenue condition that annual revenues equal annual costs including profit.

The output consists of projected income statements, delivered product price estimates, and three key financial indicators. The key financial indicators are the cost of capital, mark-up, and the profit margin.

The income statements are generated by region for a steady-state manufacturing year. The prices are computed by dividing the annual sales revenue by the demand in each region for each product type. The price estimates include all manufacturing, marketing, and distribution expenses as well as a reasonable profit.

The model forecasts are adjusted for both inflation and regional differences in marketing and distribution costs.

The equations and standard values used for the model parameters are presented in Appendix B.

2. Design Constraints - The M&D model was orginally developed to evaluate marketing and distribution costs for flat-plate photovoltaic solar arrays. Although later expanded to evaluate other solar energy products such as concentrator collectors and power conditioning units, the model has not yet been extended to other industries.

Assumptions used in the model have been predicated on the sales requirements for an established product. This was necessary due to the infancy of the solar energy field. Another limitation placed on the model is that component manufacturing has not been allowed. In reality, this may be the most logical method to develop complete photovoltaic solar energy systems. The result of this is a more conservative estimate by the model.

As previously stated, the marketing submodel ignores the interaction of supply and demand. However, input data can be varied parametrically to receive comparable results. Out of the necessity to simplify the model, salesman productivity is assumed to be independent of advertising. Also, no manufacturing price discounts are offered for large orders.

Several suppositions were also made with regard to the warehousing and storage of component parts. It is assumed that all warehouses are leased - none are owned. This again provides for a conservative estimate. In addition, there is no allowance for the sharing of a warehouse with regard to other products or other manufacturers. In the case where a warehouse is needed for small volumes, the storage cost per unit is higher than one of the afore mentioned solutions. The model also does not allow for stockouts and assumes that there is only a single factory.

Eleven test cases were run varying all input parameters over wide ranges. It was found that at very low values of demand, the model does not yield realistic results.

The computer program has been designed so that the compile/link edit functions are separate from the input data and report print out. This allows input data to be easily and inexpensively manipulated.

3. Maintaining validity of data - The block data subprogram contains data statements which initialize the values of all standard parameters. These values which are used by the other subprograms, are passed through common blocks. In all, there are more than fifty standard parameters. The following six pages list each parameter and the standard values contained in the block data subprogram.

These inflation rates are standard parameters whose values are also set in the block data subprogram and can be easily modified by the user.

While the program does inflate the values from the base price year, the dollar values should be reviewed once each year to maintain the validity of the data. Specifically the following items should be updated:

AC = Annual compensation rate for direct sales support personnel (base price year $/year/person).

CS = Annual compensation rate for salesman (base price year $/year/person).

RHOO = Office utilities cost rate ($/square meter/year).

FC = Annual fixed cost per vehicle ($/vehicle/year).

VC = Variable operating cost per vehicle ($/kilometer).

OP = Warehouse order processing cost ($/order).

RHOW = Utility cost rate ($/square meter/year).

SALD = Annual compensation rate for warehouse personnel (base price year $/year/person).

In addition to these block data subprogram parameters, there are four subroutine functions used by the marketing and distribution subprograms that contain cost coefficients expressed in 1981 dollars.

KO Subroutine - Determine the office facilities capital cost, KO in 1981 dollars, as a function of the office size O in square meters.

C Subroutine - Determine the interregional transportation cost, C in 1981 dollars, as a function of the average shipment weight, Q, in kilograms and the shipping distance, S, in kilometers.

KE Subroutine - Determine the equipment capital cost, KE in 1981 dollars, as a function of the warehouse size, F in square meters.

KB Subroutine - Determine the building and land capital cost, KB in 1981 dollars, as a function of the warehouse size, F in square meters.

These values should be reviewed periodically and updated if necessary in order to maintain the validity of the standard data.

M&D PROGRAM STANDARD DATA

```
C *** LOGICAL UNITS SPECIFYING LOCATION OF DATA INPUT AND OUTPUT
      DATA   IN, OUT
     1   /5,  6/
C *** LABOR COST INDEX FOR REGION J
      DATA   LJ(1), LJ(2), LJ(3), LJ(4), LJ(5), LJ(6), LJ(7)
     1   /1.103, 1.088, 1.014, 1.161, 0.998, 0.858, 0.937/
C *** UTILITIES COST INDEX FOR REGION J
      DATA   UJ(1), UJ(2), UJ(3), UJ(4), UJ(5), UJ(6), UJ(7)
     1   /1.32,  0.82,  0.90,  0.90,  1.30,  0.95,  1.20/
C *** FACILITIES COST INDEX FOR REGION J
      DATA   BJ(1), BJ(2), BJ(3), BJ(4), BJ(5), BJ(6), BJ(7)
     1   /1.062, 0.969, 1.052, 1.000, 1.114, 0.938, 0.927/
C *** CONSTRUCTION COST INDEX FOR REGION J
      DATA   CJ(1), CJ(2), CJ(3), CJ(4), CJ(5), CJ(6), CJ(7)
     1   /1.062, 0.969, 1.052, 1.000, 1.114, 0.938, 0.927/
C *** EQUIPMENT COST INDEX FOR REGION J
      DATA   EJ(1), EJ(2), EJ(3), EJ(4), EJ(5), EJ(6), EJ(7)
     1   /1.062, 0.969, 1.052, 1.000, 1.114, 0.938, 0.927/
C *** GA THROUGH GT ARE INFLATION RATES (%/YEAR) FOR THE FOLLOWING:
C     GA-RAW MATERIALS, GB-LABOR COST, GC-CHEMICAL COST, GD-COMMODI-
C     TIES, GE-ENERGY & UTILITIES, GG-LAND COST, GH-FACILITIES,
C     GI-CONSTRUCTION COST, GJ-EQUIPMENT, GF-RESOURCES, GT-TRANSPOR-
C     TATION, DG IS THE SOLAR PRODUCTS DEFLATION RATE (%/YEAR)
      DATA GA, GB, GC, GD, GE, GG, GH, GI, GJ, GF, GT, DG
     1   /0.11,0.08,0.13,0.08,0.12,0.04,0.09,0.08,0.07,0.15,0.07,0.06/
C *** ANNUAL COMPENSATION RATE FOR DIRECT SALES SUPPORT PERSONNEL
C     (BASE PRICE YEAR $/YEAR/PERSON)
      DATA   AC(1), AC(2), AC(3), AC(4), AC(5), AC(6)
     1    /35917., 16761., 34284., 25713., 25713., 23809./
C *** REQUIREMENT COEFFICIENT FOR DIRECT SALES SUPPORT PERSONNEL
      DATA   RC(1), RC(2), RC(3), RC(4), RC(5), RC(6)
     1   /2.0, 0.1, 0.4, 0.2, 0.2, 0.1/
C *** ANNUAL COMPENSATION RATE FOR SALESMEN TYPE I
C     (BASE PRICE YEAR $/YEAR/PERSON)
      DATA   CS(1), CS(2), CS(3)
     1   /24570., 32652., 43427./
C *** ANNUAL COMPENSATION RATE FOR INDIRECT SALES PERSONNEL
C     (BASE PRICE YEAR $/YEAR/PERSON)
      DATA   SAL(1), SAL(2), SAL(3), SAL(4), SAL(5), SAL(6), SAL(7), SAL(8),
     1   /81357., 52243., 52243., 52243., 52243., 18571., 19809., 21618./
C *** ADVERTISING RATE FOR CUSTOMER TYPE I (% OF MANUFACTURING PRICE)
      DATA   ADE(1), ADE(2), ADE(3)
     1   /0.02, 0.01, 0.001/
C *** SPP IS THE AMOUNT OF OFFICE SPACE PER PERSON (SQ. METERS/PERSON)
C     GAMMAO IS THE OFFICE FACILITIES LEASE RATE (% OF CAPITAL COST/YEAR)
C     RHOO IS THE OFFICE UTILITIES COST RATE ($/SQ. METER/YEAR)
C     OM IS THE OFFICE MAINTENANCE COST RATE (% OF CAPITAL COST/YEAR)
C     BETA IS THE PROPERTY TAX RATE (% OF CAPITAL COST/YEAR)
C     MU IS THE INSURANCE RATE (% OF CAPITAL COST/YEAR)
C     TB IS THE BASE PRICE YEAR
      DATA SPP, GAMMAO, RHOO, OM, BETA, MU, TB
     1   /12.45, 0.126, 1.89, 0.01, 0.04, 0.01, 1981/
```

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C *** INDIRECT PERSONNEL STAFFING REQUIREMENTS MATRIX
      DATA   RM(1,1),  RM(1,2), RM(1,3), RM(1,4), RM(1,5), RM(1,6),
     1   RM(1,7), RM(1,8)  /8 * 0.00/
      DATA   RM(1,9), RM(1,10), RM(1,11), RM(1,12), RM(1,13), RM(1,14),
     1   RM(1,15) /7 * 0.00/
      DATA   RM(1,16), RM(1,17)
     1  /2 * 0.00/
      DATA   RM(2,1), RM(2,2), RM(2,3), RM(2,4), RM(2,5), RM(2,6),
     1   RM(2,7), RM(2,8)  /8* 0.00/
      DATA   RM(2,9), RM(2,10), RM(2,11), RM(2,12), RM(2,13), RM(2,14),
     1   RM(2,15) /7 * 0.00/
      DATA   RM(2,16), RM(2,17)
     1   /2 * 0.00/
      DATA   RM(3,1), RM(3,2), RM(3,4), RM(3,5), RM(3,6),
     1   RM(3,7), RM(3,8)  /8 * 0.00/
      DATA   RM(3,9), RM(3,10), RM(3,11), RM(3,12), RM(3,13), RM(3,14),
     1   RM(3,15) /7 * 0.00/
      DATA   RM(3,16), RM(3,17),
     1   /2 * 0.00/
      DATA   RM(4,1), RM(4,2), RM(4,3), RM(4,4), RM(4,5), RM(4,6),
     1   RM(4,7), RM(4,8) /8 * 0.00/
      DATA   RM(4,9), RM(4,10), RM(4,11), RM(4,12), RM(4,13), RM(4,14),
     1   RM(4,15) /7 * 0.00/
      DATA   RM(4,16), RM(4,17)
     1   /2 * 0.00/
      DATA   RM(5,1), RM(5,2), RM(5,3), RM(5,4), RM(5,5), RM(5,6),
     1   RM(5,7), RM(5,8) /8 * 0.00/
      DATA   RM(5,9), RM(5,10), RM(5,11), RM(5,12), RM(5,13), RM(5,14),
     1   RM(5,15) /7 * 0.00/
      DATA   RM(5,16), RM(5,17)
     1   /2 * 0.00/
      DATA   RM(6,1), RM(6,2), RM(6,3), RM(6,4), RM(6,5), RM(6,6),
     1   RM(6,7), RM(6,8) /8 * 0.00/
      DATA   RM(6,9), RM(6,10), RM(6,11), RM(6,12), RM(6,13), RM(6,14),
     1   RM(6,15) /7 * 0.00/
      DATA   RM(6,16), RM(6,17)
     1   /2 * 0.00/
      DATA   RM(7,1), RM(7,2), RM(7,3), RM(7,4), RM(7,5), RM(7,6),
     1   RM(7,7), RM(7,8) /8 * 0.00/
      DATA   RM(7,9), RM(7,10), RM(7,11), RM(7,12), RM(7,13), RM(7,14),
     1   RM(7,15) /7 * 0.00/
      DATA   RM(7,16), RM(7,17)
     1   /2 * 0.00/
      DATA   RM(8,1), RM(8,2), RM(8,3), RM(8,4), RM(8,5), RM(8,6),
     1   RM(8,7), RM(8,8) /8 * 0.00/
      DATA   RM(8,9), RM(8,10), RM(8,11), RM(8,12), RM(8,13), RM(8,14),
     1  RM(8,15) /7 * 0.00/
      DATA   RM(8,16), RM(8,17)
     1   /2 * 0.00/
      DATA  RM(9,1), RM(9,2), RM(9,3), RM(9,4), RM(9,5), RM(9,6),
     1   RM(9,7), RM(9,8) /8 * 0.00/
      DATA   RM(9,9), RM(9,10), RM(9,11), RM(9,12), RM(9,13), RM(9,14),
     1   RM(9,15) /7 * 0.00/
```

```
 DATA   RM(9,16), RM(9,17)
1   /2 * 0.00/
 DATA   RM(10,1), RM(10,2), RM(10,3), RM(10,4), RM(10,5), RM(10,6),
1   RM(10,7)  /7 * 0.00/
 DATA   RM(10,8), RM(10,9), RM(10,10), RM(10,11), RM(10,12), RM(10,13),
1   RM(10,14) /3 * 0.00, 4 * 0.25/
 DATA   RM(10,15), RM(10,16), RM(10,17)
1   /3 * 0.00/
 DATA   RM(11,1), RM(11,2), RM(11,3), RM(11,4), RM(11,5), RM(11,6),
1   RM(11,7)  /4 * 0.00, 0.1111, 2 * 0.00/
 DATA   RM(11,8), RM(11,9), RM(11,10), RM(11,11), RM(11,12), RM(11,13),
1   RM(11,14) /0.00, 0.1667, 5 * 0.00/
 DATA   RM(11,15), RM(11,16), RM(11,17)
1   /3 * 0.00/
 DATA   RM(12,1), RM(12,2), RM(12,3), RM(12,4), RM(12,5), RM(12,6),
1   RM(12,7) /5 * 0.00, 0.1667, 0.00/
 DATA   RM(12,8), RM(12,9), RM(12,10), RM(12,11), RM(12,12), RM(12,13),
1   RM(12,14) /7 * 0.00/
 DATA   RM(12,15), RM(12,16), RM(12,17)
1   /3 * 0.00/
 DATA   RM(13,1) RM(13,2), RM(13,3), RM(13,4), RM(13,5), RM(13,6)
1   RM(13,7) /0.1111, 0.1667, 0.25, 4 * 0.00/
 DATA   RM(13,8), RM(13,9), RM(13,10), RM(13,11), RM(13,12), RM(13,13),
1   RM(13,14) /7 * 0.00/
 DATA   RM(13,15), RM(13,16), RM(13,17)
1   /3 * 0.00/
 DATA   RM(14,1), RM(14,2), RM(14,3), RM(14,4), RM(14,5), RM(14,6),
1   RM(14,7) /3 * 0.00, 0.1111, 2 * 0.00, 0.1111/
 DATA   RM(14,8), RM(14,9), RM(14,10), RM(14,11), RM(14,12), RM(14,13),
1   RM(14,14) /0.1111, 6 * 0.00/
 DATA   RM(14,15), RM(14,16), RM(14,17)
1   /3 * 0.00/
 DATA   RM(15,1), RM(15,2), RM(15,3), RM(15,4), RM(15,5), RM(15,6),
1   RM(15,7) /0.1111, 0.1667, 0.25, 2 * 0.00, 0.25, 0.00/
 DATA   RM(15,8), RM(15,9), RM(15,10), RM(15,11), RM(15,12), RM(15,13),
1   RM(15,14) /0.00, 0.25, 5 * 0.00/
 DATA   RM(15,15), RM(15,16), RM(15,17)
1   /3 * 0.00/
 DATA   RM(16,1), RM(16,2), RM(16,3), RM(16,4), RM(16,5), RM(16,6),
1   RM(16,7) /7 * 0.00/
 DATA   RM(16,8), RM(16,9), RM(16,10), RM(16,11), RM(16,12), RM(16,13),
1   RM(16,14) /3 * 0.00, 4 * 0.50/
 DATA   RM(16,15), RM(16,16), RM(16,17)
1   /3 * 0.00/
 DATA   RM(17,1), RM(17,2), RM(17,3), RM(17,4), RM(17,5), RM(17,6),
1   RM(17,7) /7 * 0.00/
 DATA   RM(17,8), RM(17,9), RM(17,10), RM(17,11), RM(17,12), RM(17,13),
1   RM(17,14) /2 * 0.00, 1.00, 4 * 0.00/
 DATA   RM(17,15), RM(17,16), RM(17,17)
1   /3 * 0.00/
```

M&D PROGRAM STANDARD DATA

```
C *** INTERREGIONAL SHIPPING DISTANCE MATRIX (KILOMETERS)
      DATA   S(1,1), S(1,2), S(1,3), S(1,4), S(1,5), S(1,6), S(1,7)
     1   /000.0, 640.0, 2788.0, 3057.0, 4344.0, 3540.0, 2293.0/
      DATA   S(2,1), S(2,2), S(2,3), S(2,4), S(2,5), S(2,6), S(2,7)
     1   /640.0, 000.0, 2100.0, 2782.0, 3595.0, 3036.0, 1652.0/
      DATA   S(3,1), S(3,2), S(3,3), S(3,4), S(3,5), S(3,6), S(3,7)
     1  /2788.0, 2100.0, 000.0, 644.0, 1770.0, 1609.0, 1064.0/
      DATA   S(4,1), S(4,2), S(4,3), S(4,4), S(4,5), S(4,6), S(4,7)
     1   /3057.0, 2782.0, 644.0, 000.0, 1287.0, 965.0, 1207.0/
      DATA   S(5,1, S(5,2), S(5,3), S(5.4), S(5,5), S(5,6), S(5,7)
     1   /4344.0, 3595.0, 1770.0, 1287.0, 000.0, 1527.0, 2414.0/
      DATA   S(6,1), S(6,2), S(6,3), S(6,4), S(6,5), S(6,6), S(6,7)
     1   /3540.0, 3036.0, 1609.0, 965.0, 1529.0, 000.0, 1287.0/
      DATA   S(7,1), S(7,2), S(7,3), S(7,4), S(7,5), S(7,6), S(7,7)
     1   /2293.0, 1652.0, 1064.0, 1207.0, 2414.0, 1287.0, 000.0/
C *** INTRAREGIONAL SHIPPING DISTANCE MATRIX - THE AVERAGE DISTANCE FROM
C     WAREHOUSE TO CUSTOMER AND THE AVERAGE DISTANCE BETWEEN CONSECTUVIE
C     CUSTOMERS ON DELIVERY TRIPS (KILOMETERS)
      DATA   Y(1,1), Y(1,2), Y(1,3), Y(1,4), Y(1,5), Y(1,6), Y(1,7)
     1   /7 * 50.0/
      DATA   Y(2,1), Y(2,2), Y(2,3), Y(2,4), Y(2,5), Y(2,6), Y(2,7)
     1   /7 * 50.0/
      DATA   Y(3,1), Y(3,2), Y(3,3), Y(3,4), Y(3,5), Y(3,6), Y(3,7)
     1   /7 * 50.0/
C *** WC IS THE VEHICLE LOAD CAPACITY (KILOGRAMS/VEHICLE)
C     MC IS THE VEHICLE DISTANCE CAPACITY (KILOMETERS/VEHICLE/YEAR)
C     FC IS THE ANNUAL FIXED COST PER VEHICLE ($/VEHICLE/YEAR)
C     VC IS THE VARIABLE OPERATING COST PER VEHICLE ($/KILOMETER)
C     OP IS THE WAREHOUSE ORDER PROCESSING COST ($/ORDER)
C     ALPHA IS THE WAREHOUSE SPACE UTILIZATION FACTOR
C     (CUBIC METERS OF PRODUCT/SQUARE METER WAREHOUSE)
C     PHI IS THE ANNUAL INVENTORY CARRYING CHARGE RATE
C     (% OF PRODUCT VALUE/YEAR)
      DATA   WC, MC, FC, VC, OP, ALPHA, PHI
     1   /8000.0, 75000.0, 31510.2, 0.125, 68.0, 0.25, 0.3775/
C *** GAMMAE IS THE ANNUAL LEASE RATE FOR EQUIPMENT
C     (% OF CAPITAL COST/YEAR)
C     GAMMAB IS THE ANNUAL LEASE RATE FOR BUILDINGS
C     (% OF CAPITAL COST/YEAR)
C     RHOW IS THE UTILITIES COST RATE ($/SQUARE METER/YEAR)
C     BETAW IS THE PROPERTY TAX RATE (% OF CAPITAL COST/YEAR)
C     MUW IS THE INSURANCE RATE (% OF CAPITAL COST/YEAR)
C     M IS THE MAINTENANCE COST RATE (% OF CAPITAL COST/YEAR)
      DATA GAMMAE, GAMMAB, RHOW, BETAW, MUW, M
     1   /0.25, 0.126,  1.89, 0.04, 0.01, 0.01/
C***  MATRIX FOR CUSTOMER TYPE AND REGION; ARRAY OF DISTRIBUTION OPTIONS
      DATA   XX(1,1), XX(1,2), XX(1,3), XX(1,4)
     1   /0.0, 1.0, 0.0, 0.0/
      DATA   XX(1,5), XX(1,6), XX(1,7), XX(1,8)
     1   /1.0, 1.0, 0.0, 1.0/
```

```
      DATA   XX(2,1), XX(2,2), XX(2,3), XX(2,4)
     1   /0.0, 1.0, 1.0, 0.0/
      DATA  XX(2,5), XX(2,6), XX(2,7), XX(2,8)
     1   /1.0, 0.0, 1.0, 0.0/
      DATA  XX(3,1), XX(3,2), XX(3,3), XX(3,4),
     1   /0.0, 1.0, 0.0, 1.0/
      DATA  XX(3,5), XX(3,6), XX(3,7), XX(3,8)
     1   /0.0, 1.0, 1.0, 0.0/
C *** INVENTORY CARRYING RATE (% OF PRODUCT VALUE/YEAR)
      DATA PHIF/.3775/
C *** EFFECTIVE INCOME TAX RATE (% OF NET PROFIT/YEAR)
      DATA   TAU/.51/
C *** MINIMUM REQUIRED RATE OF RETURN ON EQUITY
      DATA   RHO/.172/
C *** FINANCIAL LEVERAGE RATIO (TOTAL CAPITAL/EQUITY CAPITAL)
      DATA   LAMDA/1.2/
C *** AVERAGE INVENTORY TURNOVER TIME (MONTHS)
      DATA   ALFA/1.5/
C *** AVERAGE EXPENSE COVERAGE TIME(MONTHS)
      DATA   BETAF/6.0/
C *** DEBT INTEREST RATE (%/YEAR)
      DATA   DIB/.129/
C *** MODES OF TRANSPORTATION
      DATA   TRUCK (1), RAIL (1), DIRECT(1)
     1   /4HTRUC, 4H RAI, 4HDIRE/
      DATA   TRUCK(2), RAIL(2), DIRECT(2)
     1   /4HK   , 4HL   , 4HCT  /
C *** GEOGRAPHIC AREAS
      DATA   REGION(1,1), REGION(1,2), REGION(1,3), REGION(1,4), REGION(1,5)
     1   /4H    , 4HWEST, 4H COA, 4HST  , 4H    /
      DATA   REGION(2,1), REGION(2,2), REGION(2,3), REGION(2,4), REGION(2,5)
     1   /4H    , 4HROCK, 4HY MO, 4HUNTA, 4HIN  /
      DATA   REGION(3,1), REGION(3,2), REGION(3,3), REGION(3,4), REGION(3,5)
     1   /4H    , 4HNORT, 4HH CE, 4HNTRA, 4HL   /
      DATA   REGION(4,1), REGION(4,2), REGION(4,3), REGION(4,4), REGION(4,5)
     1   /4H    , 4HGREA, 4HT LA, 4HKES , 4H    /
      DATA   REGION(5,1), REGION(5,2), REGION(5,3), REGION(5,4), REGION(5,5)
     1   /4H    , 4HNORT, 4HH EA, 4HSTER, 4HN   /
      DATA   REGION(6,1), REGION(6,2), REGION(6,3), REGION(6,4), REGION(6,5)
     1   /4H    , 4HSOUT, 4HH EA, 4HSTER, 4HN   /
      DATA   REGION(7,1), REGION(7,2), REGION(7,3), REGION(7,4), REGION(7,5)
     1   /4H    , 4HSOUT, 4HH CE, 4HNTRA, 4HL   /
C *** MARKETING AND DISTRIBUTION CENTERS
      DATA   CITY(1,1), CITY(1,2), CITY(1,3)
     1   /4HLOS , 4HANGE, 4HLES /
      DATA   CITY(2,1), CITY(2,2), CITY(2,3)
     1   /4HPHOE, 4HNIX , 4H    /
      DATA   CITY(3,1), CITY(3,2), CITY(3,3)
     1   /4HOMAH, 4HA   , 4H    /
```

```
      DATA   CITY(4,1), CITY(4,2), CITY(4,3)
     1   /4HSPRI, 4HNGFI, 4HELD /
      DATA   CITY(5,1), CITY(5,2), CITY(5,3)
     1   /4HSYRA, 4HCUSE, 4H    /
      DATA   CITY(6,1), CITY(6,2), CITY(6,3)
     1   /4HATLA, 4HNTA , 4H    /
      DATA   CITY(7,1), CITY(7,2), CITY(7,3)
     1   /4HDALL, 4HAS  , 4H    /
C *** CUSTOMER TYPE
      DATA   CUST(1,1), CUST(1,2), CUST(1,3), CUST(1,4)
     1  /4HRESI, 4HDENT, 4HIAL , 4H    /
      DATA   CUST(2,1), CUST(2,2), CUST(2,3), CUST(2,4)
     1   /4HINTE, 4HRMED, 4HIATE, 4H    /
      DATA   CUST(3,1), CUST(3,2), CUST(3,3), CUST(3,4)
     1   /4HCENT, 4HRAL , 4HSTAT, 4HION /
C *** ANNUAL COMPENSATION FOR WAREHOUSE PERSONNEL
      DATA   SALD(1), SALD(2), SALD(3), SALD(4), SALD(5)
     1   /29182.5, 14965.4, 18380.2, 22856.2, 18648.2/
C *** DISTRIBUTION ALTERNATIVES
      DATA   FACTRY(1), FACTRY(2), FACTRY(3), FACTRY(4)
     1   /4HFACT, 4HORY , 4HDIRE, 4HCT  /
      DATA   WAREHS(1), WAREHS(2), WAREHS(3), WAREHS(4)
     1   /4HWARE, 4HHOUS, 4HE   , 4H    /
C *** GEOGRAPHIC AREAS
      DATA   REGIN(1,1), REGIN(1,2), REGIN(1,3), REGIN(1,4)
     1   /4H W, 4HEST, 4HCOAS, 4HT   /
      DATA   REGIN(2,1), REGIN(2,2), REGIN(2,3), REGIN(2,4)
     1   /4H ROC, 4HKY M, 4HOUNT, 4HAIN /
      DATA   REGIN(3,1), REGIN(3,2), REGIN(3,3), REGIN(3,4)
     1   /4H NO, 4HRTH , 4HCENT, 4HRAL /
      DATA   REGIN(4,1), REGIN(4,2), REGIN(4,3), REGIN(4,4)
     1   /4H G, 4HREAT, 4H LAK, 4HES  /
      DATA   REGIN(5,1), REGIN(5,2), REGIN(5,3), REGIN(5,4)
     1   /4H NO, 4HRTH, 4HEAST, 4HERN/
      DATA   REGIN(6,1), REGIN(6,2), REGIN(6,3), REGIN(6,4)
     1   /4H SO, 4HUTH, 4HEAST, 4HERN/
      DATA   REGIN(7,1), REGIN(7,2), REGIN(7,3), REGIN(7,4)
     1   /4H SO, 4HUTH, 4HCENT, 4HRAL/
C *** CUSTOMER TYPE
      DATA   CUSTOM(1,1), CUSTOM(1,2), CUSTOM(1,3), CUSTOM(1,4),
     1   CUSTOM(1,5), CUSTOM(1,6)
     2   /4H RE,4HSIDE, 4HNTIA, 4HL HO, 4HUSEH, 4HOLD/
      DATA   CUSTOM(2,1), CUSTOM(2,2), CUSTOM(2,3), CUSTOM(2,4),
     1   CUSTOM(2,5), CUSTOM(2,6)
     2   4HINTE, 4HRMED, 4HIATE, 4H COM, 4HMERC, 4HIAL/
      DATA   CUSTOM(3,1), CUSTOM(3,2), CUSTOM(3,3), CUSTOM(3,4),
     1   CUSTOM(3,5), CUSTOM(3,6)
     2   /4HCENT, 4HRAL, 4HSTAT, 4HION, 4HUTIL, 4HITY/
```

The standard parameters listed above are contained in the block data subprogram to facilitate the changing of values to represent the specific circumstances of the user. These values are then passed to other subprograms through common blocks.

Many of the standard parameters like salaries are expressed in dollar units for a base price year. The year is currently set at 1981 for all of these parameters measured in dollars.

In processing the data, the program adjusts these dollar values from the base price year to the manufacturing year using the appropriate inflation rate:

INFLATION RATES

GA	Raw Materials	11%
GB	Labor	8%
GC	Chemicals	13%
GD	Commodities	8%
GE	Energy & Utilities	12%
GG	Land	4%
GH	Facilities	9%
GI	Construction	8%
GJ	Equipment	7%
GF	Resources	15%
GT	Transportation	7%

4. Future Contingencies/Improvements - The M&D model using a macroanalytic approach makes possible the cost effective evaluation of a wide range of alternative marketing strategies and distribution programs. It has benefits for both government policy analysis and corporate strategic planning. This utility could be enhanced by the following future contingencies and improvements:

- Multiple Products - The program is designed for single product companies, but could be expanded to handle vertically integrated companies suppling a variety of solar products or distributors handling many components.

- International Markets - The program is currently limited to domestic United States markets. The seven geographic regions could be extended to include international markets in other countries of the world.

- Distribution Channels - The model currently assumes that the company salesman sell directly to the final customer. The product is shipped either from the factory or from a regional warehouse to the installation site. The model could be modified to cover other distribution channels such as wholesalers, retailers, architects, and construction contractors.

- Warehouse Utilization - The hypothetical company leases warehouse space exclusively for the single product. Another alternative might be to share warehouse space by storing several system components such as optical systems, PV receivers, inverters, regulators, batteries and frames.

- Code Subroutine Data - The subroutine functions could be coded with symbolic coefficients in the equations to facilitate maintaining the data and changing values.

- Overlay Structure - No overlay structure has been imposed at the cost of greater storage requirements. The users may wish to implement a dynamic overlay structure to reduce the storage required by the subroutines. This is more important on non-virtual memory machines since it is done to some extent automatically by a virtual operating system.

With these improvements and additional ideas from users, the M&D model would become a more useful analytical tool capable of supporting detailed parametric investigation of integrated marketing and distribution options in a variety of hypothetical or real scenarios.

B. Program Specifications

The program has been written using straightforward programming techniques. Twelve subprograms other than library routines are employed to compute repetitive model calculations. Common blocks are used to permit the sharing of memory by two or more program units and to specify the dimensions of arrays that occupy these areas. This memory is conserved by avoiding more than one allocation of memory for variables and arrays used by several program units; and arguments can be transferred implicitly between the calling program and a subprogram.

The amount of memory required and the units of measurement are extremely dependent on the type of hardware. The units used throughout this manual are bytes for IBM hardware. Each byte consists of eight bits and four byters or 32 bits make up one word. Users on non-IBM machines must translate the memory requirements given in this manual by an appropriate conversion factor provided by the equipment manufacturer.

The arrangement of variables and arrays in the M&D program common blocks is summarized on the following pages. There are 15 labeled common blocks ranging in size from 12 bytes to 2312 bytes. The total memory occupied is 8736 bytes assuming 4 bytes per word.

The following charts show the variable names and array dimensions in order by memory location for each common block. A checklist of the subprograms which share these common block memory areas is also shown. The labeled common blocks are the same size, and the same variables are specified in each subprogram.

The variables appearing in labeled common blocks are all input parameters for the marketing, distribution, and financial subprograms. The block data subprogram sets these variables equal to their standard values using data initialization statements. These statements are non-executable, and blank common variables are not allowed in them.

The variables IN and OUT refer to the card reader and line printer logical unit numbers, respectively. These variables are used in all read and write statements in the program, and are initialized in the block data subprogram. The standard values are 5 for the card reader and 6 for the line printer.

The type of variable corresponds to the type of data the variable represents. The following predefined type specifications apply to all variables which are not explicity defined in the program:

- if the first character of the variable name is L, J, K, L, M, or N, the variable is integer of full word length.
- if the first character of the variable name is any other alphabetic character, the variable is real of full word length.

In addition to these implicit type specifications, the following variables are explicitly defined in the main program:

REAL *4	where *4 indicates single precision.
REAL *8	where *8 indicates double precision.
INTEGER *4	where *4 indicates single precision.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	REGIND
BLOCK SIZE	144 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	MARKET DISTRB BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	LJ(8) = regional labor cost index UJ(7) = regional utilities cost index BJ(7) = regional facilities cost index CJ(7) = regional construction cost index EJ(7) = regional equipment cost index

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	INFLTE
BLOCK SIZE	48 bytes*
SUBROUTINES WHICH SHARE THE MEMORY	MARKET DISTRB FINANC BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	GA = raw materials inflation rate GB = labor inflation rate GC = chemicals inflation rate GD = commodities inflation rate GE = energy & utilities inflation rate GG = land inflation rate GH = facilities inflation rate GI = construction inflation rate GJ = equipment inflation rate GF = resources inflation rate GT = transportation inflation rate DG = deflation rate

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	MKTDST
BLOCK SIZE	216 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	MAIN MARKET DISTRB FINANC BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	D(5,9) = total annual demand in region (J) by customer (I) PRICE(3)= manufacturing price for customer (1) TB = base price year TM = manufacturing year TR = report year IN = logical unit specifying location of data input OUT= logical unit specifying location of data output RUNTYP = specifies which subprograms to run

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	MKT
BLOCK SIZE	140 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	MARKET FINANC
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	AC(6) = annual compensation rates for direct sales personnel RC(6) = requirement coefficients for direct support personnel CS(3) = annual compensation rates for salesmen SAL(8)= annual compensation rates for indirect personnel SAE(3)= sales expense rates ADE(3)= advertising rates SPP = amount of office space per person GAMMO = sales office facilities lease rate RHOO = sales office utilities cost rate OM = sales office maintenance cost rate BETA = sales office property tax rate MU = sales office insurance rate

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	MAINM
BLOCK SIZE	12 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	MAIN MARKET BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	AOQ(3) = average order quantity for customer (1)

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	MAIND
BLOCK SIZE	52 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	MAIN DISTRB FINANC BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	ADQ(3) = average delivery quantity for customers (1) WT = product weight V = product volume XXX(7) = array specifying how to choose distribution options for each region JR = factory location region

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	MKTFIN
BLOCK SIZE	368 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	MAIN FINANC BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	MPRICE(3,8) = marketing price as a function of customer type (1) and region (J) DSC(9) = total direct sales personnel cost in region (J) CIS(9) = annual indirect sales personnel cost in region (J) SEC(9) = annual sales expense cost in region (J) ORC(8) = sales office rental expenses in region (J) OUC(8) = sales office utilities expense in region (J) OMC(8) = sales office maintenance expense in region (J) OOC(8) = other office expenses in region (J) SAC(9) = annual advertising cost in region (J)

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	DISFIN
BLOCK SIZE	988 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	DISTRB FINANC BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	DC(7,9) = annual distribution cost in region (J) for customers supplied directly from the factory in region (JR) T(7,4) = annual transportation cost for shipments from the factory to the warehouse in region (J) L(7,4) = total annual local or inter-regional delivery cost in region (J) PC(8) = warehouse personnel cost UC(8) = warehouse utilities cost MCC(8) = warehouse maintenance cost XSC(8) = other warehouse operating cost LC(9,4)= warehouse leasing cost CC(9,4)= annual inventory carrying cost as a function of the warehouse order quantity in region (J) DPRICE(3,8) = distribution price estimates by customer (I)

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	RQMT
BLOCK SIZE	1156 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	TOTPER BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	RM(17,17) = indirect personnel requirements matrix

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	INV
BLOCK SIZE	1156 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	INVERT MATMUL BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	ENVERS(17,17) = resulting matrix from INVERT subroutine

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	ENV
BLOCK SIZE	2312 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	INVERT ROWCHK BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	ENVRTR(17,34) = matrix used to invert a matrix in INVERT subroutine

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	MINRM
BLOCK SIZE	1156 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	INVERT BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	RO(17,17) = indirect personnel staffing matrix used in subroutine TOTPER

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	DISTRI
BLOCK SIZE	752 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	MATMUL FINANC
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	S(7,7) = average shipping distance from region (JR) to region (J) Y(3,7) = intraregional shipping distance matrix WC = vehicle load capacity MC = vehicle distance capacity FC = annual fixed cost per vehicle VC = variable operating cost per vehicle OP = warehouse order processing cost ALPHA = warehouse space utilization factor GAMMAE = annual lease rate for equipment GAMMAB = annual lease rate for building RHOW = warehouse utility cost rate BETAW = warehouse property tax rate MUW = warehouse insurance rate M = warehouse maintenance cost rate PHI = annual inventory carying charge rate XX(3,8)= array of distribution options FACTRY(4) = literal factory direct WAREHS(4) = literal warehouse REGION(7,5) = literal array of region names CITY(7,3) = literal warehouse city for each region CUST(3,4) = literal array of customer types SALD(5) = annual compensation for warehouse personnel

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	TRANS
BLOCK SIZE	24 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	DISTRB BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	TRUCK(2) = shipping mode TRUCK RAIL(2) = shipping mode RAIL DIRECT(2)= shipping mode DIRECT

*Assuming 4 bytes per word.

M&D PROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	FIN
BLOCK SIZE	212 Bytes*
SUBROUTINES WHICH SHARE THE MEMORY	FINANC BLOCK
VARIABLE NAMES AND ARRAY DIMENSIONS (in order by memory location)	PHIF = financial inventory carrying rate TAU = effective income tax rate RHO = rate of return on equity LAMDA= leverage ratio ALFA = average inventory turnover time BETAF= average expense coverage time DIB = debt interest rate REGIN(7,4) = literal array of region names CUSTOM(3,6)= literal array of customer types

*Assuming 4 bytes per word.

C. Operating Environment

Hardware: The program was developed and tested at Universal Studios in Hollywood, California on an IBM 3033 computer with an MVS operating system and 4 megabytes of "real" core memory and 16 megabytes of virtual memory. The program has also been designed to be compatible with the CDC 6600 machine at Sandia National Laboratories. This machine is a product of Control Data Corporation, and has a 60 bit word configuration, while the IBM computer is a 32 bit word machine. Hence, the program should compile on any machine with at least 32 bits per word and 6 bits per character.

To be compatible with many different compilers, the program has been written in standard ANSI FORTRAN IV and tested using the following compilers: IBM FORTRAN (Levels G and H extended), WATFIV, and CDC FTN4. The program is written in the 49-character set accepted by FORTRAN. Thus, it can be run using several different language processors with little or no reprogramming.

Machine Components: The source program statements are stored on a 9-track magnetic tape at 1600 BPI using the EBCDIC character codes. The records are unblocked. All input data is read in card format via either a card reader or terminal. All output is sent to a line printer. No files are created on tape or disk.

Memory Requirements: On the IBM 3033 at Universal Studios, the program requires 128K bytes of memory to execute, while using the IBM FORTRAN IV Level H extended language processor with the no-optimization option. At 4 bytes per word, this is equivalent to 32K words. The memory storage allocations are:

M&D PROGRAM MEMORY REQUIREMENTS*

Main Program	1 K bytes		
Market Subprogram	24 K		
Distribution Subprogram	34 K		
Finance Subprogram	27 K		
Subroutines	7 K		
Total Coded		93 K bytes	
Canned Routines		23 K	
Total Program		116 K	
Labeled Common	9 K bytes		
I/O Buffers	3 K		
Total Data			12 K
Total Core		128 K bytes	

User	25 K words
IBM	7 K words
Total	32 K words

*Based on 4 bytes per word using an IBM FORTRAN H Extended Compiler with the no-optimization option.

The total data size including I/O buffers is 12K bytes. When the optimization option of the FORTRAN H compiler was used, the memory required to execute was reduced from 128K to 112K bytes, or 28K words. The program needs more memory on the CDC 6600 which is not a virtual memory machine.

Run Time: The M&D program required 2 minutes 51 seconds to compile, and an additional 1 minute 11 seconds to execute on the IBM 3033 computer using the IBM FORTRAN IV Level H extended language processor with the no-optimization option. Run time is extremely machine and compiler dependent and will vary substantially.

Library Routines: Three FORTRAN-supplied library routines are called by the program. These are standard mathematical functions, and are well-documented in many FORTRAN IV language publications.

SQRT (x) = Square root of x.

AINT (x) = Next higher integer value to x.

FLOAT(x) = Floating point value of integer x.

III SUBPROGRAMS

A. Marketing Subprogram

The marketing subprogram computes the costs of selling solar energy products. These include:

- Sales personnel salaries
- Office facilities cost
- Sales expenses
  - travel and entertainment
  - communications
  - office supplies
- Advertising expenses.

This section presents the marketing subprogram assumptions, input data requirements, and output reports. Following are the key assumptions of the marketing subprogram summarized in Exhibit III-A.

The marketing submodel is strictly a supply side model. No attempt is made to model the interaction of supply and demand. If demand in all categories is assumed known, this procedure gives the associated marketing costs. Hence, sales volume is assumed to be completely inelastic or independent of the product prices. The manufacturing costs are specified as input by the user. The use of different input data allows the measurement of the impact on costs of increased or reduced volume.

The country is divided into seven market regions and the total annual sales volume in each region is specified as input by the user. The total annual sales volume is assumed to be constant in each region.

Marketing costs are assumed to vary for different types of customers. Customers are described completely by their location and average order size in megawatts. The model allows for a maximum of three types of customers or products. The total sales volume for each customer type in each region is specified as input by the user along with the average order quantity for each customer type.

Regional sales offices are assumed to be located in every region where the sales volume is greater than zero. Marketing costs vary with customer location. The distribution submodel, however, computes the cost of warehousing and delivering the product to the customer.

MARKETING SUBPROGRAM SYSTEM SCHEMATIC

EXHIBIT III-A

INPUT DATA

- Average order size for each customer type
- Demand for each customer type in each region
- Price of manufactured product for each customer
- Manufacturing year, reporting year
- Run type indicator

STANDARD DATA - MARKETING PARAMETERS

- Logical units specifying location of data for input and output
- Labor cost index for each region
- Utilities cost index for each region
- Facilities cost index for each region
- Construction cost index
- Equipment cost index for each region
- Inflation rates for raw materials, labor cost, chemical cost, commodities, energy, utilities, land cost, facilities, and transportation
- Solar products deflation rate (%/year)
- Base price year
- Annual compensation rate for direct sales personnel
- Requirement coefficient for direct sales support personnel
- Annual compensation rate for each type of salesman
- Annual compensation rate for indirect sales personnel
- Sales expense rate for each type of customer
- Advertising rate for each type of customer
- Amount of office space per person (square meters/person)
- Office facilities lease rate (% of capital cost)
- Office utilities cost rate ($/square meter/year)
- Office maintenance cost rate (% of capital cost)
- Property tax rate (% of capital cost)
- Insurance rate (% of capital cost)
- Base price year
- Indirect staffing requirements matrix (17x17)

MARKET SUBPROGRAM

Compute costs of selling solar energy products

- Sales personnel salaries
  - salesman
  - direct support
  - indirect staff
- Office facilities cost
  - rent
  - maintenance
  - utilities
  - other
- Sales expenses
  - travel
  - entertainment
  - communication
- Advertisng expenses

OUTPUT REPORTS

- MSR-1: Market Demand Distribution
- MSR-2: Marketing Expense Summary
- MSR-3: Marketing Personnel Summary
- MSR-4: Sales Office Facilities
- MSR-5: Marketing Price Estimates
- MSR-6: Marketing Submodel Parameters

TOTPER SUBROUTINE

Given the direct sales personnel vector DV and the indirect staffing matrix RM compute the total personnel vector TV

MATMUL SUBROUTINE

Compute the total personnel vector TV given the direct personnel vector DV and the inverter matrix I-RM where RM is the 17x17 indirect staffing requirements matrix

KO SUBROUTINE

Determine the office facilities capital cost, KO, as a function of the office size

INVERT SUBROUTINE

Invert the I-RM matrix where I is the 17x17 identity matrix and RM is the 17x17 indirect staffing matrix

MWS SUBROUTINE

Determine salesman productivity in megawatts/year/person as a function of average order size in megawatts per order

ROWCHK SUBROUTINE

Switch rows in the matrix ENVRTR to assist in the inversion of the indirect staffing requirements matrix

SSI SUBROUTINE

Determine salesman support index SSI as a function of the average order size A in megawatts

Following is a list of input variables for the marketing submodel:

AOQ(I)	=	Average order quantity for customer type I (in megawatts per order).
for I	=	1, 2, and 3.
D(I,J)	=	Total annual demand in region J by customers of type I (in megawatts per year).
for I	=	1, 2, and 3.
and J	=	1, 2, ..., and 7.
PRICE(I)	=	Manufacturing price for customers of type I (manufacturing year dollars/watt).
for I	=	1, 2, and 3.
TM	=	Manufacturing year for which marketing costs are computed.
TR	=	Report year for which dollars are reported on output reports.
RUNTYP	=	Indicates whether or not the marketing subprogram should be executed.

Given this input data, the model computes the total annual marketing cost in each region. The total cost consists of the following components:

Marketing Expense	Model Symbol
Salaries and Benefits	
• Direct Personnel	DSC(J)
• Indirect Personnel	CIS(J)
Sales Expenses	SEC(J)
• Office Supplies	
• Travel and Entertainment	
• Communications	
Office Facilities Costs	OFC(J)
• Office Rental	
• Utilities	
• Maintenance	
• Other Expenses (e.g., insurance)	
Advertising Expense	SAC(J)
• Household Products	
• Commercial Products	
• Utility Products	

Salaries and Benefits: To compute salaries and benefits for the regional sales and marketing office, personnel are divided into three categories:

- Salesmen
  - household products
  - commercial products
  - central power stations
- Direct Support Personnel
  - field engineers
  - market research analysts
  - technical writers
  - commercial artists
  - technical illustrators
  - advertising salesman
- Indirect Support Personnel
  - regional vice president
  - manager, customer engineering
  - manager, advertising
  - manager, market research
  - manager, product sales
  - secretary level I
  - secretary level II
  - secretary level III

The number of salesmen required is determined by the total demand and average order size separately for each customer type.

The number of direct support personnel is determined by the number of salesmen and average order size for each type of customer recognizing that different classes of customers have different support requirements.

The remainder of the people are considered to be indirect support personnel. The number required is computed from the number of salesman and direct support personnel.

Sales Expense: Sales expenses for supplies, travel, entertainment and communications are computed separately for each type of product based on the number of salesman.

Office Facilities Costs: The size of the office facilities required is determined from the number of people. Based on this size, costs are computed for rent, utilities, maintenance, and other office expenses.

Advertising Expense: Similarly, advertising expenses are computed as a percent of the cost of goods sold for each type of product. This percentage varies to allow different advertising strategies for different products.

Common block segments utilized by this marketing subprogram include:

MARKETING SUBPROGRAM

COMMON BLOCK NAME	BLOCK SIZE (BYTES)*	VARIABLE NAMES AND ARRAY DIMENSIONS (In Order by Memory Location)	SUBROUTINES WHICH SHARE THE MEMORY				
			MARKET	TOTPER	INVERT	ROWCHK	MATMUL
REGIND	144	LJ(8), UJ(7), BJ(7), CJ(7), EJ(7)	X				
INFLTE	48	GA, GB, GC, GD, GE, GG, GH, GI, GJ, GF, GT, DG	X				
MKTDST	216	D(5,9), PRICE(3), TB, TM, TR, IN, OUT, RUNTYP	X				
MKT	140	AC(6), RC(6), CS(3), SAL(8), SAE(3), ADE(3) SPP, GAMMAO, RHOO, OM, BETA, MU	X				
MAINM	12	AOQ(3)	X				
MKTFIN	368	MPRICE(3,8), DSC(9), CIS(9), SEC(9), ORC(8), OUC(8), OMC(8), OOC(8), SAC(9)	X				
RQMT	1156	RM(17,17)		X			
INV	1156	ENVERS(17,17)			X		X
ENV	2312	ENVRTR(17,34)			X	X	
MINRM	1156	RO(17,17)			X		
TOTAL MEMORY	6708						

*assumes 4 bytes per word.

The market subprogram uses seven subroutines with the following statistics:

SUBROUTINE NAME	NUMBER OF SOURCE STATEMENTS	PROGRAM SIZE (BYTES)	MEMORY REQUIREMENTS (BYTES)
KO	16	474	63
TOTPER	26	970	63
MWS	10	332	63
INVERT	34	1150	67
SSI	10	336	63
ROWCHK	19	622	63
MATMUL	10	480	63
TOTAL	125	4364	445

The market subprogram itself consists of 402 source statements. The program size is 25,408 bytes and 368 bytes of memory are required with 4 bytes per word.

Output generated by the marketing subprogram consists of the following variables:

SR(I,J) = Total number of salesman required in region J for customers of type I.

DSP(KD,J) = Total direct sales support personnel type KD required in region J.

DSC(J) = Total direct sales personnel cost in region J (manufacturing year $/year).

ISP(KI,J) = Number of indirect sales support personnel of type KI required in region J.

CIS(J) = Annual indirect sales personnel cost in region J (manufacturing year $/year).

OS(J) = Sales office size in region J (square meters).

CAPO(J) = Office capital cost (manufacturing year $/year).

ORC(J) = Office rental expense in region J (manufacturing year $/year).

OMC(J) = Office maintenance expense in region J (manufacturing year $/year).

OOC(J) = Other office expenses in region J (manufacturing year $/year).

OFC(J) = Total annual office facility costs in region J (manufacturing year $/year).

SEC(J) = Annual sales expense cost in region J (manufacturing year $/year).

SAC(J) = Annual advertising cost in region J (manufacturing year $/year).

TSC(J) = Total indirect sales cost in region J (manufacturing year $/year).

OUC(J) = Office utilities expense (manufacturing year $/year).

SPRSN(J) = Total sales personnel in region J.

MPRICE(I,J) Marketing price per watt as a function of customer type and region (manufacturing year $/watt).

The marketing subprogram generates the following six output reports:

- MSR-1 - Market Demand Distribution Report: total annual demand in megawatts by customer type and region. This report also lists the average order quantity in megawatts for each customer type.

- MSR-2 - Marketing Expense Summary Report: annual cost for salaries and benefits, sales expenses, office facilities and advertising for each regional marketing office.

- MSR-3 - Marketing Personnel Summary Report: number of people required for salesman, direct support staff, secretaries and management in each regional marketing office. This report also lists annual compensation rates for each position.

- MSR-4 - Sales Office Facilities Report: office size (square meters), total people, initial capital cost, annual operating expenses including lease, utilities, maintenance and other for each regional marketing office.

- MSR-5 - Marketing Price Estimates Report: total cost of marketing expressed in $/watt by customer type and market region.

The model computes the alternative which minimizes the total annual distribution cost. In a given region, some types of customers may be supplied directly from the factory and others from a regional warehouse. There will not necessarily be a warehouse in every region, unless it is calculated to be economical to have one.

The size of the regional warehouses is optimized by computing the economic warehouse order quantity based on their assumed demand. This balances the number of shipments with the size of the warehouse. Transportation costs are reduced by having larger warehouses requiring fewer shipments. However, warehouse operating and inventory holding costs are higher. The problem is to compute the warehouse order quantities for each customer to minimize the total annual distribution cost.

The model assumes a single factory whose regional location is specified by the user. Multiple factory locations can be modeled by restricting the distribution demand and making separate runs for each factory.

For a given manufacturing factory, the distribution demand is specified as input. The demand is described in total megawatts per year in each region J by customer type I, (D(I,J)), and in megawatts per shipment by customer type I (ADQ(I)). Following is a list of input variables for the distribution submodel:

ADQ(I)	=	Average delivery quantity for customer type I (megawatts/shipment).
for I	=	1, 2, and 3.
D(I,J)	=	Total annual demand in region J by all customers of type I (megawatts/year).
for I	=	1, 2, and 3.
and J	=	1, 2, 3, ..., and 7.
PRICE(I)	=	Manufacturing price for customers of type I (manufacturing year dollars/watt).
for I	=	1, 2, and 3.
V	=	Solar product volume (cubic meters/megawatt).
W	=	Solar product weight (kilograms/megawatt).
JR	=	Factory location region.
XXX(J)	=	Warehouse constraint indicator for region J.
for J	=	1, 2, 3, ..., and 7.

DISTRIBUTION SUBPROGRAM SYSTEM SCHEMATIC

EXHIBIT III-B

INPUT DATA

- Average delivery quantity for each customer type
- Demand for each customer type in each region
- Price of manufactured product for each customer
- Product weight and volume
- Warehouse constraint indicator for each region
- Factory location
- Manufacturing year, reporting year
- Run type indicator

STANDARD DATA - DISTRIBUTION PARAMETERS

- Logical units specifying location of data for input and output
- Labor cost index for each region
- Utilities cost index for each region
- Facilities cost index for each region
- Construction cost index for each region
- Equipment cost index for each region
- Inflation rates for raw materials, labor cost, chemical cost, commoditie, energy, utilities, land cost, facilities, and transportation
- Solar products deflation rate (%/year)
- Base price year
- Interregional shipping distance matrix
- Intraregional shipping distance matrix
- Vehicle load capacity (kilograms/shipment)
- Vehicle distance capacity (kilometers/vehicle/year)
- Annual fixed cost per vehicle ($/vehicle/year)
- Variable operating cost per vehicle ($/kilometer)
- Warehouse order processing cost ($/shipment)
- Warehouse space utilization factor
- Annual inventory carrying charge rate (% product value)
- Annual lease rate for equipment (% of capital cost)
- Annual lease rate for warehouse building
- Warehouse utility cost rate ($/square meter/year)
- Warehouse property tax rate (% of capital cost/year)
- Warehouse insurance rate (% of capital cost/year)
- Warehouse maintenance cost rate (% of capital cost/year)
- Annual compensation rates for warehouse personnel
- Distribution options matrix for each customer type and region

DISTRB SUBPROGRAM

Compute distribution expenses
- salaries
- transportation costs
- warehouse operating costs
- inventory carrying charges

Compute network configuration
- warehouse location
- inventory levels
- distribution alternatives
- transportation modes

OUTPUT REPORTS

- DSR-1: Customer Demand Distribution
- DSR-2: Distribution Expense Summary
- DSR-3: Distribution Network Configuration
- DSR-4: Warehouse Facilities
- DSR-5: Alternative Distribution Costs
- DSR-6: Economic Warehouse Order Quantity
- DSR-7: Distribution Price Estimates
- DSR-8: Distribution Submodel Parameters

PEOPLE SUBROUTINE

Determine total warehouse personnel (PEOPLE) as a function of the warehouse size F in square meters

KE SUBROUTINE

Determine the equipment capital cost KE as a function of the warehouse size F in square meters

KB SUBROUTINE

Determine the building and land capital cost KB as a function of the warehouse size F in square meters

P SUBROUTINE

Determine the warehouse personnel cost P as a function of the warehouse size F in square meters

C SUBROUTINE

Determine the interregional transportation cost C as a function of the average shipment weight Q in kilograms and the shipping distance S in kilometers

TM	=	Manufacturing year.
TR	=	Reporting year.
RUNTYP	=	Run type indicator.

From this input, the model computes the total annual distribution cost for each region. This corresponds to the least cost combination of direct shipments and warehouse transshipments and the economic warehouse size.

The total consists of the following components:

Distribution Expense	Model Symbol
• Salaries and benefits	PC(J)
• Transportation costs	
- direct factory shipments	DC(J)
- warehouse shipments	T(J,Q)
- local delivery	L(J)
• Warehouse facility costs	W(J,Q)
- building lease	
- utilities	
- other expenses	
• Inventory carrying charges	CC(J,Q)

Transportation costs depend more on weight than on volume. However, at low weights volume becomes the determining factor. For a given weight, the model determines the least cost transportation mode: rail or truck.

Transportation costs are assumed to depend only on distance and weight and are independent of the geographic relationship between the origin and destination.

It is assumed that the manufacturer has finished goods storage space at the factory and that the associated costs are part of the manufacturing price.

The warehouse inventory model for the regional distribution centers assumes uniform, deterministic demand over time. Penalty costs for stockouts are assumed to be sufficiently high so that stockouts are not allowed. This implies that the warehouse must be large enough to supply all demand on time. Furthermore, there are no manufacturing price discounts for large order quantities, although the distribution price is lower.

The optimal warehouse order quantity, Q*(J) is determined by varying the order quantity parametrically (over a broad range), computing the corresponding warehouse size and distribution costs for each quantity, and selecting the quantity which yields the lowest annual distribution cost. This is repeated for all possible combinations of direct and indirect shipments, X(I,J). The optimal value X*(I,J) is the combination which yields the lowest total cost. The corresponding warehouse order quantity is the optimal value, Q*(J). Symbolically, the total annual distribution cost is computed as follows:

X*(I,J)	=	0	if customers of type I in region J are supplied directly from the factory.
		1	if customers of type I in region J are supplied from a warehouse in region J.
F*(J)	=		Optimal warehouse size in region J (square meters).
Q*(J)	=		Optimal warehouse order quantity in region J (megawatts/shipment).
Total Annual Distribution Cost	=		DC(JR,J) + IC(JR,J,Q*(J))

where

IC(JR,J,Q*(J))	=	Annual distribution cost in region J for customers supplied from a regional warehouse in region J with transshipments of size Q from the factory in region JR (manufacturing year dollars/year.
DC(JR,J)	=	Annual distribution cost in region J for customers supplied directly from the factory in region JR (manufacturing year $/year).

Common block segments utilized by the distribution subprogram include:

DISTRIBUTION SUBPROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	BLOCK SIZE (BYTES)*	VARIABLE NAMES AND ARRAY DIMENSIONS (IN ORDER BY MEMORY LOCATION)
REGIND	144	LJ(8), UJ(7), BJ(7), CJ(7), EJ(7)
INFLTE	48	GA, GB, GC, GD, GE, GG, GH, GI, GJ, GF, GT, DG
MKTKST	216	D(5,9), PRICE(3), TB, TM, TR, IN, OUT, RUNTYP
MAIND	52	ADQ(3), WT, V, XXX(7), JR
DISFIN	988	DC(7,9), T(7,4), L(7,4), PC(8), UC(8), MCC(8), XSC(8), LC(9,4), CC(9,4), DPRICE(3,8)
DISTRI	752	S(7,7), Y(3,7), WC, MC, FC, VC, OP, ALPHA, GAMMAE, GAMMAB, RHOW, BETAW, MUW, M, PHI, XX(3,8), FACTRY(4), WAREHS(4), REGION(7,5), CITY(7,3) CUST(3,4), SALD(5)
TRANS	24	TRUCK(2), RAIL(2), DIRECT(2)
TOTAL MEMORY	2224	

*assumes 4 bytes per word.

The distribution subprogram uses five subroutines with the following statistics:

SUBROUTINE NAME	NUMBER OF SOURCE STATEMENTS	PROGRAM SIZE (BYTES)	MEMORY REQUIREMENTS (BYTES)
C	23	664	67
KE	10	336	63
KB	12	374	63
P	14	412	63
PEOPLE	14	416	63
TOTAL	73	2202	319

The distribution subprogram itself consists of 576 source statements. The program size is 35,800 bytes and 534 bytes of memory are required assuming 4 bytes per word.

Output generated by the distribution subprogram consists of the following variables:

IK	=	Indicator for distribution run option to specify which alternatives should be evaluated.
QQ	=	1/26th of the annual demand supplied from the warehouse.
DC(J,K)	=	Annual cost in region J for direct shipments for each distribution K alternative (manufacturing $/year).
KM(J)	=	Local delivery travel distance in region J (kilometers/year).
TK(J)	=	Vehicle fleet size in region J (vehicles).
FDC(J,KK)	=	Fixed delivery cost in region J for distribution alternative KK (manufacturing year $/year).
VDC(J,KK)	=	Variable delivery cost in region J for distribution alternative KK (manufacturing year $/year).
L(J,KK)	=	Total annual local or intraregional delivery cost in region J for distribution alternative KK (manufacturing year $/year).
SHPCST(J,KK)		Transportation costs for shipping from the factory to the warehouse in region J for distribution alternative KK (manufacturing year $/year).
OPC(J,KK)	=	Order processing cost in region J (manufacturing year $/year).
F(J)	=	Warehouse size in region J (square meters).
LC(J,KK)	=	Warehouse leasing cost in region J for distribution alternative KK (manufacturing year $/year).
KC(J,KK)	=	Building, land, and equipment capital cost in region J for distribution alternative KK (manufacturing year $).
PC(J)	=	Warehouse personnel cost in region J (manufacturing year $/year).

UC(J)	=	Warehouse utilities cost in region J (manufacturing year $/year).
MCC(J)	=	Warehouse maintenance cost in region J (manufacturing year $/year).
XSC(J)	=	Other warehouse operating costs for taxes and insurance in region J (manufacturing year $/year).
OC(J,KK)	=	Annual warehouse operating cost in region J for distribution alternative KK (manufacturing year $/year).
CC(J,KK)	=	Annual inventory carrying cost in region J for distribution alternative KK (manufacturing year $/year).
W(J,KK)	=	Annual warehousing cost in region J (manufacturing year $/year).
IC(J,KK)	=	Total annual distribution cost for region J warehouse transshipments from the factory in region JR (manufacturing year $/year).
TAC(J,K)	=	Total annual distribution costs in region J for distribution alternative K (manufacturing year $/year.
SMODE(J,KK,LLL)		Factory shipping mode to region J.
TWP(J)	=	Total warehouse personnel in region J.
FREQ(J)	=	Factory shipping frequency to region J (years).
AIL(J)	=	Average inventory level in region J (megawatts).
DPRICE(I,J)	=	Distribution price per watt as a function of customer type and region (manufacturing year $/watt).
WTDUSE	=	Weighted average use of warehouse facility.
TRKUSE	=	Weighted average use of trucks.

The distribution subprogram generates the following eight output reports:

- DSR-1 - Customer Demand Distribution Report: total annual demand in megawatts by customer type and geographic region. This report also lists the average delivery quantity in megawatts for each customer type and the number of deliveries per year.

- DSR-2 - Distribution Expense Summary Report: annual cost for transportation, warehouse operations, warehouse lease expense and inventory carrying charges for each regional distribution center.

- DSR-3 - Distribution Network Configuration Report: regional warehouse locations, factory shipping mode, shipping frequency, warehouse size in square meters, average inventory level in megawatts, number of delivery trucks, and number of warehouse personnel.

- DSR-4 - Warehouse Facilities Report - warehouse size in square meters, total people, initial capital cost maintenance and other, lease expense and inventory carrying charges for each regional distribution center.

- DSR-5 - Alternative Distribution Costs Report: annual cost for direct shipments, annual cost for transshipments and total annual distribution cost for each of the eight combinations of distribution alternatives for a given distribution region.

- DSR-6 - Economic Warehouse Order Quantity Function: as a function of four different levels of warehouse order quantity in megawatts, this report lists annual transportaion costs, annual warehousing cost and annual delivery cost for a given region.

- DSR-7 - Distribution Price Estimates Report: total cost of distribution expressed in $/watt by customer type and geographic region.

- DSR-8 - Distribution Submodel Parameters Report: this report lists various parameters used by the distribution submodel such as warehouse personnel requirements, annual compensation rates, warehouse space utilization factor, maintenance cost rate, utility cost rate, insurance cost rate, property tax rate, equipment lease rate, and building lease rate.

C. Financial Subprogram

The financial subprogram consists of the equations to compute sales revenues, taxes, and profit based on manufacturing costs and M&D expenses. The model parameters are expressed in standard financial statement terms to facilitate the preparation of projected income statements for each region. These terms include:

- Sales
- Cost of goods sold
- Expenses
  - distribution
  - marketing
- Income tax
- Net profit after tax

This section presents the financial subprogram assumptions, input data requirements, and output reports. The financial subprogram is summarized in Exhibit III-C.

Following is a list of input variables for the financial submodel:

- D(I,J) = total annual demand in region J by all customers of type I (megawatts/year).
- PRICE(I) = manufacturing price of product for customers of type I (manufacturing year $/watt).
- JR = factory location region.
- TM = manufacturing year.
- TR = report year for which dollars are reported on output reports.
- RUNTYP = run type indicator
  (=1 for distribution only)
  (=2 for marketing only)
  (=3 for both marketing and distribution).

The financial submodel combines the user specified cost of goods sold with marketing and distribution expenses from the marketing and distribution submodels. Marketing and distribution costs consist of the following components:

FINANCIAL SUBPROGRAM SYSTEM SCHEMATIC

EXHIBIT III-C

INPUT DATA

- Demand for each customer type in each region
- Price of manufactured product for each customer type
- Factory location
- Manufacturing year
- Reporting year
- Run type indicator

FINANC SUBPROGRAM

Compute projected income statements
- Revenues
- Cost of goods sold
- Gross profit
- M&D expenses
- Income taxes
- Profit

Compute solar product price estimates
- By customer type
- By geographic region

Compute key financial indicators
- Markup by customer
- Profit margin

OUTPUT REPORTS

- FSR-1: Consolidated Income Statement
- FSR-2: Schedule A - Distribution Expenses
- FSR-3: Schedule B - Marketing Expenses
- FSR-4: Regional Income Statements
- FSR-5: Delivered Price Estimates
- FSR-6: Delivered Price Estimates
- FSR-7: Key Financial Indicators
- FSR-8: General M&D Model Parameters

STANDARD DATA - FINANCIAL PARAMETERS

- Logical units specifying location of data for input and output
- Base price year
- Inflation rates for raw materials, labor cost, chemical cost, commodities, energy, utilities, land cost, facilities, and transportation
- Solar products deflation rate (%/year)
- Finance inventory carrying rate (% product value)
- Effective income tax rate (% of income)
- Minimum required rate of return on equity
- Financial leverage ratio (total capital/equity)
- Average inventory turnover time (months)
- Average expense coverage time (months)
- Debt interest rate (%/year)

MARKET SUBPROGRAM

MPRICE - marketing price per watt as a function of customer type and region (manufacturing year $/watt)

DSC - total direct sales personnel cost by region (manufacturing year $/year)

SEC - annual sales expense cost by region (manufacturing year $/year)

ORC - office rental expense by region (manufacturing year $/year)

OUC - office utilities expense by region (manufacturing year $/year)

OMC - office maintenance expense by region (manufacturing year $/year)

OOC - other office expenses by region (manufacturing year $/year)

CIS - annual indirect sales personnel cost by region (manufacturing year $/year)

SAC - annual advertising cost by region (manufacturing year $/year)

DISTRB SUBPROGRAM

DC - annual distribution cost by region for customers supplied directly from the factory (manufacturing year $/year)

T - annual transportation cost for shipments from the factory to the warehouse by region (manufacturing year $/year)

L - total annual local or intraregional delivery cost by region (manufacturing year $/year)

PC - warehouse personnel cost (manufacturing year $/year)

UC - warehouse utilities cost (manufacturing year $/year)

MCC- warehouse maintenance cost (manufacturing year $/year)

XSC- other warehouse operating cost - taxes and insurance (manufacturing year $/year)

LC - warehouse leasing cost (manufacturing year $/year)

CC - annual inventory carrying cost as a function of the warehouse order quantity by region (manufacturing year $/year)

DPRICE-distribution price estimates by customer (manufacturing year $/watt)

Market Subprogram Expenses	Model Symbol
• marketing price per watt as a function of customer type and region (manufacturing year $/watt).	MPRICE
• total direct sales personnel cost by region (manufacturing year $/year).	DSC
• annual sales expense cost by region (manufacturing year $/year).	SEC
• office rental expense by region (manufacturing year $/year).	ORC
• office utilities expense by region (manufacturing year $/year).	OUC
• office maintenance expense by region (manufacturing year $/year).	OMC
• other office expenses by region (manufacturing year $/year).	OOC
• annual indirect sales personnel cost by region (manufacturing year $/year).	CIS
• annual advertising cost by region (manufacturing year $/year).	SAC

Distrb Subprogram Expenses	Model Symbol
• distribution price estimates by customer (manufacturing year $/watt).	DPRICE
• annual distribution cost by region for customers supplied directly from the factory (manufacturing year $/year).	DC
• annual transportation cost for shipments from the factory to the warehouse by region (manufacturing year $/year).	T
• total annual local or intraregional delivery cost by region (manufacturing year $/year).	L
• warehouse personnel cost (manufacturing year $/year).	PC
• warehouse utilities cost (manufacturing year $/year).	UC
• warehouse maintenance cost (manufacturing year $/year).	MCC
• other warehouse operating cost - taxes and insurance (manufacturing year $/year).	XSC
• warehouse leasing cost (manufacturing year $/year).	LC
• annual inventory carrying cost as a function of the warehouse order quantity by region (manufacturing year $/year).	CC

Working capital requirement: The financial submodel computes the amount of working capital required for inventories and a cash reserve to cover fixed expenses.

$$\text{Average Working Capital} = \text{Average Inventory Value} + \text{BETAF} \times \text{Monthly M\&D Expenses}$$

where BETAF = risk coverage period (months).

Normative profit equation: Profit after tax is computed to earn a minimum required return on equity.

$$\text{Profit After Tax} = \frac{\text{RHO}}{\text{LAMDA}} \times \text{Average Working Capital}$$

where RHO = minimum required rate of return on equity.
and LAMDA = financial leverage ratio (total capital/equity).

Required revenue condition: Product prices are derived from the required revenue condition that annual revenues equal annual costs.

$$\text{Annual Revenue} = \text{Annual Costs}$$

$$\text{Product Price (\$/watt)} \times \text{Production Quantity (watts)} = \text{Cost of Goods Sold} + \text{Annual M\&D Expenses} + \text{Income Tax} + \text{Profit After Tax}$$

$$\text{Income Tax} = \frac{\text{TAU}}{1-\text{TAU}} \times \text{Profit After Tax}$$

where TAU = effective income tax rate.

These equations are solved for delivered product price.

Projected income statements: The financial submodel prepares projected income states listing the following items:

- revenues
- cost of goods sold
- gross profit
- M&D expenses
- income taxes
- profit after tax

The income statements are generated separately for each region and are also consolidated over all regions.

Delivered product prices: Delivered product prices are computed by dividing the annual sales revenue by the demand in each region for each product type. The result is expressed in dollars per watt for customer type I in region J. The price estimates include all manufacturing, marketing, and distribution expenses as well as taxes and a reasonable profit.

Key financial indicators: The model computes three key financial indicators:

$$\text{Markup} = \frac{\text{Revenue} - \text{Cost of Goods Sold}}{\text{Cost of Goods Sold}}$$

$$\text{Profit Margin} = \frac{\text{Profit After Tax}}{\text{Revenue}}$$

$$\text{Cost of Capital} = (1-TAU) \times (1-1/LAMDA) + (RHO/LAMDA) \times DIB$$

where
DIB = debt interest rate
TAU = effective income tax rate
LAMDA = financial leverage rate
RHO = minimum required rate of return on equity

Common block segments utilized by the financial subprogram include:

FINANCE SUBPROGRAM COMMON BLOCK USAGE

COMMON BLOCK NAME	BLOCK SIZE (BYTES)*	VARIABLE NAMES AND ARRAY DIMENSIONS (IN ORDER BY MEMORY LOCATION)
INFLTE	48	GA, GB, GC, GD, GE, GG, GH, GI, GJ, GF, GT, DG
MKDST	216	D(5,9), PRICE(3), TB, TM, TR, IN, OUT, RUNTYP
MAIND	52	ADQ(3), WT, V, XXX(7), JR
MKTFIN	368	MPRICE (3,8), DSC(9), CIS(9), SEC(9), ORC(8), OUC(8), OMC(8), OOC(8), SAC(9)
DISFIN	988	DC(7,9), T(7,4), L(7,4), PC(8), UC(8), MCC(8), XSC(8), LC(9,4), CC(9,4), DPRICE(3,8)
FIN	212	PHIF, TAU, RHO, LAMDA, ALFA, BETAF, DIB, REGIN(7,4), CUSTOM(3,6)
TOTAL MEMORY	1884	

*assumes 4 bytes per word.

The finance subprogram does not use any subroutines. It consists of 566 source statement. The program size is 27494 bytes and 203 bytes of memory are required with 4 bytes per word.

Output generated by the financial subprogram consists of the following variables:

TSB = total annual sales personnel cost (manufacturing year $/year).

STE = travel expense cost (manufacturing year $/year).

SCC = communications expense cost (manufacturing year $/year).

SOS = supplies expense cost (manufacturing year $/year).

TSC(J) = total indirect sales cost in region J (manufacturing year $/year).

TT = total transportation and distribution costs (manufacturing year $/year).

TAC(J,K)= total annual distribution cost in region J for distribution alternative K (manufacturing year $/year).

ACAP = after tax cost of capital (%/year).

AREGN = integer number equal to one plus the number of distribution regions.

ACUST = integer number equal to one plus the number of customer types.

APRICE = weighted average manufacturing price over all customer types (manufacturing year $/watt).

DSUM = sum of annual demand over all regions and customers (megawatts/year).

CGS(I,J)= annual manufacturing cost of goods sold for customer type I in region J (manufacturing year $/year).

TMX(I,J)= annual marketing expense for customer type I in region J (manufacturing year $/year).

TDX(I,J)= annual distribution expense for customer type I in region J (manufacturing year $/year).

NPA(I,J)= annual net profit after tax for customer type I in region J (manufacturing year $/year).

TAX(I,J)= annual income tax expense for customer type I in region J (manufacturing year $/year).

REV(I,J) = total annual revenue from customer type I in region J (manufacturing year $/year).

PPRICE(I,J)delivered product price estimates for customer type I in region J (manufacturing year $/watt).

MARK(J) = markup in region J (ratio of revenue less manufacturing cost to manufacturing cost).

PROF(J) = profit margin in region J (ratio of net profit after taxes to total revenue.

GROSS = gross profit (manufacturing year $/year).

TEXPEN = total expenses (manufacturing year $/year).

NPBT = net profit before taxes. (manufacturing year $/year).

The financial subprogram generates the following eight output reports:

- FSR-1 - Consolidated Income Statement Report: annual sales revenue by product class, cost of goods sold by product class, total marketing expenses, total distribution expenses, income tax and net profit after tax consolidated over all geographic regions.

- FSR-2 - Schedule A: Distribution Expenses Report: transportation warehouse operations, warehouse lease expense, inventory carrying charges, and total distribution expenses consolidated over all geographic regions.

- FSR-3 - Schedule B: Marketing Expenses Report: salaries and benefits, sales expenses including travel, entertainment, communications, and office supplies, office facilities, advertising and total marketing expenses consolidated over all geographic regions.

- FSR-4 - Regional Income Statements Report: sales revenues, cost of goods sold, marketing expenses, distribution expenses, income taxes, and net profit for each regional marketing office.

- FSR-5 - Delivered Price Estimates Report: delivered product prices expressed in $/watt and broken down by cost of goods sold, expenses, income taxes and net profit after tax consolidated over all geographic regions.

- FSR-6 - Delivered Price Estimates Report: delivered product prices expressed in $/watt for each type of customer by market region.

- FSR-7 - Key Financial Indicators Report - product markup for each type of customer by market region. This report also lists profit margins as a percent of sales for each market region. Other financial parameters include rate of return on equity, after tax cost of capital, financial leverage, corporate income tax rate, cost of debt capital, deflation rate, average inventory turnover time, average expense coverage time and inventory carrying charge rate.

- FSR-8 - General M&D Model Parameters Report: input data reported includes product manufacturing cost, manufacturing year, product volume, product weight, factory location region. Standard data reported includes base price year, deflation rate for solar products and inflation rates for raw materials, labor, chemicals, commodities, energy, facilities, construction, equipment, resources and transportation.

D. Block Data Subprogram

The block data subprogram contains values for all standard parameters used by the main program and marketing, distribution, and finance subprograms. The block data subprogram contains no executable statements. The data values are initialized in DATA statements and passed to the other subprograms through common blocks. Following is a list of the standard parameters:

IN = logical unit number specifying the location of input data for READ statements, e.g. card reader.

OUT = logical unit number specifying the location of output data for WRITE statements, e.g. line printer.

LJ(J)= labor cost index for region J.

UJ(J)= utilities cost index for region J.

BJ(J)= facilities cost index for region J.

CJ(J)= construction cost index for region J.

EJ(J)= equipment cost index for region J.

GA = raw materials inflation rate (%/year).

GB = labor cost inflation rate (%/year).

GC = chemical cost inflation rate (%/year).

GD = commodities cost inflation rate (%/year).

GE = energy and utilities cost inflation rate (%/year).

GG = land cost inflation rate (%/year).

GH = facilities cost inflation rate (%/year).

GI = construction cost inflation rate (%/year).

GJ = equipment inflation rate (%/year).

GF = resources inflation rate (%/year).

GT = transportation inflation rate (%/year).

DG = solar products deflation rate (%/year).

AC(KD) = annual compensation rate for direct sales personnel type KD (base price year $/year).

RC(KD) = requirement coefficient for direct sales support personnel type KD.

CS(I) = annual compensation rate for salesman type I (base price year $/year/person).

SAL(KI) = annual compensation rate for indirect sales personnel (base price year $/year/person).

SAE(I) = sales expense rate for customer type I (% of salaries).

ADE(I) = advertising rate for customer type I (% of manufacturing price).

SPP = amount of office space per person (square meters per person).

GAMMAO	= sales office facilities lease rate (% of capital cost/year).
RHOO	= sales office utilities cost rate ($/square meter/year).
OM	= sales office maintenance cost rate (% of capital cost/year).
BETA	= sales office property tax rate (% of capital cost/year).
MU	= sales office insurance rate (% of capital cost/year).
TB	= base price year.
RM(I,J)	= indirect staffing requirements matrix (17 rows x 17 columns).
S(JR,J)	= interregional shipping distance matrix (kilometers from region JR to region J).
Y(I,J)	= intraregional shipping distance matrix - average distance from warehouse to customer and the average distance between consecutive customers on a single delivery trip (kilometers to customer type I in region J).
WC	= vehicle load capacity (kilograms/shipment).
MC	= vehicle distance capacity (kilometers/vehicle/year).
FC	= annual fixed cost per vehicle ($/vehicle/year).
VC	= variable operating cost per vehicle ($/kilometer).
OP	= warehouse processing cost ($/order).
ALPHA	= warehouse space utilization factor (cubic meters of product per square meter of warehouse).
PHI	= annual inventory carrying charge rate (% of product value).
GAMMAE	= annual lease rate for equipment (% of capital cost/year).
GAMMAB	= annual lease rate for building (% of capital cost /year).
RHOW	= warehouse utility cost rate ($/square meter/year).

BETAW	= warehouse property tax rate (% of capital cost/year).
MUW	= warehouse insurance rate (% of capital cost/year).
M	= warehouse maintenance cost rate (% of capital cost/year).
SALD(KW)	= annual compensation rate for warehouse personnel type KW (base price year $/year).
XX(I,J)	= distribution options matrix for customer type I in region J.
PHIF	= finance inventory carrying rate (% of product value/year).
TAU	= effective income tax rate (% of net profit/year).
RHO	= minimum required rate of return on equity (%/year).
LAMDA	= financial leverage ratio (total capital/equity capital).
ALFA	= average inventory turnover time (months).
BETAF	= average expense coverage time (months).
DIB	= debt interest rate (%/year).
TRUCK	= literal print label for mode of transportation.
RAIL	= literal print label for mode of transportation.
DIRECT	= literal print label for mode of transportation.
REGION(J)	= literal print label for geographic region J.
CITY(J)	= literal print label for distribution center J.
CUSTOM(I)	= literal print label for customer type I.

IV INPUT REQUIREMENTS

User specified input for the M&D model is grouped together to facilitate alterations by user programmers. This also allows more cost efficient running of the program, by enabling the compile and link-edit functions to be separated from the actual execution of the program and report processing.

Exhibit IV-A M&D Model Input Sheet lists all data that must be specified by the user. It is organized into three sections:

- General Information - input data required for all options.
- Marketing - input data required for marketing
- Distribution - input data required for distribution.

Note, however, that even if the user does not desire all three options, all of the input data must be completed, using zeros where appropriate. This is also necessary in cases where there are less than three customer types and less than seven regions -zeros must be entered for the demand.

The information provided on the input sheet must then be transferred to computer cards in the format defined in Exhibit IV-B.

Cards 1, 2, and 3 specify the demand for each customer type in each region, and are listed in the following order: West Coast residential, intermediate, and public utility; Rocky Mountain residential, intermediate, and public utility; etc. for each region in the order listed on the model input sheet.

Cards 4, 5 and 6 are for the average order quantity, average delivery quantity, and manufacturing price for residential, intermediate, and public utility customers, in that order.

Card 7 provides five types of information: the manufacturing year, report year, solar product weight, solar product volume, and the factory location. The factory location is specified using a "1" for West Coast, "2" for Rocky Mountain region, etc.

Card 8 specifies determination of a warehouse in each region. A "0" is listed for each region in which the program should determine a warehouse, "1" for each region which is forbidden to have a warehouse, and "2" for each region which must have a warehouse. Column 1 is for the West Coast, column 2 for the Rocky Mountain Region, etc.

Card 9 is used to select the run option: "1" is for distribution only, "2" is for marketing only, and "3" is for marketing, distribution, and finance.

Card 10 is used to establish the product type: "1" is for power conditioning units and "2" is for photovoltaic collectors.

EXHIBIT IV-A

M&D MODEL INPUT SHEET - page 1 of 2

GENERAL INFORMATION

- Manufacturing Year 1986 Card 7
  (the steady-state year for which the marketing costs are computed)

- Report Year 1980 Card 7
  (the year in which dollars are expressed on the output reports)

- Run Type (check one) Card 9

  _____ 1. Distribution only

  _____ 2. Marketing only

  X 3. Marketing, Distribution, & Financial

- Demand by Customer Type and Region (megawatts per year) Cards 1,2,&3

	CUSTOMER TYPE		
MARKET REGION	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION
WEST COAST	5.0	2.5	5.0
ROCKY MOUNTAIN	6.0	3.0	5.0
NORTH CENTRAL	1.0	0.5	0.0
GREAT LAKES	1.0	0.5	0.0
NORTH EASTERN	2.0	1.0	5.0
SOUTH EASTERN	1.0	0.5	0.0
SOUTH CENTRAL	4.0	2.0	5.0

- Manufacturing Price by Customer Type Card 6
  (manufacturing year dollars per watt)

  Residential/Household .9929

  Commercial/Intermediate .9929

  Public Utility/Central Station .9929

EXHIBIT IV-A
M&D MODEL INPUT SHEET - page 2 of 2

MARKETING

- Average Order Quantity by Customer Type (megawatt per order) — Card 4

Residential/Household	.005
Commercial/Intermediate	.500
Public Utility/Central Station	5.00

DISTRIBUTION

- Solar Product Volume (cubic meters per megawatt) 10,200 — Card 7
- Solar Product Weight (kilograms per megawatt) 462,800 — Card 7
- Factory Location Region (check one) — Card 7

	West Coast		North Eastern
x	Rocky Mountain		South Eastern
	North Central		South Central
	Great Lakes		

- Average Delivery Quantity by Customer Type (megawatts per shipment) — Card 5

Residential/Household	.005	
Commercial/Intermediate	.500	
Public Utility/Central Station	5.00	Card 8

- Use of a Warehouse (put a 0 in each region for which the program should determine if a warehouse is wanted; 1 for each region which is forbidden to have a warehouse; and 2 for each region which must have a warehouse)

0	West Coast	0	North Eastern
0	Rocky Mountain	0	South Eastern
0	North Central	0	South Central
0	Great Lakes		

- Solar Product Type 1. _____ Power Conditioning Unit
  2. x Collector — Card 10

EXHIBIT IV-B

INPUT DATA CARD SPECIFICATIONS

Card	Parameter	Format	Columns	Description	Edit Criteria
1	D(I,J)	F8.2	1-80	Demand for each customer type (I) in each region (J) (megawatts/year)	$0.0 \leq D(I,J) \leq 100000.0$
2	D(I,J)	F8.2	1-80	Demand for each customer type (I) in each region (J) (megawatts/year)	$0.0 \leq D(I,J) \leq 100000.0$
3	D(I,J)	F8.2	1-8	Demand for each customer type (I) in each region (J) (megawatts/year)	$0.0 \leq D(I,J) \leq 100000.0$
4	AOQ(I)	F6.3	1-18	Average order quantity for customer type (I) (megawatts/order)	$0.0 \leq AOQ(I) \leq 100.0$
5	ADQ(I)	F6.3	1-18	Average delivery quantity for customer type (I) (megawatts/shipment)	$0.0 \leq ADQ(I) \leq 100.0$
6	PRICE(I)	F5.3	1-15	Manufacturing price for customer type (I) (manufacturing year dollars/watt)	$0.0 \leq PRICE(I) \leq 10.0$
7	TM	I6	1-6	Manufacturing year	$1980 \leq TM \leq 2000$
	TR	I6	7-12	Report year	$1980 \leq TR \leq 2000$
	WT	F8.0	13-20	Solar product weight (kilograms/megawatt)	$1000 \leq WT \leq 10000000$
	V	F9.3	21-29	Solar product volume (cubic meters/megawatt)	$100.0 \leq V \leq 100000.0$
	JR	I2	30-31	Factory location region	$1 \leq JR \leq 7$
8	XXX(J)	I1	1-7	Use of a warehouse in each region (J)	$0 \leq XXX(J) \leq 2$
9	RUNTYP	I4	4	Program run type	$1 \leq RUNTYP \leq 3$
0	PRODUC	I4	4	Product type	$1 \leq PRODUC \leq 2$

Following is the card image input data format for the photovoltaic concentrator collector used for the sample case described in Section VII.

CARD 1

5.0 2.5 5.0 6.0 3.0 5.0 1.0 0.5 0.0 1.0

CARD 2

0.5 0.0 2.0 1.0 5.0 1.0 0.5 0.0 4.0 2.0

CARD 3

5.0

CARD 4

0.005 0.500 5.000

CARD 5

0.005 0.500 5.000

CARD 6

0.9929 0.9929 0.9929

CARD 7

1986 1980 10200. 462800. 2

CARD 8

0000000

CARD 9

3

CARD 10

2

The program edits all input data for validity within the ranges shown on Exhibit IV-B. Values outside of the range causes immediate termination of the program with an error message stating the variable, the valid range and the user input value. If all input data is read within the edit ranges, then the data is printed out in two formats. The first is a mirror image of the input data card format. The second is a more user friendly listing with labels similar to those on the M&D model input sheet shown in Exhibit IV-A.

V OUTPUT REPORTS

A. MARKET Subprogram Reports

The market subprogram generates the following six output reports:

- MSR-1: Market Demand Distribution Report
- MSR-2: Marketing Expense Summary Report
- MSR-3: Marketing Personnel Summary Report
- MSR-4: Sales Office Facilities Report
- MSR-5: Marketing Price Estimates Report
- MSR-6: Marketing Submodel Parameters Report

MARKET DEMAND DISTRIBUTION *** MSR-1
(MW/YR)

MARKET REGION	CUSTOMER TYPE			TOTAL ANNUAL DEMAND	
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION	MW	(%)
WEST COAST	5.00	2.50	5.00	12.50	(25.0)
ROCKY MOUNTAIN	6.00	3.00	5.00	14.00	(28.0)
NORTH CENTRAL	1.00	0.50	0.00	1.50	(3.0)
GREAT LAKES	1.00	0.50	0.00	1.50	(3.0)
NORTH EASTERN	2.00	1.00	5.00	8.00	(16.0)
SOUTH EASTERN	1.00	0.50	0.00	1.50	(3.0)
SOUTH CENTRAL	4.00	2.00	5.00	11.00	(22.0)
TOTAL MW	20.00	10.00	20.00	50.00	
(%)	(40.0)	(20.0)	(40.0)	(100.0)	(100.0)
AVERAGE ORDER QUANTITY (MW)	0.005	0.500	5.000		

** Demand distribution assumed as input to the model

MSR-1 Market Demand Distribution - This is an array of the demand by region and customer type as specified by the user for input data. Total megawatt demand and percentages over all customers and all regions are calculated by the model. The average order quantity by customer type is also listed. Again, this is input data to the model. As can be seen for this example concentrator manufacturer, the demand distribution is 40% residential, 20% commercial and 40% utility.

MARKETING EXPENSE SUMMARY
(1980 $1,000/YEAR)

MSR-2

	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL REGIONS $1,000	(%)
SALARIES & BENEFITS									
Direct Personnel	$637	$733	$97	$112	$289	$82	$451	$2,401	(55.4)
Support Staff	289	332	44	50	131	37	204	1,087	(25.1)
GENERAL & ADMIN									
Sales & Expenses	94	108	15	17	42	12	66	353	(8.2)
-travel/entertain									
-communications									
-office supplies									
OFFICE FACILITIES	32	33	6	6	19	6	23	124	(2.9)
-lease									
-utilities									
-maintenance									
-other expenses									
ADVERTISING	91	109	18	18	9	18	74	364	(8.4)
TOTAL	$1,142	$1,315	$180	$202	$519	$155	$819	$4,331	(100.0)

MSR-2 Marketing Expense Summary - Salaries and benefits, as well as general and administrative expenses, are listed by region and consolidated over all regions. These are calculated from standard parameters and the indirect requirements matrix. For this example concentrator manufacturer, salaries and benefits account for the largest portion of marketing expenses, comprising 80.5% of the cost. Total marketing expenses are $4,331,000 per year over all regions.

MARKETING PERSONNEL SUMMARY MSR-3

JOB TITLE	ANNUAL COMPENSATION (1980$)*	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL ** REGIONS #	(%)
SALESMAN										
-Residential	$23267	10	12	2	2	4	2	8	40	(38.1)
-Commercial	30920	3	4	1	1	2	1	3	11	(9.9)
-Utility	41124	1	1	0	0	1	0	1	4	(3.7)
DIRECT SUPPORT										
-Field Engineer	34012	4	5	1	1	3	1	4	16	(14.5)
-Artist	15872	1	1	1	1	1	1	1	1	(0.7)
-Market Research	32465	1	1	1	1	1	1	1	4	(2.9)
-Illustrator	24349	1	1	1	1	1	1	1	2	(1.5)
-Technical Writer	24349	1	1	1	1	1	1	1	2	(1.5)
-Advertising	22546	1	1	1	1	1	1	1	1	(0.7)
SECRETARIES										
-Level I	17586	2	3	1	1	1	1	2	9	(7.7)
-Level II	18758	2	2	1	1	1	1	2	5	(4.7)
-Level III	20471	1	1	1	1	1	1	1	3	(2.4)
MANAGEMENT										
-VP	77042	1	1	1	1	1	1	1	3	(2.4)
-Advertising	49472	1	1	0	0	1	0	1	1	(0.2)
-Market Research	49472	1	1	1	1	1	1	1	1	(0.5)
-Sales	49472	2	3	1	1	1	1	2	8	(6.8)
-Sales Engineer	49472	1	1	1	1	1	1	1	3	(1.9)
TOTAL **		26	30	4	4	13	4	22	104	(100)

** Totals may not equal sum of numbers due to rounding.

MSR-3 Marketing Personnel Summary - This listing of all personnel needed to market the three product lines includes salesman, direct support staff, secretaries and management. Annual compensation rates in report year dollars, *include wages and 40% benefits, averaged over all regions. These average rates are adjusted by labor indices to compute annual sales personnel costs by region. The number of salesman required is computed from the demand by each type of customer and a salesman productivity function. The number of support personnel is computed from the number of salesman and the indirect staff requirements matrix. In this example for the concentrator company residential product salesman account for 38% of the total personnel. A total of 104 marketing personnel are required over all regions.

SALES OFFICE FACILITIES MSR-4

	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL REGIONS
OFFICE SIZE (square meters)	324	379	56	56	157	56	268	1295
TOTAL PEOPLE	26	30	4	4	13	4	22	104
CAPITAL COST (1980 $)	$164461	173974	32821	31199	98140	29264	121371	651231
OPERATING COSTS (1980 $/year)								
-Lease	20772	21921	4135	3931	12366	3687	15293	82055
-Utilities	1004	731	117	117	479	124	756	3328
-Maintenance	1645	1740	328	312	981	293	1214	6512
-Other	8223	8699	1641	1560	4907	1463	6069	32562
TOTAL ANNUAL OPERATING COSTS (1980 $/YEAR)	31593	33090	6222	5920	18733	5567	23331	124457

MSR-4 Sales Office Facilities - This report lists various statistics related to the regional sales office facilities including office size, total people, capital cost and total annual operating costs in report year dollars. Total personnel agrees with report MSR-3. In this case, the Rocky Mountain Region has the largest staff of 30 people which is approximately 29% of the total of 104. The demand is 14 megawatts which is 28% of the total of 50 megawatts.

MARKETING PRICE ESTIMATES
(1980 $/WATT)

MSR-5

MARKET REGION	CUSTOMER TYPE			
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION	TOTAL ANNUAL DEMAND MW (%)
WEST COAST	0.126	0.087	0.027	12.50 (25.0)
ROCKY MOUNTAIN	0.124	0.086	0.026	14.00 (28.0)
NORTH CENTRAL	0.118	0.081	0.000	1.50 (3.0)
GREAT LAKES	0.132	0.091	0.000	1.50 (3.0)
NORTH EASTERN	0.116	0.080	0.024	8.00 (16.0)
SOUTH EASTERN	0.102	0.070	0.000	1.50 (3.0)
SOUTH CENTRAL	0.109	0.075	0.023	11.00 (22.0)
AVERAGE	0.120	0.082	0.025	

MSR-5 Marketing Price Estimates - The estimated marketing price per watt for each type of customer in each region is also averaged over all regions. These prices are for marketing only and do not include manufacturing cost, distribution cost, income tax or profit. For the example concentrator company the highest price is $0.132 for residential customers in the Great Lakes region and lowest is 0.023 for utility customers in the South Central region.

SALES AND ADVERTISING EXPENSE RATES

CUSTOMER/PRODUCT TYPE	AVERAGE ORDER QUANTITY MW	SALES EXPENSE RATE %	ADVERTISING EXPENSE RATE %
Small Household Products	0.005	20.0	2.000
Intermediate Commercial Products	0.500	25.0	1.000
Large Central Power Stations	5.000	30.0	0.100

OFFICE FACILITIES COST PARAMETERS

Office Space Per Person	12.45 Square Meters Per Person
Office Capital Cost	$502.81 Per Square Meter (1980$)
Lease Rate	12.60 Percent of Captial Cost
Utilities Cost Rate	$1.69 Per Square Meter (1980$)
Maintenance Cost Rate	1.00 Percent of Capital Cost
Property Tax Rate	4.00 Percent of Capital Cost

MSR-6 Marketing Submodel Parameters - This report is basically a recapitulation of the important elements of standard data. Sales expenses for travel, entertainment, office supplies and communications are computed as a percent of salaries and benefits for marketing personnel. Similarly, advertising expenses are computed as a percent of the cost of goods sold. The percentages vary with the type of product.

B. DISTRB Subprogram Reports

The DISTRB Subprogram generates the following eight output reports:

- DSR-1: Customer Demand Distribution Report
- DSR-2: Distribution Expense Summary Report
- DSR-3: Distribution Network Configuration Report
- DSR-4: Warehouse Facilities Report
- DSR-5: Alternative Distribution Costs Report
- DSR-6: Economic Warehouse Order Quantity Function Report
- DSR-7: Distribution Price Estimates Report
- DSR-8: Distribution Submodel Parameters Report

CUSTOMER DEMAND DISTRIBUTION ** DSR-1
(MW/YR)

MARKET REGION	CUSTOMER TYPE			TOTAL ANNUAL DEMAND	
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION	MW	(%)
WEST COAST	5.00	2.50	5.00	12.50	(25.0)
ROCKY MOUNTAIN	6.00	3.00	5.00	14.00	(28.0)
NORTH CENTRAL	1.00	0.50	0.00	1.50	(3.0)
GREAT LAKES	1.00	0.50	0.00	1.50	(3.0)
NORTH EASTERN	2.00	1.00	5.00	8.00	(16.0)
SOUTH EASTERN	1.00	0.50	0.0	1.50	(3.0)
SOUTH CENTRAL	4.00	2.00	5.00	11.00	(22.0)
TOTAL MW	20.00	10.00	20.00	50.00	
(%)	(40.0)	(20.0)	(40.0)	(100.0)	(100.0)
AVERAGE DELIVERY QUANTITY (MW)	0.005	0.500	5.000		
NUMBER OF DELIVERIES PER YEAR	4000.00	20.00	4.00		

** Demand distribution assumed as input to the model

Factory Location: Rocky Mountain

DSR-1 Customer Demand Distribution - The demand distribution array is the same as the one generated in MSR-1. Also included is the average delivery quantity, and from this the number of deliveries per year are calculated. For example, the total utility demand is 20 MW, delivered in shipments of 5 MW, requiring 4 deliveries per year.

DISTRIBUTION EXPENSE SUMMARY DSR-2
(1980 $1,000/YEAR)

	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL REGIONS $1,000 (%)
TRANSPORTATION	537	346	215	271	1655	292	1089	4404 (90.9)
- Direct Shipments								
- Transshipments								
- Local Delivery								
WAREHOUSE OPERATIONS	57	0	43	49	45	37	46	276 (5.7)
- Salaries & Benefit								
- Utilities								
- Maintenance								
- Other Expenses								
WAREHOUSE LEASE EXPENSE	28	0	9	8	12	8	20	85 (1.8)
INVENTORY CARRYING CHARGE	25	0	8	8	10	8	20	79 (1.6)
TOTAL	647	346	274	336	1722	344	1175	4844 (100.0)

DSR-2 Distribution Expense Summary - An annual breakdown by region for transportation costs, warehouse operations, warehouse leasing expenses, and inventory carrying charges may be found in this report. For the example concentrator company, the total distribution expense is $4,844,000 per year. The bulk of the distribution expense is for transportation - 90.9%, with the North Eastern region incurring the largest share of the total expense.

REGIONAL WAREHOUSE LOCATION	FACTORY SHIPPING MODE/ FREQUENCY	WAREHOUSE SIZE (SQUARE METERS)	AVERAGE INVENTORY LEVEL (MW)	DELIVERY TRUCKS	WAREHOUSE PERSONNEL
West Coast Los Angeles	Rail 2.0 Weeks	490	0.10	1	2
Rocky Mountain Phoenix	Direct 0.0 Weeks	0	0.00	0	0
North Central Omaha	Rail 2.0 Weeks	147	0.03	1	2
Great Lakes Springfield	Rail 2.0 Weeks	147	0.03	1	2
North Eastern Syracuse	Rail 1.0 Weeks	196	0.04	1	2
South Eastern Atlanta	Rail 2.0 Weeks	147	0.03	1	2
South Central Dallas	Rail 2.0 Weeks	392	0.08	1	2
ALL REGIONS		1520	0.30	6	12

DSR-3 Distribution Network Configuration - The program determines which factory shipping modes - direct, truck, or rail - is most cost effective for each region, as well as the frequency of delivery. In addition, warehouse sizes are calculated according to the average inventory level, and from this.the number of delivery trucks and warehouse personnel are determined. Since the concentrator manufacturing factory is in the Rocky Mountain region, a ware house is not needed - there are only direct shipments. Every other region requires one delivery truck and two warehouse personnel.

WAREHOUSE FACILITIES DSR-4

	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL REGIONS
WAREHOUSE SIZE (Square Meters)	490	0	147	147	196	147	392	1520
TOTAL PEOPLE	2	0	2	2	2	2	2	12
CAPITAL COST (1980$)	$207229	$0	$63501	$60362	$89657	$56619	$145881	$623249
OPERATING COSTS (1980 $/Year)								
-Salaries & Benefits	42611	0	39173	44852	38555	33147	36199	234537
-Utilities	1520	0	311	311	599	328	1105	4174
-Maintenance	2072	0	635	604	897	566	1459	6232
-Other	10361	0	3175	3018	4483	2831	7294	31162
LEASE EXPENSE (1980 $/Year)	28288	0	8648	8221	12210	7711	19901	84980
Carrying Charges (1980 $/Year)	25410	0	7623	7623	10164	7623	20328	78770
TOTAL ANNUAL FACILITIES COSTS (1980 $/Year)	$110263	$0	$59565	$64628	$66908	$52206	$86286	$439856

DSR-4 Warehouse Facilities - This report is a breakdown of the total annual facilities costs in report year dollars. The warehouse sizes and number of personnel are listed for each region, and the capital cost is derived by the program. Operating costs for salaries and benefits, utilities, maintenance, and other are given, as well as lease expenses and carrying charges. For the example concentrator company, the highest costs are incurred on the West Coast, and the lowest in the South Eastern region, with the exception of the Rocky Mountain region, where there is no warehouse because this is the factory location.

ALTERNATIVE DISTRIBUTION COSTS
FOR WEST COAST REGION
(1980$)

DSR-5

CUSTOMER TYPE	DISTRIBUTION ALTERNATIVE	ANNUAL COST FOR DIRECT SHIPMENTS	ANNUAL COST FOR TRANSSHIPMENTS	TOTAL ANNUAL DISTRIBUTION COST
1 Residential	0 Factory Direct	$566367	$ 0	
2 Intermediate	0 Factory Direct	$ 99233	$ 0	$864066
3 Central Station	0 Factory Direct	$198466	$ 0	
1 Residential	1 Warehouse	$ 0	$311660	
2 Intermediate	1 Warehouse	$ 0	$155830	$779150
3 Central Station	1 Warehouse	$ 0	$311660	
1 Residential	0 Factory Direct	$566367	$ 0	
2 Intermediate	1 Warehouse	$ 0	$178943	$943776
3 Central Station	0 Factory Direct	$198466	$ 0	$
1 Residential	0 Factory Direct	$566367	$ 0	$
2 Intermediate	0 Factory Direct	$ 99233	$ 0	1009027
3 Central Station	1 Warehouse	$ 0	$343427	$
1 Residential	1 Warehouse	$ 0	$321973	$
2 Intermediate	1 Warehouse	$ 0	$160987	$681426
3 Central Station	0 Factory Direct	$198466	$ 0	$
1 Residential	1 Warehouse	$ 0	$308132	$
2 Intermediate	0 Factory Direct	$ 99233	$ 0	$715497
3 Central Station	1 Warehouse	$ 0	$308132	$
1 Residential	0 Factory Direct	$566367	$ 0	$
2 Intermediate	1 Warehouse	$ 0	$158929	1043153
3 Central Station	1 Warehouse	$ 0	$317857	$
1 Residential	1 Warehouse	$ 0	$349600	$
2 Intermediate	0 Factory Direct	$ 99233	$ 0	$647300
3 Central Station	0 Factory Direct	$198466	$ 0	$

DSR-5 Alternative Distribution Costs - A separate report is generated for each region with the exception of the region where the factory is located because there can only be direct shipments, there is no warehouse. As can be seen for the example concentrator company, annual shipment costs for each customer type are calculated for both factory direct and warehouse distribution to determine the lowest total annual distribution cost. In the case of the West Coast region, it was found that the use of a warehouse was most cost effective for residential whose total demand is 5 megawatts per year. However, for intermediate and central station customers direct shipments from the factory are more economical with only 6 deliveries per year.

ECONOMIC WAREHOUSE ORDER QUANTITY FUNCTION
FOR WEST COAST REGION
(1980$)

DSR-6

WAREHOUSE ORDER QUANTITY	0.1923 MW	0.3846 MW	0.5769 MW	0.7692 MW
- Shipping Mode	Rail	Rail	Rail	Rail
- Order Processing Cost	$1748	$ 874	$ 583	$ 437
- Cost Per Shipment	198466	198466	198466	198466
ANNUAL TRANSPORTATION COST	200214	199340	199049	198903
- Inventory Carrying Cost	25410	50819	76229	101638
- Warehouse Operating Cost	56565	70116	82710	95268
- Warehouse Leasing Cost	28288	55731	80753	105689
ANNUAL WAREHOUSING COST	110263	176666	239692	302596
- Fixed Delivery Cost	31156	31156	31156	31156
- Variable Delivery Cost	7967	7967	7967	7967
ANNUAL DELIVERY COST	39123	39123	39123	39123
TOTAL DISTRIBUTION COST FOR TRANSSHIPMENTS	349600	415129	477864	540622

Major Assumptions

Factory Location: Rocky Mountain
Warehouse Location: Los Angeles
Shipping Distance: 640. Kilometers
Order Processing Cost: $62.96 Per Shipment
Minimum Shipping Frequency: Two Weeks
All Costs are in 1980 $

DSR-6 Economic Warehouse Order Quantity Function - A separate report is generated for each region with the exception of the region where the factory is located; because there can only be direct shipments, there is no warehouse. As can be seen for the example concentrator company, total annual distribution costs are computed for four different levels of warehouse order quantity. This order quantity, given the annual demand determines the number of shipments to the warehouse and the inventory level required to avoid stockouts. In this example for the concentrator company, the most economical order quantity is 0.1923 MW with 26 deliveries per year which is equivalent to one delivery every 2 weeks.

DISTRIBUTION PRICE ESTIMATES (1980$/WATT)

DSR-7

MARKET REGION	CUSTOMER TYPE			TOTAL ANNUAL DEMAND	
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION	MW	(%)
WEST COAST	0.069920	0.039693	0.039693	12.50	(25.0)
ROCKY MOUNTAIN	0.042460	0.004462	0.004462	14.00	(28.0)
NORTH CENTRAL	0.193533	0.161619	0.000000	1.50	(3.0)
GREAT LAKES	0.234451	0.202537	0.000000	1.50	(3.0)
NORTH EASTERN	0.253860	0.202361	0.202361	8.00	(16.0)
SOUTH EASTERN	0.240152	0.208238	0.000000	1.50	(3.0)
SOUTH CENTRAL	0.126793	0.095402	0.095402	11.00	(22.0)
AVERAGE	0.114369	0.079198	0.085480		

DSR-7 Distribution Price Estimates - The estimated price per watt is listed for each type of customer in each region. For the example concentrator company, the highest price is $0.253860 per watt for residential customers in the North Eastern region. The lowest price is $0.004462 per watt for commercial and public utility customers in the Rocky Mountain region.

WAREHOUSE STAFFING RELATIONSHIPS

WAREHOUSE SIZE (SQUARE METERS)	TOTAL PERSONNEL REQUIRED
1 < F < 2000	2.00
2000 < F < 5000	0.66 + 0.00067 * F
5000 < F <15000	1.00 + 0.00060 * F
15000 < F	2.50 + 0.00050 * F

TOTAL PERSONNEL PERCENTAGE	PERSONNEL TITLE	ANNUAL COST* (1980$)
10%	Warehouse Supervisor	$27021
50%	Forklift Operator	13857
20%	Inventory Clerk	17019
20%	Material Handler	21163
100%	Weighted Average	$17267

* The annual cost for warehouse personnel includes both wages and benefits and is based on a nationwide survey. The costs should be multiplied by the appropriate labor cost index to reflect regional conditions.

WAREHOUSE FACILITIES COST PARAMETERS

Warehouse Space Utilization Factor	0.25 Cubic Meters of Product Per Square Meter Warehouse
Maintenance Cost Rate	1.00 Percent of Capital Cost
Utility Cost Rate	$1.69 Per Square Meter (1980$)
Insurance Cost Rate	1.00 Percent of Capital Cost
Property Tax Rate	4.00 Percent of Capital Cost
Equipment Lease Rate	25.00 Percent of Capital Cost
Building Lease Rate	12.60 Percent of Capital Cost
Inventory Carrying Charge	37.75 Percent of Unit Value

DSR-8 Distribution Submodel Parameters - There are two sections to this report. The first part shows the warehouse staffing relationships: 1) the total personnel required depending on the warehouse size, and 2) the breakdown of personnel types and their annual costs. The second section is a listing of some of the more important standard data used by the program, including: warehouse space utilization factor, maintenance cost rate, utility cost rate (in base price year dollars), insurance cost rate, property tax rate, equipment lease rate, building lease rate, and inventory carrying charge.

C. FINANC Subprogram Reports

The FINANC Subprogram generates the following eight output reports:

- FSR-1: Consolidated Income Statement Report
- FSR-2: Schedule A-Distribution Expenses
- FSR-3: Schedule B-Marketing Expenses
- FSR-4: Regional Income Statements
- FSR-5: Delivered Price Estimates
- FSR-6: Delivered Price Estimates
- FSR-7: Key Financial Indicators
- FSR-8: General M&D Model Parameters

MARKETING AND DISTRIBUTION COMPANY
CONSOLIDATED INCOME STATEMENT ***
FOR THE YEAR ENDING DECEMBER 31, 1986

FSR-1

	(1980 $000)		(% SALES)
SALES:			
- Residential Products	$19878		43.2%
- Intermediate Products	9109		19.8%
- Central Power Stations	17047		37.0%
TOTAL SALES		$46034	
COST OF GOODS SOLD:			
- Residential Products	14001		30.4%
- Intermediate Products	7000		15.2%
- Central Power Stations	14001		30.4%
TOTAL COST		$35001	76.0%
GROSS PROFIT		$11032	24.0%
EXPENSES:			
- Distribution (Schedule A)	4789		10.4%
- Marketing (Schedule B)	3719		8.1%
TOTAL EXPENSES		$ 8508	18.5%
NET PROFIT BEFORE TAX		$ 2524	5.5%
NET INCOME TAX		$ 1287	2.8%
NET PROFIT AFTER TAX		$ 1237	2.7%

***Consolidated over all geographic regions.
Based on an average manufacturing price of $0.70 per watt,
a manufacturing facility in the Rocky Mountain Region,
and a particular assumed demand distribution.

FSR-1 Consolidated Income Statement - A typical income statement showing sales, cost of goods sold, gross profit, expenses, net profit before tax, and net profit after tax is generated based on an average manufacturing price of $.70/watt, a factory in the Rocky Mountain region, an assumed demand distribution given as input by the user, and standard data specified in the program. For the concentrator company residential products comprise 43.2 percent of sales. Marketing & distribution expenses contribute about 18.5% to the final price of the collector with 10.4% for marketing and 8.1% for distribution.

MARKETING AND DISTRIBUTION COMPANY FSR-2
SCHEDULE A: DISTRIBUTION EXPENSES***
FOR THE YEAR ENDING DECEMBER 31, 1986

	(1980$)		(%TOTAL)
TRANSPORTATION:			
- Direct Shipments	$2525351		
- Transshipments	1669172		
- Local Deliver,	209796		
TOTAL TRANSPORT		$4404320	90.9%
WAREHOUSE OPERATIONS:			
- Salaries & Benefits	234537		
- Utilities	4174		
- Maintenance	6232		
- Other	31162		
TOTAL WAREHOUSE		$ 276106	5.7%
WAREHOUSE LEASE EXPENSE		84980	1.8%
INVENTORY CARRYING CHARGES		78770	1.6%
TOTAL DISTRIBUTION EXPENSES		$ 4844176	100.0%

**Consolidated over all distribution regions
For all types of customers,
Based on a single manufacturing facility
Located in the Rocky Mountain Region
and a particular assumed demand distribution

FSR-2 Schedule A: Distribution Expenses - In this report, transportation costs are broken down by direct shipments, transshipments, are local deliveries; and warehouse operations are broken down for salaries and benefits, utilities, maintenance, and other. For the example concentrator company 90.9% of total distribution expenses are transportation. Warehousing costs including lease and carrying charges are only 9.1% of the total.

MARKETING AND DISTRIBUTION COMPANY FSR-3
SCHEDULE B: MARKETING EXPENSES ***
FOR THE YEAR ENDING DECEMBER 31, 1986

	(1980 $)		(% TOTAL)
SALARIES & BENEFITS:			
- Direct Staff	$2401255		
- Support Staff	1087481		
TOTAL SALARIES		$3488736	80.6%
SALES EXPENSES:			
- Travel/Entertainment	176710		
- Communications	106026		
- Office Supplies	70684		
TOTAL EXPENSES		$353420	8.2%
OFFICE FACILITIES:			
- Lease	82055		
- Utilities	3328		
- Maintenance	6512		
- Other Expenses	32562		
TOTAL FACILITIES		$124457	2.9%
ADVERTISING		$364014	8.4%
TOTAL MARKETING EXPENSES		$4330626	100.0%

***Consolidated over all marketing regions
for all types of customers.
Based on a particular assumed demand distribution.

FSR-3 Schedule B: Marketing Expenses - In this report, marketing expenses are broken down by salaries & benefits, sales expenses, office facilities, and advertising. For the example concentrator company, salaries and benefits comprise 80.6% of the total marketing expenses. Advertising represents 8.4% of the total for the concentrator company.

MARKETING AND DISTRIBUTION COMPANY FSR-4
REGIONAL INCOME STATEMENTS ***
FOR THE YEAR ENDING DECEMBER 31, 1986
(1980 $000)

	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL REGIONS
SALES	10935	11789	1584	1677	8277	1640	10132	46034
COST OF GOODS SOLD	8750	9800	1050	1050	5600	1050	7700	35001
EXPENSES:								
- Marketing	980	1132	158	177	435	137	700	3719
- Distribution	647	290	274	336	1722	344	1175	4789
INCOME TAXES	285	289	52	58	265	55	283	1287
NET PROFIT	273	278	50	56	255	53	272	1237

*** Based on an average manufacturing price of $0.70 per watt in 1980 dollars, a manufacturing facility in the Rocky Mountain region, and a particular assumed demand distribution.

FSR-4 Regional Income Statements - This report lists income statements for each regional office. For the example concentrator company, the Rocky Mountain region is the highest profit center earning $278,000 net profit after tax. In this case the Great Lakes region has the highest profit margin of 3.3% of sales while the Rocky Mountain region yields the lowest margin of 2.4% after tax.

MARKETING AND DISTRIBUTION COMPANY FSR-5
DELIVERED PRICE ESTIMATES ***

	(1980 $/WATT)		(% PRICE)	
COST OF GOODS SOLD:				
- Residential Products	$0.700			
- Intermediate Products	0.700			
- Central Power Stations	0.700			
TOTAL COST		$0.700		76.0%
EXPENSES				
- Distribution	0.096		10.4%	
- Marketing	0.074		8.1%	
TOTAL EXPENSES		0.170		18.5%
INCOME TAXES		0.026		2.8%
NET PROFIT AFTER TAX		0.025		2.7%
DELIVERED PRODUCT PRICES:				
- Residential Products	0.994			
- Intermediate Products	0.911			
- Central Power Stations	0.852			
ALL PRODUCTS		$0.921		100.0%

*** Based on an average manufacturing price of $0.70 per watt, a manufacturing facility in the Rocky Mountain region, and a particular assumed demand distribution.

FSR-5 Delivered Price Estimates - This report lists the components of the delivered product price in report year $ per watt and as a percent of the total price. These figures are consolidated over all regions. For the example concentrator company, the cost of goods sold or manufacturing cost is 76.0% of the average price of $0.921 per watt over all customers. Residential prices are the highest at $0.994 per watt and public utility prices are lowest at $0.852 per watt for the example concentrator company.

MARKETING AND DISTRIBUTION COMPANY FSR-6
DELIVERED PRICE ESTIMATES ***
FOR EACH TYPE OF CUSTOMER BY REGION
(1980 $/WATT)

MARKET REGION	RESIDENTIAL HOUSEHOLD PRODUCTS	INTERMEDIATE COMMERCIAL PRODUCTS	CENTRAL STATION PUBLIC UTILITY PRODUCTS	ALL CUSTOMER PRODUCTS
WEST COAST	$0.950	$0.871	$0.802	$0.875
ROCKY MOUNTAIN	0.916	0.829	0.761	0.842
NORTH CENTRAL	1.082	1.004	0.000	1.056
GREAT LAKES	1.146	1.062	0.000	1.118
NORTH EASTERN	1.150	1.049	0.986	1.035
SOUTH EASTERN	1.118	1.044	0.000	1.093
SOUTH CENTRAL	0.996	0.921	0.861	0.921
ALL REGIONS	$0.994	$0.911	$0.852	$0.921

PRICE RANGES:

MINIMUM = $0.761/Watt for Central Station Utility in the Rocky Mountain Region

MAXIMUM = $1.150/Watt for Residential Household in the North Eastern Region

AVERAGE = $0.921/Watt Over All Products and Regions

*** Based on an average manufacturing price of $0.70 per watt, a manufacturing facility in the Rocky Mountain region, and a particular assumed demand distribution.

FSR-6 Delivered Price Estimates - In this report, delivered price estimates in report year $/watt are listed by region and customer type. The minimum is $.761/watt for utility customers in the Rocky Mountain region, and the maximum is $1.150/watt for residential customers in the North Eastern region.

MARKETING AND DISTRIBUTION COMPANY
KEY FINANCIAL INDICATORS

FSR-7

MARKET REGION	CUSTOMER TYPE			MARK-UP (REVENUE - CGS)/CGS)	PROFIT MARGIN (NPAT/REVENUE)
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION		
WEST COAST	35.7%	24.4%	14.5%	25.0%	2.5%
ROCKY MOUNTAIN	30.9%	18.4%	8.7%	20.3%	2.4%
NORTH CENTRAL	54.6%	43.4%	0.0%	50.9%	3.1%
GREAT LAKES	63.6%	51.7%	0.0%	59.7%	3.3%
NORTH EASTERN	64.3%	49.9%	40.8%	47.8%	3.1%
SOUTH EASTERN	59.7%	49.2%	0.0%	56.2%	3.2%
SOUTH CENTRAL	42.3%	31.5%	23.0%	31.6%	2.7%
ALL REGIONS	42.0%	30.1%	21.8%	31.5%	2.7%

FINANCIAL PARAMETERS:

Rate of Return on Equity	=	17.20% (input)
After Tax Cost of Capital	=	15.39% (derived)
Financial Leverage	=	1.20 (input)
Corporate Income Tax Rate	=	51.00% (standard data)
Cost of Debt Capital	=	12.90% (standard data)
Deflation Rate	=	6.00% (standard data)
Average Inventory Turnover Time	=	1.50 months (standard data)
Average Expense Coverage Time	=	6.00 months (standard data)
Inventory Carrying Charge Rate	=	37.75% (standard data)

FSR-7 Key Financial Indicators - An array by region and customer type shows mark-up percentages, for all products. A listing of financial parameters is provided at the bottom of the report, specifying whether the information is part of the user input, derived, or part of the standard data base which can also be modified by the user. For the example concentrator company, the North Eastern region posted the highest markup of 64.3% for residential products and a profit margin of 3.1% over all products. The lowest markup is 8.7% for public utility customers in the Rocky Mountain region closest to the factory.

MARKETING AND DISTRIBUTION COMPANY
GENERAL M&D MODEL PARAMETERS

INPUT DATA:

• Product Manufacturing Cost (Mfg Year $/Watt)	$0.993
• Manufacturing Year	1986
• Product Volume (Cubic Meters/MW)	10200.0
• Product Weight (kilograms/MW)	462800.0
• Factory Location Region	Rocky Mountain

STANDARD DATA:

• Base Price Year	1981
• Deflation Rate Solar Products	6.00%
• Inflation Rates	
- Raw Materials	11.00%
- Labor	8.00%
- Chemicals	13.00%
- Commodities	8.00%
- Energy	12.00%
- Land	4.00%
- Facilities	9.00%
- Construction	8.00%
- Equipment	7.00%
- Resources	15.00%
- Transportation	7.00%

FSR-8 General M&D Model Parameters - There are two sections to this financial report: 1) input data including the product manufacturing cost, manufacturing year, volume, weight, and factory location region, and 2) standard data in cluding the base price year, deflation rate, and eleven inflation rates. The numbers listed here are for the example concentrator company.

VI SUBROUTINES

A. MWS Subroutine

This subroutine determines the salesman productivity (MWS in megawatts/year/person) as a function of the average order size (A in megawatts/order).

```
REAL FUNCTION MWS(A)
REAL  A
IF (A.LT.0.001) MWS  = 1000.0 * A
IF (A.GE.0.001) MWS  = .999 + 1.902 * A
IF (A.GE.10.000) MWS = 2 * A
RETURN
END
```

B. SSI Subroutine

This subroutine determines the salesman support index (SSI) as a function of the average order size (A in megawatts/order).

```
REAL FUNCTION SSI(A)
REAL   A
IF(A.LT.0.001) SSI  = 50.00 * A
IF(A.GE.0.001) SSI  = 0.05 + 0.045 * A
IF(A.GE.10.000) SSI = 0.2778 + 0.0222 * A
RETURN
END
```

C. KO Subroutine

This subroutine determines the office facilities capital cost (KO in 1981$) as a function of the office size (O in square meters).

```
REAL FUNCTION KO(O)
REAL O
IF(O.LE.185.00)  KO  =            517.33 * O
IF(O GT.185.00)  KO  = 40107.13 + 300.53 * O
IF(O.GT.278.00)  KO  =  7598.52 + 417.46 * O
IF(O.GT.372.00)  KO  = 30625.99 + 355.56 * O
IF(O.GT.557.00)  KO  =  4636.98 + 402.23 * O
IF(O.GT.1115.00) KO  = 34980.74 + 375.01 * O
```

D. TOTPER Subroutine

This subroutine computes the total personnel vector (TV) given the direct personnel vector (DV) and the indirect staffing matrix (RM).

```
      SUBROUTINE TOTPER (SRT, ISP)
      COMMON/RQMT/RM/MINRM/RO
      REAL TV(17), DV(17), ISP(8), RO(17,17), RM(17,17), SRT(9)
      DO 500 I = 1, 17, 1
      TV (I) = 0.0
      DV (I) = 0.0
  500 CONTINUE
      DO 561 I = 1, 9, 1
      DV(I) = SRT(I)
  561 CONTINUE
      DO 570 I = 1, 17, 1
      DO 570 J = 1, 17, 1
      IF (I.EQ. J) GO TO 560
      RO (I, J) = -RM (I,J)
      GO TO 570
C**** SUBTRACT INDIRECT STAFF REQUIREMENTS MATRIX (RM) FROM
C**** IDENTITY MATRIX (I)
  560 RO (I,J) = 1.00 - RM (I,J)
  570 CONTINUE
C**** CALL INVERT SUBROUTINE TO INVERT THE MATRIX RO = I - RM
      CALL INVERT
C**** CALL MATMUL SUBROUTINE TO MULTIPLY THE INVERTED MATRIX (RO)
C**** TIMES THE DIRECT REQUIREMENTS VECTOR (DV) TO COMPUTE THE
C**** TOTAL PERSONNEL VECTOR (TV = INVERSE (I-RM) *DV)
      CALL MATMUL (DV,TV)
C**** COMPUTE THE INDIRECT PERSONNEL (ISP) FROM THE TOTAL
      PERSONNEL VECTOR (TV)
      DO 580 I = 1, 8, 1
      J = 9 + 1
      ISP (I) = TV(J)
  580 CONTINUE
      RETURN
      END
```

E. INVERT Subroutine

This subroutine is called by the TOTPER Subroutine to invert the I-RM matrix where I is the 17x17 identity matrix and RM is the 17x17 indirect staffing matrix.

```
      SUBROUTINE INVERT
      REAL ARIGNL (17,17), ENVERS (17,17), ENVRTR(17,34)
      COMMON/MINRM/ARIGNL/INV/ENVERS/ENV/ENVRTR
C**** GIVE THE LEFT HALF OF THE INVERTER MATRIX THE
C**** SAMES VALUES AS THE ORIGINAL MATRIX, GIVE THE
C**** RIGHT HALF THE VALUES OF THE IDENTITY MATRIX
      DO 600 I = 1,17
      DO 590 J = 1,17
```

```
      ENVRTR (I,JCOLM) = 0.0
  590 CONTINUE
      INCOLM = I + 17
      ENVRTR (I, ICOLM) = 1.0
  600 CONTINUE
C**** SEARCH FOR GREATEST VALUE IN NCOLM, SWITCH
C**** CORRESPONDING ROW WITH NCOLM ROW, DIVIDE
C**** NCOLM ROW BY VALUE OF NCOLM ENTRY TO GET
C**** 1 ON THE DIAGONAL, ZERO ALL OTHER VALUES IN
C**** COLUMN
      DO 630 NCOLM = 1,17
C**** CALL ROWCHK SUBROUTINE TO FIND THE LARGEST
C**** VALUE IN NCOLM OF THE MATRIX ENVRTR AND SWITCH
C**** ROWS SO THAT THE LARGEST VALUE OF NCOLM IS ON
C**** THE DIAGONAL OF ENVRTR
      CALL ROWCHK (NCOLM)
      DIVR = ENVRTR (NCOLM, NCOLM)
      DO 610 J = NCOLM, 34
      If (DIVR.NE.0.0 ENVRTR (NCOLM, J) = ENVRTR (NCOLM,J)/DIVR
  610 CONTINUE
      DO 630 I=1,17
      If (I.EQ.NCOLM) GO TO 630
      CONST = ENVRTR (I,NCOLM)
      DO 620 J = NCOLM, 34
      ENVRTR (I,J) = ENVRTR (I,J)-CONST * ENVRTR (NCOLM,J)
  620 CONTINUE
  630 CONTINUE
      DO 640 I=1,17
      DO 640 J=1,17
      KOLM = J + 17
      ENVERS (I,J) = ENVRTR (I,KOLM)
  640 CONTINUE
      RETURN
      END
```

F. ROWCHK Subroutine

This subroutine is called by the INVERT subroutine to assist in the inversion of the Indirect Staffing Requirements Matrix.

```
      SUBROUTINE ROWCHK (NCOLM)
      REAL ENVRTR (17,34)
      COMMON / ENV / ENVRTR
C**** FIND THE LARGEST VALUE IN NCOLM OF THE 17 x 34
C**** MATRIX ENVRTR
      N = NCOLM
      IF (NCOLM.GT.16) RETURN
      DO 50 I = NCOLM, 16,1
      IF (ABS(ENVRTR(I+1,NCOLM)).GT.ABS(ENVRTR(I,NCOLM)))N=N+1
   50 CONTINUE
      IF (N.EQ.NCOLM) RETURN
```

```
C****  SWITCH ROWS SO LARGEST VALUE IN NCOLM
C****  IS ON DIAGONAL OF MATRIX ENVRTR
       DO 60 I = 1,34,1
       SAVE = ENVRTR (NCOLM,I)
       ENVRTR (NCOLM,I) = ENVRTR (N,I)
       ENVRTR (N,I) = SAVE
  60   CONTINUE
       RETURN
       END
```

G. MATMUL Subroutine

This subroutine is used by TOTPER subroutine to compute the total personnel vector, TV, given the direct personnel vector, DV, and the inverted matrix (I-RM) where RM is the 17 x 17 indirect staffing requirements matrix.

```
       SUBROUTINE MATMUL (DV,TV)
       REAL ENVRS (17,17), DV ( 17), TV (17)
       COMMON / INV/ ENVERS
C****  SET TOTAL PERSONNEL VECTOR EQUAL TO ZERO
       DO 650 I = 1,17
       TV (I) = 0.00
       DO 650 J = 1,17
       TV (I) = TV (I) + ENVERS (I,J) * DV (J)
 650   CONTINUE
       RETURN
       END
```

H. C Subroutine

This subroutine determines the interregional transportation cost (C in 1981$) as a function of the average shipment weight (Q in kilograms) and the shipping distance (S in kilometers.) The transportation cost is computed in 1981 dollars per year.

```
       REAL FUNCTION C(S,Q)
       Real S,Q
       IF (Q.LT. 225.0) C = 27.3170 + 0.02418 * S
       If (Q.GE. 225.0) C = 21.3791 + 0.02603 * S
       IF (Q.GE. 450.0) C = 17.4860 + 0.02557 * S
       IF (Q.GE. 900.0) C = 15.0479 + 0.02325 * S
       IF (Q.GE.2250.0) C =  9.2791 + 0.02418 * S
       IF (Q.GE.4500.0) C =  7.7363 + 0.02464 * S
       IF (Q.GE.10800.0)C =  7.1202 + 0.01488 * S
       IF (Q.GE.18000.0)C =  0.9752 + 0.01203 * S
       IF (Q.GE.36000.0)C =  0.0252 + 0.01232 * S
```

```
C****  MULTIPLY COST PER 100 KILOGRAMS BY THE
C****  NUMBER OF KILOGRAMS AND DIVIDE BY 100
       C = C * Q / 100.0
       RETURN
       END
```

I. KI Subroutine

This subroutine determines the equipment capital cost (KI in 1981 $) as a function of the warehouse size (F in square meters)

```
REAL FUNCTION KE(F)
REAL F
IF ( F.LE. 1000.0)  KE = 34.1 * F
IF ( F.GT. 1000.0)  KE = 27.5 * F + 6554.0
IF ( F.GT. 2500.0)  KE = 24.9 * F + 13108.0
RETURN
END
```

J. KB Subroutine

This subroutine determines the building and land capital cost (KB in 1981 $) as a function of the warehouse size (F in square meters)

```
REAL FUNCTION KB(F)
REAL F
IF (F.LE. 250.0)  KB =              347.19 * F
IF (F.GT. 250.0)  KB =   5825.17 + 323.89 * F
IF (F.GT.1000.0)  KB =  29102.23 + 300.61 * F
IF (F.GT.2500.0)  KB = 154060.02 + 250.63 * F
RETURN
END
```

K. P Subroutine

This subroutine determines the warehouse personnel cost (P in 1981 $/year) as a function of the warehouse size (F in square meters)

```
REAL FUNCTION P(F)
REAL F
IF (F.EQ.    0.0)  P =     0.00
IF (F.GT.    0.0)  P = 37296.44
IF (F.GT. 2000.0)  P = 12432.15 + 12.4321 * F
IF (F.GT. 5000.0)  P = 18648.22 + 11.1889 * F
IF (F.GT.15000.0)  P = 46620.56 +  9.324  * F
RETURN
END
```

L. PEOPLE Subroutine

This subroutine determines the total number of warehouse personnel (PEOPLE) as a function of the warehouse size (F in square meters)

```
REAL FUNCTION PEOPLE (F)
REAL F
IF (F.LT.     1.00) PEOPLE = 0.00
IF (F.GE.     1.00) PEOPLE = 2.00
IF (F.GE. 2000.00) PEOPLE = 0.66 + 0.00067 * F
IF (F.GE. 5000.00) PEOPLE = 1.00 + 0.00060 * F
IF (F.GE.15000.00) PEOPLE = 2.50 + 0.00050 * F
RETURN
END
```

VII PROGRAM USE

A. Example Case Description

The following example will be used to demonstrate the use of the M&D program.

The case involves a hypothetical manufacturer of photovoltaic concentrator collectors with a factory in Phoenix, Arizona. The company sells systems of three standard sizes: 5 kilowatts for residential customers, 500 kilowatts for commercial customers and 5 megawatts for public utility customers.

It is 1980 and the company anticipates rapid growth over the next five years due to technological advances and cost reductions of its photovoltaic solar energy systems. As the cost per watt declines, demand is expected to grow exponentially.

The company plans to expand its production capacity to supply the increased demand. The target capacity is 50 megawatts per year for all types of products by 1986. Demand is expected to be distributed over three major product lines: 40% residential, 20% commercial and 40% public utility.

The engineering department has just completed a detailed manufacturing cost analysis for the new plant. Using the SAMIS model, they estimate an average manufacturing cost of $0.9929 per watt in 1986 dollars including overhead and profits. These systems weigh 462,800 kilograms per megawatt and occupy 10,200 cubic meters per megawatt.

The marketing department has just performed a long range sales forecast for the next five years. They predicted the following total sales in 1986 by general customer category:

Residential	4000 systems
Commercial	20 systems
Public Utility	4 systems

The president of the company would like to estimate its annual marketing and distribution costs, number of sales people, where to locate its warehouses, how much inventory to store in each warehouse, and what price to charge for each major product in order to cover all expenses and earn a net profit after tax of 3% of sales.

This analysis can be performed quickly and easily with the M&D program. To do this, the quantitative information is compiled in the following format for input to the computer.

B. M&d Model User Data Sheet

GENERAL INFORMATION

- Manufacturing Year 1986
  (the steady-state year for which the marketing costs are computed)

- Report Year 1980
  (the year in which dollars are expressed on the output reports)
- Run Type (check one)

  _____ 1. Distribution only

  _____ 2. Marketing only

  X 3. Marketing, Distribution, & Financial

- Demand by Customer Type and Region (megawatts per year)

MARKET REGION	CUSTOMER TYPE		
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION
WEST COAST	5.0	2.5	5.0
ROCKY MOUNTAIN	6.0	3.0	5.0
NORTH CENTRAL	1.0	0.5	0.0
GREAT LAKES	1.0	0.5	0.0
NORTH EASTERN	2.0	1.0	5.0
SOUTH EASTERN	1.0	0.5	0.0
SOUTH CENTRAL	4.0	2.0	5.0

- Manufacturing Price by Customer Type
  (manufacturing year dollars per watt)

  Residential/Household .9929

  Commercial/Intermediate .9929

  Public Utility/Central Station .9929

MARKETING

- Average Order Quantity by Customer Type (megawatts per order)

Residential/Household	0.005
Commercial/Intermediate	0.500
Public Utility/Central Station	5.000

DISTRIBUTION

- Solar Product Volume (cubic meters per megawatt) 10,200
- Solar Product Weight (kilograms per megawatt) 462,800
- Factory Location Region (check one)

	West Coast		North Eastern
x	Rocky Mountain		South Eastern
	North Central		South Central
	Great Lakes		

- Average Delivery Quantity by Customer Type (megawatts per shipment)

Residential/Household	0.005
Commercial/Intermediate	0.500
Public Utility/Central Station	5.000

- Use of a Warehouse (put a 0 in each region for which the program should determine if a warehouse is desired; 1 for each region which is forbidden to have a warehouse; and 2 for each region which must have a warehouse)

0	West Coast	0	North Eastern
0	Rocky Mountain	0	South Eastern
0	North Central	0	South Central
0	Great Lakes		

- Solar Product Type: 1. _____ Power Conditioning Unit
  2. x Collector

C. Input Card Deck Structure

The deck/tape set-up to run the M&D model is listed below:

- Control Cards - these are installation-dependent and must include the control language to compile and execute a FORTRAN IV program.
- Source Cards - the M&D Model source code written in FORTRAN IV is available at cost from Sandia National Laboratories.
- Data Cards - the user specified input data cards detailing the options desired.

Following is the card image for the photovoltaic concentrator collector example case.

CARD 1
5.0 2.5 5.0 6.0 3.0 5.0 1.0 0.5 0.0 1.0

CARD 2
0.5 0.0 2.0 1.0 5.0 1.0 0.5 0.0 4.0 2.0

CARD 3
5.0

CARD 4
0.005 0.500 5.000

CARD 5
0.005 0.500 5.000

CARD 6
0.9929 0.9929 0.9929

CARD 7
1986 1980 10200. 462800. 2

CARD 8
0000000

CARD 9
3

CARD 10
2

D. Output Reports

MARKET DEMAND DISTRIBUTION *** MSR-1
(MW/YR)

MARKET REGION	CUSTOMER TYPE			TOTAL ANNUAL DEMAND	
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION	MW	(%)
WEST COAST	5.00	2.50	5.00	12.50	(25.0)
ROCKY MOUNTAIN	6.00	3.00	5.00	14.00	(28.0)
NORTH CENTRAL	1.00	0.50	0.00	1.50	(3.0)
GREAT LAKES	1.00	0.50	0.00	1.50	(3.0)
NORTH EASTERN	2.00	1.00	5.00	8.00	(16.0)
SOUTH EASTERN	1.00	0.50	0.00	1.50	(3.0)
SOUTH CENTRAL	4.00	2.00	5.00	11.00	(22.0)
TOTAL MW	20.00	10.00	20.00	50.00	
(%)	(40.0)	(20.0)	(40.0)	(100.0)	(100.0)
AVERAGE ORDER QUANTITY (MW)	0.005	0.500	5.000		

** Demand distribution assumed as input to the model

MSR-1 Market Demand Distribution - This is an array of the demand by region and customer type as specified by the user as input data. Total megawatts and percentages are calculated. In addition, the average order quantity by customer type is also listed. Again, this is input to the model. As can be seen, the demand distribution in this example case for the hypothetical concentrator manufacturer is 40% residential, 20% commercial, and 40% utility.

MARKETING EXPENSE SUMMARY
(1980 $1,000/YEAR)

MSR-2

	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL REGIONS $1,000	(%)
SALARIES & BENEFITS									
Direct Personnel	$637	$733	$97	$112	$289	$82	$451	$2,401	(55.4)
Support Staff	289	332	44	50	131	37	204	1,087	(25.1)
GENERAL & ADMIN									
Sales & Expenses	94	108	15	17	42	12	66	353	(8.2)
-travel/entertain									
-communications									
-office supplies									
OFFICE FACILITIES	32	33	6	6	19	6	23	124	(2.9)
-lease									
-utilities									
-maintenance									
-other expenses									
ADVERTISING	91	109	18	18	39	18	74	364	(8.4)
TOTAL	$1,142	$1,315	$180	$202	$519	$155	$819	$4,331	(100.0)

MSR-2 Marketing Expense Summary - Salaries and benefits, as well as general and administrative expenses, are listed by region and consolidated over all regions. These are calculated from standard parameters and the indirect requirements matrix. For this example concentrator manufacturer, salaries and benefits account for the largest portion of marketing expenses, comprising 80.5% of the cost. Total marketing expenses are $4,331,000 per year over all regions.

MARKETING PERSONNEL SUMMARY MSR-3

JOB TITLE	ANNUAL COMPENSATION (1980$)*	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL ** REGIONS #	(%)
SALESMAN										
-Residential	$23267	10	12	2	2	4	2	8	40	(38.1)
-Commercial	30920	3	4	1	1	2	1	3	11	(9.9)
-Utility	41124	1	1	0	0	1	0	1	4	(3.7)
DIRECT SUPPORT										
-Field Engineer	34012	4	5	1	1	3	1	4	16	(14.5)
-Artist	15872	1	1	1	1	1	1	1	1	(0.7)
-Market Research	32465	1	1	1	1	1	1	1	4	(2.9)
-Illustrator	24349	1	1	1	1	1	1	1	2	(1.5)
-Technical Writer	24349	1	1	1	1	1	1	1	2	(1.5)
-Advertising	22546	1	1	1	1	1	1	1	1	(0.7)
SECRETARIES										
-Level I	17586	2	3	1	1	1	1	2	9	(7.7)
-Level II	18758	2	2	1	1	1	1	2	5	(4.7)
-Level III	20471	1	1	1	1	1	1	1	3	(2.4)
MANAGEMENT										
-VP	77042	1	1	1	1	1	1	1	3	(2.4)
-Advertising	49472	1	1	0	0	1	0	1	1	(0.2)
-Market Research	49472	1	1	1	1	1	1	1	1	(0.5)
-Sales	49472	2	3	1	1	1	1	2	8	(6.8)
-Sales Engineer	49472	1	1	1	1	1	1	1	3	(1.9)
TOTAL **		26	30	4	4	13	4	22	104	(100)

** Totals may not equal sum of numbers due to rounding.

MSR-3 Marketing Personnel Summary - This listing of all personnel needed to market the three product lines includes salesman, direct support staff, secretaries and management. Annual compensation rates in report year dollars, *include wages and 40% benefits, averaged over all regions. These average rates are adjusted by labor indices to compute annual sales personnel costs by region. The number of salesman required is computed from the demand by each type of customer and a salesman productivity function. The number of support personnel is computed from the number of salesman and the indirect staff requirements matrix. In this example for the concentrator company residential product salesman account for 38% of the total personnel. A total of 104 marketing personnel are required over all regions.

SALES OFFICE FACILITIES MSR-4

	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL REGIONS
OFFICE SIZE (square meters)	324	379	56	56	157	56	268	1295
TOTAL PEOPLE	26	30	4	4	13	4	22	104
CAPITAL COST (1980 $)	$164461	173974	32821	31199	98140	29264	121371	651231
OPERATING COSTS (1980 $/year)								
-Lease	20722	21921	4135	3931	12366	3687	15293	82055
-Utilities	1004	731	117	117	479	124	756	3328
-Maintenance	1645	1740	328	312	981	293	1214	6512
-Other	8223	8699	1641	1560	4907	1463	6069	32562
TOTAL ANNUAL OPERATING COSTS (1980 $/YEAR)	31593	33090	6222	5920	18733	5567	23331	124457

MSR-4 Sales Office Facilities - This report lists various statistics related to the regional sales office facilities including office size, total people, capital cost and total annual operating costs in report year dollars. Total personnel agrees with report MSR-3. In this case, the Rocky Mountain Region has the largest staff of 30 people which is approximately 29% of the total of 104. The demand is 14 megawatts which is 28% of the total of 50 megawatts.

MARKETING PRICE ESTIMATES
(1980 $/WATT)

MSR-5

MARKET REGION	CUSTOMER TYPE			
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION	TOTAL ANNUAL DEMAND MW (%)
WEST COAST	0.126	0.087	0.027	12.50 (25.0)
ROCKY MOUNTAIN	0.124	0.086	0.026	14.00 (28.0)
NORTH CENTRAL	0.118	0.081	0.000	1.50 (3.0)
GREAT LAKES	0.132	0.091	0.000	1.50 (3.0)
NORTH EASTERN	0.116	0.080	0.024	8.00 (16.0)
SOUTH EASTERN	0.102	0.070	0.000	1.50 (3.0)
SOUTH CENTRAL	0.109	0.082	0.023	11.00 (22.0)
AVERAGE	0.120	0.082	0.025	

MSR-5 Marketing Price Estimates - The estimated marketing price per watt for each type of customer in each region is also averaged over all regions. These prices are for marketing only and do not include manufacturing cost, distribution cost, income tax or profit. For the example concentrator company the highest price is $0.132 for residential customers in the Great Lakes region and lowest is 0.023 for utility customers in the South Central region.

SALES AND ADVERTISING EXPENSE RATES

CUSTOMER/PRODUCT TYPE	AVERAGE ORDER QUANTITY MW	SALES EXPENSE RATE %	ADVERTISING EXPENSE RATE %
Small Household Products	0.005	20.0	2.000
Intermediate Commercial Products	0.500	25.0	1.000
Large Central Power Stations	5.000	30.0	0.100

OFFICE FACILITIES COST PARAMETERS

Office Space Per Person	12.45 Square Meters Per Person
Office Capital Cost	$502.81 Per Square Meter (1980$)
Lease Rate	12.60 Percent of Captial Cost
Utilities Cost Rate	$1.69 Per Square Meter (1980$)
Maintenance Cost Rate	1.00 Percent of Capital Cost
Property Tax Rate	4.00 Percent of Capital Cost

MSR-6 Marketing Submodel Parameters - This report is basically a recapitulation of the important elements of standard data. Sales expenses for travel, entertainment, office supplies and communications are computed as a percent of salaries and benefits for marketing personnel. Similarly, advertising expenses are computed as a percent of the cost of goods sold. The percentages vary with the type of product.

CUSTOMER DEMAND DISTRIBUTION ** DSR-1
(MW/YR)

MARKET REGION	CUSTOMER TYPE			TOTAL ANNUAL DEMAND	
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION	MW	(%)
WEST COAST	5.00	2.50	5.00	12.50	(25.0)
ROCKY MOUNTAIN	6.00	3.00	5.00	14.00	(28.0)
NORTH CENTRAL	1.00	0.50	0.00	1.50	(3.0)
GREAT LAKES	1.00	0.50	0.00	1.50	(3.0)
NORTH EASTERN	2.00	1.00	5.00	8.00	(16.0)
SOUTH EASTERN	1.00	0.50	0.0	1.50	(3.0)
SOUTH CENTRAL	4.00	2.00	5.00	11.00	(22.0)
TOTAL MW	20.00	10.00	20.00	50.00	
(%)	(40.0)	(20.0)	(40.0)	(100.0)	(100.0)
AVERAGE DELIVERY QUANTITY (MW)	0.005	0.500	5.000		
NUMBER OF DELIVERIES PER YEAR	4000.00	20.00	4.00		

** Demand distribution assumed as input to the model

Factory Location: Rocky Mountain

DSR-1 Customer Demand Distribution - The demand distribution array is the same as the one generated in MSR-1. Also included is the average delivery quantity, and from this the number of deliveries per year are calculated. For example, the total utility demand is 20 MW, delivered in shipments of 5 MW, requiring 4 deliveries per year.

DISTRIBUTION EXPENSE SUMMARY DSR-2
(1980 $1,000/YEAR)

	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL REGIONS $1,000 (%)
TRANSPORTATION - Direct Shipments - Transshipments - Local Delivery	537	346	215	271	1655	292	1089	4404 (90.9)
WAREHOUSE OPERATIONS - Salaries & Benefit - Utilities - Maintenance - Other Expenses	57	0	43	49	45	37	46	276 (5.7)
WAREHOUSE LEASE EXPENSE	28	0	9	8	12	8	20	85 (1.8)
INVENTORY CARRYING CHARGE	25	0	8	8	10	8	20	79 (1.6)
TOTAL	647	346	274	336	1722	344	1175	4844 (100.0)

DSR-2 Distribution Expense Summary - An annual breakdown by region for transportation costs, warehouse operations, warehouse leasing expenses, and inventory carrying charges may be found in this report. For the example concentrator company, the total distribution expense is $4,844,000 per year. The bulk of the distribution expense is for transportation - 90.9%, with the North Eastern region incurring the largest share of the total expense.

DISTRIBUTION NETWORK CONFIGURATION DSR-3

REGIONAL WAREHOUSE LOCATION	FACTORY SHIPPING MODE/ FREQUENCY	WAREHOUSE SIZE (SQUARE METERS)	AVERAGE INVENTORY LEVEL (MW)	DELIVERY TRUCKS	WAREHOUSE PERSONNEL
West Coast Los Angeles	Rail 2.0 Weeks	490	0.10	1	2
Rocky Mountain Phoenix	Direct 0.0 Weeks	0	0.00	0	0
North Central Omaha	Rail 2.0 Weeks	147	0.03	1	2
Great Lakes Springfield	Rail 2.0 Weeks	147	0.03	1	2
North Eastern Syracuse	Rail 1.0 Weeks	196	0.04	1	2
South Eastern Atlanta	Rail 2.0 Weeks	147	0.03	1	2
South Central Dallas	Rail 2.0 Weeks	392	0.08	1	2
ALL REGIONS		1520	0.30	6	12

DSR-3 Distribution Network Configuration - The program determines which factory shipping modes - direct, truck, or rail - is most cost effective for each region, as well as the frequency of delivery. In addition, warehouse sizes are calculated according to the average inventory level, and from this the number of delivery trucks and warehouse personnel are determined. Since the concentrator manufacturing factory is in the Rocky Mountain region, a ware house is not needed - there are only direct shipments. Every other region requires one delivery truck and two warehouse personnel.

WAREHOUSE FACILITIES DSR-4

	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL REGIONS
WAREHOUSE SIZE (Square Meters)	490	0	147	147	196	147	392	1520
TOTAL PEOPLE	2	0	2	2	2	2	2	12
CAPITAL COST (1980$)	$207229	$0	$63501	$60362	$89657	$56619	$145881	$623249
OPERATING COSTS (1980 $/Year)								
-Salaries & Benefits	42611	0	39173	44852	38555	33147	36199	234537
-Utilities	1520	0	311	311	599	328	1105	4174
-Maintenance	2072	0	635	604	897	566	1459	6232
-Other	10361	0	3175	3018	4483	2831	7294	31162
LEASE EXPENSE (1980 $/Year)	28288	0	8648	8221	12210	7711	19901	84980
Carrying Charges (1980 $/Year)	25410	0	7623	7623	10164	7623	20328	78770
TOTAL ANNUAL FACILITIES COSTS (1980 $/Year)	$110263	$0	$59565	$64628	$66908	$52206	$86286	$439856

DSR-4 Warehouse Facilities - This report is a breakdown of the total annual facilities costs in report year dollars. The warehouse sizes and number of personnel are listed for each region, and the capital cost is derived by the program. Operating costs for salaries and benefits, utilities, maintenance, and other are given, as well as lease expenses and carrying charges. For the example concentrator company, the highest costs are incurred on the West Coast, and the lowest in the South Eastern region, with the exception of the Rocky Mountain region, where there is no warehouse because this is the factory location.

ALTERNATIVE DISTRIBUTION COSTS
FOR WEST COAST REGION
(1980$)

DSR-5

CUSTOMER TYPE	DISTRIBUTION ALTERNATIVE	ANNUAL COST FOR DIRECT SHIPMENTS	ANNUAL COST FOR TRANSSHIPMENTS	TOTAL ANNUAL DISTRIBUTION COST
1 Residential	0 Factory Direct	$566367	$ 0	
2 Intermediate	0 Factory Direct	$ 99233	$ 0	$864066
3 Central Station	0 Factory Direct	$198466	$ 0	
1 Residential	1 Warehouse	$ 0	$311660	
2 Intermediate	1 Warehouse	$ 0	$155830	$779150
3 Central Station	1 Warehouse	$ 0	$311660	
1 Residential	0 Factory Direct	$566367	$ 0	
2 Intermediate	1 Warehouse	$ 0	$178943	$943776
3 Central Station	0 Factory Direct	$198466	$ 0	$
1 Residential	0 Factory Direct	$566367	$ 0	$
2 Intermediate	0 Factory Direct	$ 99233	$ 0	$1009027
3 Central Station	1 Warehouse	$ 0	$343427	$
1 Residential	1 Warehouse	$ 0	$321973	$
2 Intermediate	1 Warehouse	$ 0	$160987	$681426
3 Central Station	0 Factory Direct	$198466	$ 0	$
1 Residential	1 Warehouse	$ 0	$308132	$
2 Intermediate	0 Factory Direct	$ 99233	$ 0	$715497
3 Central Station	1 Warehouse	$ 0	$308132	$
1 Residential	0 Factory Direct	$566367	$ 0	$
2 Intermediate	1 Warehouse	$ 0	$158929	$1043153
3 Central Station	1 Warehouse	$ 0	$317857	$
1 Residential	1 Warehouse	$ 0	$349600	$
2 Intermediate	0 Factory Direct	$ 99233	$ 0	$647300
3 Central Station	0 Factory Direct	$198466	$ 0	$

DSR-5 Alternative Distribution Costs - A separate report is generated for each region with the exception of the region where the factory is located because there can only be direct shipments, there is no warehouse. As can be seen for the example concentrator company, annual shipment costs for each customer type are calculated for both factory direct and warehouse distribution to determine the lowest total annual distribution cost. In the case of the West Coast region, it was found that the use of a warehouse was most cost effective for residential whose total demand is 5 megawatts per year. However, for intermediate and central station customers direct shipments from the factory are more economical with only 6 deliveries per year.

ECONOMIC WAREHOUSE ORDER QUANTITY FUNCTION
FOR WEST COAST REGION
(1980$)

DSR-6

WAREHOUSE ORDER QUANTITY	0.1923 MW	0.3846 MW	0.5769 MW	0.7692 MW
- Shipping Mode	Rail	Rail	Rail	Rail
- Order Processing Cost	$1748	$ 874	$ 583	$ 437
- Cost Per Shipment	198466	198466	198466	198466
ANNUAL TRANSPORTATION COST	200214	199340	199049	198903
- Inventory Carrying Cost	25410	50819	76229	101638
- Warehouse Operating Cost	56565	70116	82710	95268
- Warehouse Leasing Cost	28288	55731	80753	105689
ANNUAL WAREHOUSING COST	110263	176666	239692	302596
- Fixed Delivery Cost	31156	31156	31156	31156
- Variable Delivery Cost	7967	7967	7967	7967
ANNUAL DELIVERY COST	39123	39123	39123	39123
TOTAL DISTRIBUTION COST FOR TRANSSHIPMENTS	349600	415129	477864	540622

Major Assumptions

Factory Location: Rocky Mountain
Warehouse Location: Los Angeles
Shipping Distance: 640. Kilometers
Order Processing Cost: $62.96 Per Shipment
Minimum Shipping Frequency: Two Weeks
All Costs are in 1980 $

DSR-6 Economic Warehouse Order Quantity Function - A separate report is generated for each region with the exception of the region where the factory is located; because there can only be direct shipments, there is no warehouse. As can be seen for the example concentrator company, total annual distribution costs are computed for four different levels of warehouse order quantity. This order quantity, given the annual demand determines the number of shipments to the warehouse and the inventory level required to avoid stockouts. In this example for the concentrator company, the most economical order quantity is 0.1923 MW with 26 deliveries per year which is equivalent to one delivery every 2 weeks.

DISTRIBUTION PRICE ESTIMATES DSR-7
(1980$/WATT)

MARKET REGION	CUSTOMER TYPE			TOTAL ANNUAL DEMAND	
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION	MW	(%)
WEST COAST	0.069920	0.039693	0.039693	12.50	(25.0)
ROCKY MOUNTAIN	0.042460	0.004462	0.004462	14.00	(28.0)
NORTH CENTRAL	0.193533	0.161619	0.000000	1.50	(3.0)
GREAT LAKES	0.234451	0.202537	0.000000	1.50	(3.0)
NORTH EASTERN	0.253860	0.202361	0.202361	8.00	(16.0)
SOUTH EASTERN	0.240152	0.208238	0.000000	1.50	(3.0)
SOUTH CENTRAL	0.126793	0.095402	0.095402	11.00	(22.0)
AVERAGE	0.114369	0.079198	0.085480		

DSR-7 Distribution Price Estimates - The estimated price per watt is listed for each type of customer in each region. For the example concentrator company, the highest price is $0.253860 per watt for residential customers in the North Eastern region. The lowest price is $0.004462 per watt for commercial and public utility customers in the Rocky Mountain region.

WAREHOUSE STAFFING RELATIONSHIPS

WAREHOUSE SIZE (SQUARE METERS)	TOTAL PERSONNEL REQUIRED
1 < F < 2000	2.00
2000 < F < 5000	0.66 + 0.00067 * F
5000 < F <15000	1.00 + 0.00060 * F
15000 < F	2.50 + 0.00050 * F

TOTAL PERSONNEL PERCENTAGE	PERSONNEL TITLE	ANNUAL COST* (1980$)
10%	Warehouse Supervisor	$27021
50%	Forklift Operator	13857
20%	Inventory Clerk	17019
20%	Material Handler	21163
100%	Weighted Average	$17267

* The annual cost for warehouse personnel includes both wages and benefits and is based on a nationwide survey. The costs should be multiplied by the appropriate labor cost index to reflect regional conditions.

WAREHOUSE FACILITIES COST PARAMETERS

Warehouse Space Utilization Factor	0.25 Cubic Meters of Product Per Square Meter Warehouse
Maintenance Cost Rate	1.00 Percent of Capital Cost
Utility Cost Rate	$1.69 Per Square Meter (1980$)
Insurance Cost Rate	1.00 Percent of Capital Cost
Property Tax Rate	4.00 Percent of Capital Cost
Equipment Lease Rate	25.00 Percent of Capital Cost
Building Lease Rate	12.60 Percent of Capital Cost
Inventory Carrying Charge	37.75 Percent of Unit Value

DSR-8 Distribution Submodel Parameters - There are two sections to this report. The first part shows the warehouse staffing relationships: 1) the total personnel required depending on the warehouse size, and 2) the breakdown of personnel types and their annual costs. The second section is a listing of some of the more important standard data used by the program, including: warehouse space utilization factor, maintenance cost rate, utility cost rate (in base price year dollars), insurance cost rate, property tax rate, equipment lease rate, building lease rate, and inventory carrying charge.

MARKETING AND DISTRIBUTION COMPANY
CONSOLIDATED INCOME STATEMENT ***
FOR THE YEAR ENDING DECEMBER 31, 1986

FSR-1

	(1980 $000)		(% SALES)
SALES:			
- Residential Products	$19878		43.2%
- Intermediate Products	9109		19.8%
- Central Power Stations	17047		37.0%
TOTAL SALES		$46034	
COST OF GOODS SOLD:			
- Residential Products	14001		30.4%
- Intermediate Products	7000		15.2%
- Central Power Stations	14001		30.4%
TOTAL COST		$35001	76.0%
GROSS PROFIT		$11032	24.0%
EXPENSES:			
- Distribution (Schedule A)	4789		10.4%
- Marketing (Schedule B)	3719		8.1%
TOTAL EXPENSES		$ 8508	18.5%
NET PROFIT BEFORE TAX		$ 2524	5.5%
NET INCOME TAX		$ 1287	2.8%
NET PROFIT AFTER TAX		$ 1237	2.7%

***Consolidated over all geographic regions.
Based on an average manufacturing price of $0.70 per watt,
a manufacturing facility in the Rocky Mountain Region,
and a particular assumed demand distribution.

FSR-1 Consolidated Income Statement - A typical income statement showing sales, cost of goods sold, gross profit, expenses, net profit before tax, and net profit after tax is generated based on an average manufacturing price of $.70/watt, a factory in the Rocky Mountain region, an assumed demand distribution given as input by the user, and standard data specified in the program. For the concentrator company residential products comprise 43.2 percent of sales. Marketing & distribution expenses contribute about 18.5% to the final price of the collector with 10.4% for marketing and 8.1% for distribution.

MARKETING AND DISTRIBUTION COMPANY
SCHEDULE A: DISTRIBUTION EXPENSES***
FOR THE YEAR ENDING DECEMBER 31, 1986

	(1980$)		(%TOTAL)
TRANSPORTATION:			
- Direct Shipments	$2525351		
- Transshipments	1669172		
- Local Deliver,	209796		
TOTAL TRANSPORT		$4404320	90.9%
WAREHOUSE OPERATIONS:			
- Salaries & Benefits	234537		
- Utilities	4174		
- Maintenance	6232		
- Other	31162		
TOTAL WAREHOUSE		$ 276106	5.7%
WAREHOUSE LEASE EXPENSE		84980	1.8%
INVENTORY CARRYING CHARGES		78770	1.6%
TOTAL DISTRIBUTION EXPENSES		$ 4844176	100.0%

**Consolidated over all distribution regions
For all types of customers,
Based on a single manufacturing facility
Located in the Rocky Mountain Region
and a particular assumed demand distribution

FSR-2 Schedule A: Distribution Expenses - In this report, transportation costs are broken down by direct shipments, transshipments, are local deliveries; and warehouse operations are broken down for salaries and benefits, utilities, maintenance, and other. For the example concentrator company 90.9% of total distribution expenses are transportation. Warehousing costs including lease and carrying charges are only 9.1% of the total.

MARKETING AND DISTRIBUTION COMPANY FSR-3
SCHEDULE B: MARKETING EXPENSES ***
FOR THE YEAR ENDING DECEMBER 31, 1986

	(1980 $)		(% TOTAL)
SALARIES & BENEFITS:			
- Direct Staff	$2401255		
- Support Staff	1087481		
TOTAL SALARIES		$3488736	80.6%
SALES EXPENSES:			
- Travel/Entertainment	176710		
- Communications	106026		
- Office Supplies	70684		
TOTAL EXPENSES		$353420	8.2%
OFFICE FACILITIES:			
- Lease	82055		
- Utilities	3328		
- Maintenance	6512		
- Other Expenses	32562		
TOTAL FACILITIES		$124457	2.9%
ADVERTISING		$364014	8.4%
TOTAL MARKETING EXPENSES		$4330626	100.0%

***Consolidated over all marketing regions
for all types of customers.
Based on a particular assumed demand distribution.

FSR-3 Schedule B: Marketing Expenses - In this report, marketing expenses are broken down by salaries & benefits, sales expenses, office facilities, and advertising. For the example concentrator company, salaries and benefits comprise 80.6% of the total marketing expenses. Advertising represents 8.4% of the total for the concentrator company.

MARKETING AND DISTRIBUTION COMPANY
REGIONAL INCOME STATEMENTS ***
FOR THE YEAR ENDING DECEMBER 31, 1986
(1980 $000)

	WEST COAST	ROCKY MOUNTAIN	NORTH CENTRAL	GREAT LAKES	NORTH EASTERN	SOUTH EASTERN	SOUTH CENTRAL	ALL REGIONS
SALES	10935	11789	1584	1677	8277	1640	10132	46034
COST OF GOODS SOLD	8750	~~9799~~ 9800	~~9880~~ 1050	1050	5600	1050	7700	35001
EXPENSES:								
- Marketing	980	1132	158	177	435	137	700	3719
- Distribution	647	290	274	336	1722	344	1175	4789
INCOME TAXES	285	289	52	58	265	55	283	1287
NET PROFIT	273	278	50	56	255	53	272	1237

*** Based on an average manufacturing price of $0.70 per watt in 1980 dollars, a manufacturing facility in the Rocky Mountain region, and a particular assumed demand distribution.

FSR-4 Regional Income Statements - This report lists income statements for each regional office. For the example concentrator company, the Rocky Mountain region is the highest profit center earning $278,000 net profit after tax. In this case the Great Lakes region has the highest profit margin of 3.3% of sales while the Rocky Mountain region yields the lowest margin of 2.4% after tax.

MARKETING AND DISTRIBUTION COMPANY FSR-5
DELIVERED PRICE ESTIMATES ***

	(1980 $/WATT)		(% PRICE)	
COST OF GOODS SOLD:				
- Residential Products	$0.700			
- Intermediate Products	0.700			
- Central Power Stations	0.700			
TOTAL COST		$0.700		76.0%
EXPENSES				
- Distribution	0.096		10.4%	
- Marketing	0.074		8.1%	
TOTAL EXPENSES		0.170		18.5%
INCOME TAXES		0.026		2.8%
NET PROFIT AFTER TAX		0.025		2.7%
DELIVERED PRODUCT PRICES:				
- Residential Products	0.994			
- Intermediate Products	0.911			
- Central Power Stations	0.852			
ALL PRODUCTS		$0.921		100.0%

*** Based on an average manufacturing price of $0.70 per watt, a manufacturing facility in the Rocky Mountain region, and a particular assumed demand distribution.

FSR-5 Delivered Price Estimates - This report lists the components of the delivered product price in report year $ per watt and as a percent of the total price. These figures are consolidated over all regions. For the example concentrator company, the cost of goods sold or manufacturing cost is 76.0% of the average price of $0.921 per watt over all customers. Residential prices are the highest at $0.994 per watt and public utility prices are lowest at $0.852 per watt for the example concentrator company.

MARKETING AND DISTRIBUTION COMPANY FSR-6
DELIVERED PRICE ESTIMATES ***
FOR EACH TYPE OF CUSTOMER BY REGION
(1980 $/WATT)

MARKET REGION	RESIDENTIAL HOUSEHOLD PRODUCTS	INTERMEDIATE COMMERCIAL PRODUCTS	CENTRAL STATION PUBLIC UTILITY PRODUCTS	ALL CUSTOMER PRODUCTS
WEST COAST	$0.950	$0.871	$0.802	$0.875
ROCKY MOUNTAIN	0.916	0.829	0.761	0.842
NORTH CENTRAL	1.082	1.004	0.000	1.056
GREAT LAKES	1.146	1.062	0.000	1.118
NORTH EASTERN	1.150	1.049	0.986	1.035
SOUTH EASTERN	1.118	1.044	0.000	1.093
SOUTH CENTRAL	0.996	0.921	0.861	0.921
ALL REGIONS	$0.994	$0.911	$0.852	$0.921

PRICE RANGES:

MINIMUM = $0.761/Watt for Central Station Utility in the Rocky Mountain Region

MAXIMUM = $1.150/Watt for Residential Household in the North Eastern Region

AVERAGE = $0.921/Watt Over All Products and Regions

*** Based on an average manufacturing price of $0.70 per watt, a manufacturing facility in the Rocky Mountain region, and a particular assumed demand distribution.

FSR-6 Delivered Price Estimates - In this report, delivered price estimates in report year $/watt are listed by region and customer type. The minimum is $.761/watt for utility customers in the Rocky Mountain region, and the maximum is $1.150/watt for residential customers in the North Eastern region.

MARKETING AND DISTRIBUTION COMPANY
KEY FINANCIAL INDICATORS

FSR-7

MARKET REGION	CUSTOMER TYPE			MARK-UP (REVENUE - CGS)/CGS)	PROFIT MARGIN (NPAT/REVENUE)
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION		
WEST COAST	35.7%	24.4%	14.5%	25.0%	2.5%
ROCKY MOUNTAIN	30.9%	18.4%	8.7%	20.3%	2.4%
NORTH CENTRAL	54.6%	43.4%	0.0%	50.9%	3.1%
GREAT LAKES	63.6%	51.7%	0.0%	59.7%	3.3%
NORTH EASTERN	64.3%	49.9%	40.8%	47.8%	3.1%
SOUTH EASTERN	59.7%	49.2%	0.0%	56.2%	3.2%
SOUTH CENTRAL	42.3%	31.5%	23.0%	31.6%	2.7%
ALL REGIONS	42.0%	30.1%	21.8%	31.5%	2.7%

FINANCIAL PARAMETERS:

Rate of Return on Equity	=	17.20% (input)
After Tax Cost of Capital	=	15.39% (derived)
Financial Leverage	=	1.20 (input
Corporate Income Tax Rate	=	51.00% (standard data)
Cost of Debt Capital	=	12.90% (standard data)
Deflation Rate	=	6.00% (standard data)
Average Inventory Turnover Time	=	1.50 months (standard data)
Average Expense Coverage Time	=	6.00 months (standard data)
Inventory Carrying Charge Rate	=	37.75% (standard data)

FSR-7 Key Financial Indicators - An array by region and customer type shows mark-up percentages, for all products. A listing of financial parameters is provided at the bottom of the report, specifying whether the information is part of the user input, derived, or part of the standard data base which can also be modified by the user. For the example concentrator company, the North Eastern region posted the highest markup of 64.3% for residential products and a profit margin of 3.1% over all products. The lowest markup is 8.7% for public utility customers in the Rocky Mountain region closest to the factory.

MARKETING AND DISTRIBUTION COMPANY
GENERAL M&D MODEL PARAMETERS

INPUT DATA:

• Product Manufacturing Cost (Mfg Year $/Watt)	$0.993
• Manufacturing Year	1986
• Product Volume (Cubic Meters/MW)	10200.0
• Product Weight (kilograms/MW)	462800.0
• Factory Location Region	Rocky Mountain

STANDARD DATA:

• Base Price Year	1981
• Deflation Rate Solar Products	6.00%
• Inflation Rates	
- Raw Materials	11.00%
- Labor	8.00%
- Chemicals	13.00%
- Commodities	8.00%
- Energy	12.00%
- Land	4.00%
- Facilities	9.00%
- Construction	8.00%
- Equipment	7.00%
- Resources	15.00%
- Transportation	7.00%

FSR-8 General M&D Model Parameters - There are two sections to this financial report: 1) input data including the product manufacturing cost, manufacturing year, volume, weight, and factory location region, and 2) standard data in cluding the base price year, deflation rate, and eleven inflation rates. The numbers listed here are for the example concentrator company.

E. Example Case Summary

The example case involves a hypothetical photovoltaic concentrator manufacturer with a factory in Phoenix, Arizona. The company sells photovoltaic concentrator systems of three standard sizes: 5 kilowatts for residential customers, 500 kilowatts for commercial customers and 5 megawatts for public utility customers. In 1986, sales are predicted to be 50 megawatts distributed as follows:

1986 SALES FORECAST

	Units	Megawatts
Residential	4000	20
Commercial	20	10
Public Utility	4	20
	4024	50

Based on a manufacturing cost analysis, the company estimates an average manufacturing cost including overhead and profit of $0.9929 per watt in 1986 dollars. This is equivalent to $0.70 per watt in 1980 dollars.

Using the M&D model, the company estimates average marketing expenses of $0.074 per watt and distribution expenses of $0.096 per watt in 1980 dollars. After adding in taxes and profit, the following delivered product prices were obtained:

DELIVERED PRODUCT PRICES

	(1980 $/Watt)
Residential	0.994
Commercial	0.911
Public Utility	0.852
Weighted Average	0.921

Based on the demand forecast for 1986, these prices will generate the following sales revenues:

SALES REVENUES

	(1980 $000)	
Residential	$19878	43.2%
Commercial	9109	19.8%
Public Utility	17047	37.0%
All products	$46034	100.0%

Distribution costs will total $4,789,000 and marketing costs will total $3,719,000 in 1980 dollars. Together these costs represent 18.5% of sales. Net profit after tax is estimated at $1237 or 2.7% of sales.

Markup, defined as revenue less cost of goods manufactured divided by cost of goods manufactured, varies by region and type of customer.

MARK-UP

	(Revenue - CGS/CGS)
Residential	42.0%
Commercial	30.1%
Public Utility	21.8%
All Products	31.5%

The M&D model projects a sales force of about 104 people for this level of sales and productivity. About 52% consist of salesman and the balance are support staff and management

	SALES FORCE SIZE
SALESMAN	
- Residential	40
- Commercial	10
- Public Utility	4
DIRECT SUPPORT STAFF	
- Field Engineer	15
- Commercial Artist	1
- Marketing Research Analyst	3
- Technical Illustrator	1
- Technical Writer	1
- Advertising Salesman	1
SECRETARIES	
- Level I	8
- Level II	5
- Level III	2
MANAGEMENT	
- Vice President	2
- Advertising Manager	1
- Marketing Research Manager	1
- Sales Manager	7
- Sales Engineering Manager	2
TOTAL	104

To minimize shipping costs, the company determined that it would be economical to supply its residential and commercial customers from regional warehouses in the following locations:

REGIONAL WAREHOUSE CONFIGURATION

	Inventory (kilowatts)	Delivery Trucks	Warehouse Personnel
West Coast - Los Angeles	100	1	2
North Central - Omaha	30	1	2
Great Lakes - Springfield	30	1	2
North Eastern - Syracuse	40	1	2
South Eastern - Atlanta	30	1	2
South Central - Dallas	80	1	2

Customers in the Rocky Mountain region around the factory will be supplied directly from the factory in Phoenix. The four public utility units sold each year will also be shipped directly.

These results for the hypothetical photovoltaic inverter manufacturer of course would vary substantially with production level. The number of sales people, the location of the warehouses and the average inventory mix all depend on the level of sales, geographic distribution and product mix. The M&D model is a useful tool to analyze all of these interdependent variables simultaneously.

APPENDIX A

GLOSSARY OF SYMBOLS

A A A A

A = ADQ or Q dummy variable for MWS function and SII function.

AC(KD) = annual compensation rate for direct sales support personnel type KD (base price year $/year/person)

ACAP = after tax cost of capital (percent/year).

ACC = average capital cost for the marketing office facility ($/square meter).

ACUST = integer number equal to one plus the number of customer types.

ADE(I) = advertising rate for customer type I (percent of manufacturing price).

ADQ(I) = average delivery quantity for customer type I (megawatts/shipment).

AIL(J) = average inventory level in region J (megawatts).

AINT(X)= FORTRAN IV library routine for next higher integer value to X.

ALFA = average inventory turnover time (months).

ALPHA = warehouse space utilization factor (cubic meters of product/square meter of warehouse).

ALT = value of column in array of distribution alternative which has lowest total cost of alternative tested.

AOQ(I) = average order quantity for customer type I (megawatts per order).

APRICE = weighted average manufacturing price over all customer types (manufacturing year $/watt).

AREGN = integer number equal to one plus the number of distribution regions.

AWC(I,J)= average working capital for customer type I in region J (manufacturing year dollars).

GLOSSARY OF SYMBOLS

B B B B

BETA = sales office property tax rate (percent of capital cost/year).

BETAF = average expense coverage time (months).

BETAW = warehouse property tax rate (percent of capital cost/year).

BJ(J) = facilities cost index for region J.

GLOSSARY OF SYMBOLS

C C C C

C(Q,S)	=	interregional transportation cost as a function of the average shipment weight Q in kilograms, and the shipping distance S in kilometers ($/shipment)
CAPO(J)	=	office capital cost (manufacturing year $/year).
CC(J,KK)	=	annual inventory carrying cost in region J for distribution alternative KK (manufacturing year $/year).
CGS(I,J)	=	annual manufacturing cost of goods sold for customer type I in region J (manufacturing year dollars/year).
CIS(J)	=	annual indirect sales personnel cost in region J (manufacturing year $/year).
CITY(J,3)	=	literal array containing city of warehouse location for each distribution region.
CJ(J)	=	construction cost index for region J.
CONST	=	dummy variable in INVERT subroutine.
CS(I)	=	annual compensation rate for salesman type I (base price year $/year/person).
CUSTOM	=	literal printing label for customer types.

GLOSSARY OF SYMBOLS

D D D D

D(I,J)	=	total annual demand in region J by all customers of type I (megawatts per year).
DC(J,K)	=	annual cost in region J for direct shipments for each distribution alternative K (manufacturing year $/year).
DC(JR,J)	=	annual distribution cost in region J for customers supplied directly from the factory in region JR (manufacturing year dollars/year).
DELIV(I)	=	average number of deliveries per year.
DFLATE	=	function to deflate (or inflate) the argument from manufacturing year to report year dollars.
DG	=	solar products deflation rate (as a decimal fraction/year).
DIB	=	debt interest rate (percent/year).
DIRECT	=	shipping mode DIRECT.
DIST(I,K,N)		literal distribution alternative.
DISTRB	=	distribution subprogram.
DIVR	=	dummy variable in subroutine INVERT.
DPRICE(I,J)	=	distribution price estimates by customer and region ($/watt).
DSC(J)	=	total direct sales personnel cost in region J (manufacturing year $/year).
DSP(KD,J)	=	total direct sales support personnel type KD required in region J.
DSR(1-8)	=	distribution reports.
DSUM	=	sum of annual demand over all regions and customers (megawatts/year).
DV(J)	=	direct sales personnel vector (17,1) for region J.

GLOSSARY OF SYMBOLS

E E E E

EJ(J)	=	equipment cost index for region J.
ENVRS	=	matrix resulting from INVERT subroutine.
ENVRTR	=	matrix used to invert matrix in INVERT subroutine.

GLOSSARY OF SYMBOLS

F F F F

F(J)	=	warehouse size in region J (square meters).
FACTRY	=	literal FACTORY DIRECT.
FC	=	annual fixed cost per vehicle ($/vehicle/year).
FDC(J,KK)	=	fixed delivery cost in region J for distribution alternative KK (manufacturing year $/year).
FF	=	dummy variable to convert F(J) from array element to variable for use with functions.
FINANC	=	finance subprogram.
FLOAT(X)	=	FORTRAN IV library routine for floating point value of integer X.
FREQ(J)	=	factory shipping frequency to region J (years).
FSR(1-8)	=	financial reports.

GLOSSARY OF SYMBOLS

G G G G

G	=	dummy argument for inflation rate in MARKET subroutine.
GA	=	raw materials inflation rate (as a decimal fraction/year).
GAMMAB	=	annual lease rate for buildings (percent of capital cost/year).
GAMMAE	=	annual lease rate for equipment (percent of capital cost/year).
GAMMAO	=	sales office facilities lease rate (% of capital cost/year).
GB	=	labor cost inflation rate (as a decimal fraction/year).
GC	=	chemical cost inflation rate (as a decimal fraction/year).
GD	=	commodities cost inflation rate (as a decimal fraction/year).
GE	=	energy and utilities inflation rate (as a decimal fraction/year).
GF	=	resources inflation rate (as a decimal fraction/year).
GG	=	land cost inflation rate (as a decimal fraction/year).
GH	=	facilities cost inflation rate (as a decimal fraction/year).
GI	=	construction cost inflation rate (as a decimal fraction/year).
GJ	=	equipment inflation rate (as a decimal fraction/year).
GRO(I,J)	=	annual gross profit for customer type I in region J (manufacturing year dollars/year).
GROSS	=	annual gross profit (manufacturing year $/year).
GROW(G)	=	growth factor for inflation rate.
GT	=	transportation inflation rate (as a decimal fraction/year).

GLOSSARY OF SYMBOLS

H H H H

GLOSSARY OF SYMBOLS

I I I I

I	=	type of customer (I=1,2,3); index for loops.
IC(JR,J,Q)	=	total annual distribution cost in region J for customers supplied from a regional warehouse in region J with transshipments of size Q from the factory in region JR (manufacturing year $/year).
ICC(III)	=	four lowest transshipment costs indentified.
ICOLM	=	index in INVERT subroutine.
II	=	index for loops.
III	=	index for loops.
IJ	=	index for loops.
IK	=	indicator for distribution run option to specify which alternatives should be evaluated.
IMAX	=	largest integer value assigned to customer type.
IMIN	=	smallest integer value assigned to customer type.
IN	=	logical unit number specifying the location of input data e.g. card reader.
INVERT	=	subroutine to invert a matrix.
ISP(KI,J)	=	number of indirect sales support personnel of type KI required in region J.
ISPT(KI)	=	array used to pass rows of ISPT in subroutine TOTPER.
IV(J)	=	indirect sales personnel vector (17x1) for region J.

GLOSSARY OF SYMBOLS

J J J J

J	=	type of region (J = 1,2,...,7); index for loops.
JCOLM	=	index in INVERT subroutine.
JMAX	=	largest integer value assigned to regions.
JMIN	=	smallest integer value assigned to regions.
JR	=	factory location region.

GLOSSARY OF SYMBOLS

K K K K

K	=	index for distribution alternative.
KB(J)	=	building and land capital cost in base price year dollars as a function of the warehouse size F in square meters.
KC(J,KK)	=	building, land, and equipment capital cost in region J for distribution alternative KK (manufacturing year $).
KD	=	index of direct support personnel K=1, ..., 6.
KE(F)	=	equipment capital cost in base year $ as a function of the warehouse size F in square meters.
KI	=	index of indirect support personnel K=1,...,8.
KK	=	index for rank of Q the warehouse order quantity.
KKK	=	index for loops.
KM(J)	=	local delivery travel distance in region J (kilometers/year).
KO(J)	=	office facilities capital cost function in region J ($/year).
KOLM	=	dummy variable in INVERT subroutine.

GLOSSARY OF SYMBOLS

L L L L

L(J,KK)	=	total annual local or intraregional delivery cost in region J for distribution alternative KK (manufacturing year dollars/year).
LAMDA	=	financial leverage ratio (total capital/equity capital).
LC(J,KK)	=	warehouse leasing cost in region J for distribution alternative KK (manufacturing $/year).
LJ(J)	=	labor cost index for region J.
LL	=	dummy variable used as indicator within loop.
LLL	=	index for loops.

GLOSSARY OF SYMBOLS

M M M M

M	=	warehouse maintenance cost rate (percent of capital cost/year).
MARK(J)	=	markup in region J (ratio of revenue less manufacturing cost to manufacturing cost).
MARKET	=	marketing subprogram.
MARKUP (I,J)	=	markup for customer type I in region J.
MATMUL	=	subroutine to multiply two matrices.
MC	=	vehicle distance capacity (kilometers/vehicle-year).
MCC(J)	=	warehouse maintenance cost in region J (manufacturing year $/year).
MCOLM	=	dummy variable in INVERT subroutine.
MM	=	dummy variable used as indicator within loop.
MPRICE (I,J)	=	marketing price per watt as a function of customer type and region (manufacturing year $/watt).
MSR(1-6)	=	marketing reports.
MU	=	sales office insurance rate (percent of capital cost/year).
MUW	=	warehouse insurance rate (percent of capital cost/year).
MWS(I)	=	annual megawatt sales per salesman to customer type I (megawatts/salesman/year).

GLOSSARY OF SYMBOLS

N N N N

N	=	(manufacturing year) - (base price year).
NCOLM	=	dummy variable in ROWCHK subroutine.
NCUST	=	number of customer types.
NPA(I,J)	=	net profit after income tax for customer type I in region J (manufacturing year $/year).
NPBT	=	net profit before taxes (manufacturing year $/year).
NREGN	=	number of regions.

GLOSSARY OF SYMBOLS

O O O O

O	=	OS(J) dummy variable for KO function.
OC(J,KK)	=	annual warehouse operating cost in region J for distribution alternative (manufacturing year dollars/year).
OFC(J)	=	total annual office facility costs in region J (manufacturing year $/year).
OM	=	sales office maintenance cost rate (percent of capital cost/year).
OMC(J)	=	office maintenance expense in region J (manufacturing year $/year).
OOC(J)	=	other office expenses in region J (manufacturing year $/year).
OP	=	warehouse order processing cost ($/order).
OPC(J,KK)	=	order processing cost in region J for distribution alternative KK (manufacturing year $/year).
ORC(J)	=	office rental expense in region J (manufacturing year $/year).
OS(J)	=	sales office size in region J (square meters).
OUC(J)	=	office utilities expense (manufacturing year $/year).
OUT	=	logical unit number specifying the location of output data e.g. line printer.

GLOSSARY OF SYMBOLS

P P P P

P(J)	=	warehouse personnel cost function (manufacturing year $/year).
PC(J)	=	warehouse personnel cost in region J (manufacturing year $/year).
PEOPLE(J)	=	total warehouse personnel (persons).
PERCEN	=	percent.
PHI	=	annual inventory carrying charge rate (percent of product value/year).
PHIF	=	financial inventory carrying rate (percent of product value/year).
PMAX	=	maximum product price (manufacturing year $/watt).
PMIN	=	minimum product price (manufacturing year $/watt).
PPRICE(I,J)		delivered product price estimates for customer type I in region J (manufacturing year $/watt).
PRICE(I)	=	manufacturing price of product for customers of type I (manufacturing year dollars per watt).
PRODUC	=	product type indicator 1 = PCU or inverter 2 = collector
PROF(J)	=	profit margin in region J (ratio of net profit after taxes to total revenue).

GLOSSARY OF SYMBOLS

Q Q Q Q

Q(J)	=	warehouse order quantity in region J (megawatts per shipment).
QC(III)	=	Q(J) corresponding to four lowest transshipment costs identified.
QCC	=	QC(III) storage corresponding to four lowest transshipment costs identified.
QQ	=	1/26th of the annual demand supplied from the warehouse.
QSTAR	=	optimal Q(J) which corresponds to best distribution alternative identified.

GLOSSARY OF SYMBOLS

R R R R

RAIL	=	literal printing label for shipping mode RAIL.
RC(KD)	=	requirement coefficient for direct sales support personnel type KD.
REGIN	=	literal printing label for geographic region names.
REGION	=	literal printing label for geographic region names.
REV(I,J)	=	total annual revenue from customer type I in region J (manufacturing year dollars/year).
RHO	=	minimum required rate of return on equity (percent of equity/year).
RHOO	=	sales office utilities cost rate ($/square meter/year).
RHOW	=	warehouse utilities cost rate ($/square meter/year).
RM(17,17)	=	indirect personnel staffing requirements matrix.
RO(17,17)	=	indirect personnel staffing matrix used in subroutine TOTPER; matrix to be inverted in subroutine INVERT.
ROWCHK	=	subroutine performing function with INVERT subroutine.
RUNTYP	=	determines which subprograms should be executed: 1. - marketing only, 2. - distribution only, 3. - both marketing and distribution.

GLOSSARY OF SYMBOLS

S S S S

S(JR,J) = interregional shipping distance matrix containing the average shipping distance from region JR to region J (kilometers).

SAC(J) = annual advertising cost in region J (manufacturing year $/year).

SAE(I) = sales expense rate for customer type I (percent of marketing salaries).

SAL(KI) = annual compensation rates for indirect sales personnel type KI (base price year $/year/person).

SALD(K) = annual compensation rate for warehouse personnel (base price year $/year).

SAVE = dummy variable in ROWCHK subroutine.

SC = S(JR,J) dummy variable for C function.

SCC = communications expense cost (manufacturing year $/year).

SEC(J) = annual sales expense cost in region J (manufacturing year $/year).

SHIP(Z) = function to determine shipping mode.

SHPCST(J,KK) transportation costs for shipping from the factory to warehouse in region J for distribution alternative KK (manufacturing year $/year).

SMODE(J,KK,LLL) factory shipping mode to region J.

SOS = supplies expense cost (manufacturing year $/year).

SPERSN(J)= total sales personnel in region J.

SPP = amount of office space per person (square meters/person).

SQRT(x) = FORTRAN IV library routine for square root of X.

SR(I,J) = total number of salesmen required in region J for customers of type I.

SRT(I) = array to pass rows of SR and DSP to subroutine TOTPER.

SSI(I) = salesman support index for customer type I.

STE = travel expense cost (manufacturing year $/year).

GLOSSARY OF SYMBOLS

T T T T

T(J)	=	annual transportation cost for shipments from the factory to the warehouse in region J (manufacturing year $/year).
TAC(J,K)	=	total annual distribution costs in region J for distribution alternative K (manufacturing year $/year).
TACSTR	=	lowest total annual cost achieved with alternatives already analyzed.
TAU	=	effective income tax rate (percent of net profit/year).
TAX(I,J)	=	annual income tax expense for customer type I in region J (manufacturing year dollars/year).
TB	=	base price year.
TDX(I,J)	=	annual distribution expense for customer type I in region J (manufacturing year dollars/year).
TEXPEN	=	total expenses (manufacturing year $/year).
TK(J)	=	vehicle fleet size in region J (vehicles).
TM	=	manufacturing year.
TMX(I,J)	=	annual marketing expense for customer type I in region J (manufacturing year $/year).
TOT	=	used as a dummy variable in calculation of inventory carrying cost; total number of units passing through warehouse during year.
TOTPER	=	subroutine to calculate total personnel.
TR	=	report year for which dollars are reported on output reports.
TRANS(J)	=	total transportation costs for distribution.
TRKUSE	=	weighted average use of trucks.
TRUCK	=	literal printing label for shipping mode TRUCK.
TSB	=	total annual sales personnel cost (manufacturing year $/year).

GLOSSARY OF SYMBOLS

T T T T

TSC(J)	=	total indirect sales cost in region J (manufacturing year $/year).
TT	=	total transportation and distribution costs (manufacturing year $/year).
TV(J)	=	total sales personnel vector (17x1) for region J.
TWP(J)	=	total warehouse personnel in region J.

GLOSSARY OF SYMBOLS

U U U U

UC(J)	=	warehouse utilities cost in region J (manufacturing year $/year).
UJ(J)	=	utilities cost index for region J.

GLOSSARY OF SYMBOLS

V V V V

V	=	solar product volume (cubic meters/megawatt).
VC	=	variable operating cost per vehicle ($/kilometer).
VDC(J,KK)	=	variable delivery cost in region J for distribution alternative KK (manufacturing year $/year)

GLOSSARY OF SYMBOLS

W W W W

W(J,KK)	=	annual warehousing cost in region J for distribution alternative KK (manufacturing year $/year).
WAREHS	=	literal WAREHOUSE.
WC	=	vehicle load capacity (kilograms/vehicle).
WT	=	product weight (kilograms/megawatt).
WTDPRC	=	weighted average price of product stored in warehouse ($/watt).
WTDUSE	=	weighted average use of warehouse facility.

GLOSSARY OF SYMBOLS

X X X X

X(I,J)	=	indication for customer type I, in region J whether supplied directly from the factory or from a warehouse in region J.
XREV	=	total annual revenue (manufacturing year $/year).
XSC(J)	=	other warehouse operating costs for (taxes and insurance in region J) (manufacturing year $/year).
XX(I,J)	=	array of distribution options for customer type I in region J.
XXX(J)	=	warehouse constraint indicator for region J.

GLOSSARY OF SYMBOLS

Y Y Y Y

Y(I,J) = intraregional shipping distance matrix containing the average distance from the warehouse to the customer and the average distance between consecutive customers on a local delivery trip (kilometers).

GLOSSARY OF SYMBOLS

Z Z Z Z

Z	=	product weight class (kilograms).

APPENDIX B

ALGORITHMS AND CALCULATIONS

MARKETING SUBMODEL EQUATIONS

Following are the algorithms and calculations for the marketing submodel.

Direct Sales Requirements: The primary determinant of selling requirements is the average order quantity per customer expressed in megawatts per order. Sales requirements are implicitly assumed to vary for different types of customers. It is assumed that this variation can be modeled through the average order size.

AOQ(I) = Average order quantity in megawatts for customer type I.

Note: This is specified as input by the user and is not necessarily the same as the physical delivery quantity or the total sales contract which may extend over several years. It is defined as the total sales contract for one year.

Salesman Productivity Assumptions: The first step in determining how many salesmen are required for a particular product-market scenario is to identify the number of orders an individual salesman can obtain per year at various levels of AOQ. Clearly, when the order quantity is small, less sales effort will be devoted to each order and each salesman will be expected to obtain more orders than if the order size were larger. At the same time, at larger values of AOQ, the overall productivity of each salesman will be greater.

The basic assumptions used for computing salesman productivity are outlined below. The assumptions are predicated on the sales requirements for an established product. Although the photovoltaics industry is far from established today, this is consistent with the steady-state assumption.

To simplify the analysis, the interaction between advertising and salesman productivity is not modeled explicitly. That is, productivity is assumed to be independent of advertising. The impact of advertising is extremely difficult to model even for established products and is beyond the scope of this model. The user could test different relationships by varying the advertising expense rates and the salesman productivity rates for different types of customers.

The specific productivity assumptions are as follows:

At very low levels of AOQ (one kilowatt per order) it is assumed that the order-taking ability of salesmen for collectors will be comparable to that of account representatives for industrial products firms, namely that each salesman can make an average of 1750 calls per year and obtain one order for every 3.5 calls. Hence, for an average order quantity of .001 MW, each salesman averages 500 orders per year.

It is further assumed that at the level of 10 MW per order and above, approximately one salesman is required for every order obtained. Through linear interpolation, an equation is thus designed to yield the value for any level of AOQ.

AOQ Average Order Quantity (MW)	Annual Orders Per Salesman (Order/YR)	Megawatts Sales Per Salesman (MW/YR)
.000	0.00	.00
.001	500.00	.50
.010	51.00	.51
.100	5.90	.59
1.000	1.45	1.45
10.000 and above	1.00	10.00 or more

Note: the intermediate points in this table are interpolations, not break-points on a piece-wise linear function.

The size of a typical residential unit could range from 1 kilowatt (.001 MW) to 10 kilowatts (0.010 MW), depending upon the application.

Thus, the productivity relationships imply that a salesman could sell 500 solar water heating units in a year or 50 larger household electrical units.

Solar collectors of 5 MW or more would be purchased by public or private utilities for subfields in central power stations. Based on experience with the utility industry, a single salesman can typically make one large sale per year.

For the salesman of inverters, it is assumed that the productivity is twice as high. Clearly, once a customer has decided to buy a solar collector, he needs to buy a PCU too. This simplifies the sales effort.

Annual Megawatt Sales Per Person: Assuming a piece-wise linear relationship between annual megawatt sales per salesman and the average order quantity per customer, the following equations correspond to the data presented in the table above.

MWS(AOQ(I)) = Annual megawatt sales per salesman to customer type I (megawatt/year)

PRODUC = Product type indicator 1 = PCU or inverter
2 = Collector

Collector

$$\frac{MWS(AOQ(I))}{PRODUC} = \begin{cases} 0 & \text{for } 0 \geq AOQ \\ 500*AOQ & \text{for } 0 \leq AOQ < .001 \\ .4999 + .9501*AOQ & \text{for } 0.001 \leq AOQ < 10.000 \\ AOQ & \text{for } AOQ \geq 10.000 \end{cases}$$

Power Conditioning Unit

$$\frac{MWS(AOQ(I))}{PRODUC} = \begin{cases} 0 & \text{for } 0.0 \geq AOQ \\ 1000*AOQ & \text{for } 0.0 \leq AOQ < 0.001 \\ .999 + 1.902*AOQ & \text{for } 0.001 \leq AOQ < 10.000 \\ 2*A & \text{for } AOQ \geq 10.000 \end{cases}$$

The coefficients are expressed to 4 decimal digits so that substitution will yield the results presented in the table. They do not reflect the degree of accuracy of the linear productivity assumptions.

Size of Sales Force: The number of salesmen required is computed separately for each type of customer based on the total annual demand and the salesman productivity ratio. The total annual demand in each region and the average demand per customer are assumed to be known and constant over time for each customer type.

D(I,J) = Total annual demand in region J by customers of type I (MW/Year)
PRODUC = Product type indicator 1 = PCU or inverter
2 = Collector
SR(I,J) = Total number of salesmen required in region J for customers of type I
SR(I,J) = D(I,J)/(MWS(AOQ(I))*PRODUC

Salesman Support Index: Direct sales support personnel include:

- Field Engineers
- Market Research Analysts
- Technical Writers
- Commercial Artists
- Technical Illustrators
- Advertising Salesmen.

The amount of direct support per salesperson in the solar collector industry is assumed to depend on the type of customer. For power conditioning units(PCU), it is assumed to be half as large.

AOQ Average Order Quantity (MW)	SSI Salesman Support Index Collector	PCU
0.000	0.00	0.000
.001	0.10	0.050
1.000	0.19	0.185
10.000	1.00	0.500
100.000	5.00	2.500

PRODUC = Product type indicator 1 = PCU or inverter
2 = Collector

SSI(AOQ(I)) = Salesman support index for customer type I

Collector

$$
\begin{aligned}
PRODUC*SSI(AOQ(I)) &= 0 && \text{for } 0 \geq AOQ(I) \\
&= 100*AOQ(I) && \text{for } 0 \leq AOQ(I) < .001 \\
&= .0999+.0900*AOQ(I) && \text{for } 0.001 \leq AOQ(I) < 10.000 \\
&= .5556+.0444*AOQ(I) && \text{for } AOQ(I) \geq 10.000
\end{aligned}
$$

Power Conditioning Unit

$$
\begin{aligned}
PRODUC*SSI(AOQ(I)) &= 0 && \text{for } 0 \geq AOQ(I) \\
&= 50*AOQ(I) && \text{for } 0 \leq AOQ(I) < .001 \\
&= 0.05+0.045*AOQ(I) && \text{for } 0.001 \leq AOQ(I) < 10.000 \\
&= 0.2778+0.0222*AOQ(I) && \text{for } 10.000 \leq AOQ(I)
\end{aligned}
$$

These equations correspond to the data presented in the table above assuming a piece-wise linear relationship. The coefficients are expressed to 4 decimal digits so that the linear segments intersect at the breakpoints. This does not indicate the degree of accuracy in the estimates.

The number of direct sales support personnel required is computed by multiplying the number of salesmen by the support index by a requirement coefficient for each type of personnel.

DSP(KD,J) = Total number of direct sales support personnel type KD required in region J

$$= \sum_{I=1}^{3} RC(KD)*SSI(AOQ(I))*SR(I,J)*PRODUC$$

where,

RC(KD) = Requirement coefficient for direct support personnel of type KD

Index KD	Description	Requirement Coefficient RC(KD) Collector	PCU
1	Field Engineer	2.0	1.00
2	Commercial Artist	.1	.05
3	Market Research Analyst	.4	.20
4	Technical Illustrator	.2	.10
5	Technical Writer	.2	.10
6	Advertising Salesman	.1	.05

The requirement coefficients indicate the number of direct support personnel required per salesman when the salesman support index is one. This corresponds to an average order quantity per customer of 5 MW. It is assumed that the sales support required for customers of this size is equivalent to that for a small public utility.

Total Direct Sales Personnel Cost: From the number of salesman and the number of direct support personnel, the total direct sales personnel cost is computed.

DSC(J)= Total direct sales cost in region J
(in manufacturing year dollars per year)

$$= LJ(J)*(1+GB)^N\left(\sum_{I=1}^{3} SR(I,J)*CS(I) + \sum_{KD=1}^{6} DSP(KD,J)*AC(KD)\right)$$

where,

LJ(J)= Labor cost index in region J

GB = Labor cost inflation rate

N = (Manfacturing year) - (base price year)

AC(KD)= Annual compensation rate for direct sales personnel type KD (base price year $/year)

CS(I) = Annual compensation rate for salesman type I (base price year $/year)

The following standard values to be used for these parameters are contained in the block data subprogram.

Direct Sales Personnel Compensation Rates

Index I	Description	Annual Compensation* CS(I)
1	Salesman, Household Products	$24,570
2	Salesman, Commercial Products	$32,652
3	Salesman, Central Power Stations	$43,427

*Compensation rates include all wages and benefits expressed in 1981 dollars per year, and based on nationwide averages.

Index KD	Description	Annual Compensation* AC(KD)
1	Field Engineer	$35,917
2	Commercial Artist	$16,761
3	Market Research Analyst	$34,284
4	Technical Illustrator	$25,713
5	Technical Writer	$25,713
6	Advertising Salesman	$23,809

Indirect Sales Support Personnel: Indirect sales support personnel include the following:

- Regional Vice President, Sales and Marketing
- Manager, Advertising
- Manager, Marketing Research
- Manager, Sales
- Manager, Sales Engineering
- Secretary I (lower management)
- Secretary II (middle management)
- Secretary III (upper management)

The number required is determined from the number of salesman and direct sales staff following the line-staff relationships indicated on the organization chart and the indirect requirements matrix as follows:

TV = Total sales personnel vector (17 x 1)

DV = Direct sales personnel vector (17 x 1)

ISP = Indirect sales personnel vector (17 x 1)

RM = Indirect personnel requirements matrix (17 x 17)

I = Identity matrix (17 x 17)

Step 1: Compute total personnel from direct personnel vector, DV, and the indirect requirements matrix RM.

$$TV = (I - RM)^{-1} * DV$$

where, $DV = \begin{bmatrix} SR(1,J) \\ SR(2,J) \\ SR(3,J) \\ DSP(1,J) \\ DSP(2,J) \\ DSP(3,J) \\ DSP(4,J) \\ DSP(5,J) \\ DSP(6,J) \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$ (17 x 1 vector) (Last 8 rows = 0)

Step 2: Subtract direct from total to get indirect personnel.

$$ISP = TV - DV$$

where, $ISP = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ ISP(1,J) \\ ISP(2,J) \\ ISP(3,J) \\ ISP(4,J) \\ ISP(5,J) \\ ISP(6,J) \\ ISP(7,J) \\ ISP(8,J) \end{bmatrix}$ (First 9 rows = 0) (17 x 1 vector)

The elements in row I and column J of the indirect requirements matrix r_{ij} indicates the amount of indirect personnel type I required by direct personnel type J. The coefficients of this 17 x 17 matrix are presented on the following pages.

INDIRECT SALES SUPPORT STAFF RELATIONSHIPS*

Indirect Staff	Required By Staff	Matrix Element RM(I,J)
Vice President, Sales and Marketing	Manager, Sales Engineering	RM(10,11)=1/4
	Manager, Sales	RM(10,12)=1/4
	Manager, Advertising	RM(10,13)=1/4
	Manager, Marketing Research	RM(10,14)=1/4
Manager, Sales Engineering	Field Engineer	RM(11,4) =1/9
	Technical Writer	RM(11,8) =1/9
	Technical Illustrator	RM(11,7) =1/9
Manager, Sales	Salesman, Household Products	RM(12,1) =1/9
	Salesman, Commercial	RM(12,2) =1/6
	Salesman, Central Stations	RM(12,3) =1/4
Manager, Advertising	Commercial Artist	RM(13,5) =1/9
	Salesman, Advertising	RM(13,9) =1/6
Manager, Marketing Research	Marketing Research Analyst	RM(14,6) =1/6
Secretary I (Lower Management)	Salesman, Household Products	RM(15,1) =1/9
	Salesman, Commercial	RM(15,2) =1/6
	Salesman, Central Stations	RM(15,3) =1/4
	Market Research Analyst	RM(15,6) =1/4
	Salesman, Advertising	RM(15,9) =1/4
Secretary II (Middle Management)	Manager, Sales Engineering	RM(16,11)=1/2
	Manager, Sales	RM(16,12)=1/2
	Manager, Advertising	RM(16,13)=1/2
	Manager, Market Research	RM(16,14)=1/2
Secretary II (Upper Management)	Vice President, Sales and Marketing	RM(17,10)=1/2

*RM(I,J) is the number of "Indirect Staff" type I required for each one of direct staff type J. For example, one Secretary I (Lower Management) is required for every nine salesman of household products. R(I,J) is the element in the Ith row and Jth column of the 17x17 indirect requirements matrix. Only the nonzero elements of the matrix are listed in this table. All other elements are zero.

Total Indirect Sales Personnel Cost: The compensation rates for all indirect sales support personnel are listed below. These rates are used to compute indirect personnel costs as follows:

CIS(J) = Annual indirect sales personnel cost in region J (manufacturing year dollars/year)

$$= \sum_{KI=1}^{8} ISP(KI,J)*SAL(KI)*LJ(J)*(1+GB)^{N}$$

where,

LJ(J) = labor cost index in region J

GB = labor cost inflation rate

N = (manufacturing year) - (base price year)

SAL(KI) = annual compensation rate for indirect sales personnel type KI (base price year $/year)

ISP(KI,J) total number of indirect sales support personnel type KI required in region J

The following standard values to be used for these parameters are contained in the block data subprogram.

Indirect Sales Personnel Compensation Rates

Index KI	Description	Annual Compensation* SAL(KI)
1	Vice President, Sales and Marketing	81,357
2	Manager, Sales Engineering	52,243
3	Manager, Sales	52,243
4	Manager, Advertising	52,243
5	Manager, Marketing Research	52,243
6	Secretary I (Lower Management)	18,571
7	Secretary II (Middle Management)	19,809
8	Secretary III (Upper Management)	21,618

* Compensation rates include all wages and benefits expressed in 1981 dollars per year, and based on nationwide averages.

Office Facilities Cost: Office facility costs include:

- Office rental
- Utilities
- Maintenance
- Other expenses (e.g., insurance).

Office rental consists of the buildings, furniture, fixtures, and equipment. The amount of space required is determined by the number of people.

OS(J) = Sales office size in region J (square meters)

$$= [\sum_{KD=1}^{6} (DSP(KD,J) + \sum_{KI=1}^{8} ISP(KI,J) + \sum_{I=1}^{3} SR(I,J)]*SPP$$

where,

SPP = Amount of office space per person (square meters/person)

Note that the amount of office space per person has been expressed as a constant for all types of personnel. Actually, different personnel require different amounts of space. However, these differences are not significant. For the purposes of this model, an average figure will provide a good enough estimate of the office space because the personnel mix remains homogeneous at all levels of sales.

The total annual office facility costs in region J are computed from the following relationship:

OFC(J) = Total annual sales office facility costs in region J (manufacturing year dollars/year)

= ORC(J) + OUC(J) + OMC(J) + OOC(J)

where,

ORC(J) = Sales office rental expense in region J (manufacturing year $/year)

OUC(J) = Sales office utilities expense in region J (manufacturing year $/year)

OMC(J) = Sales office maintenance expense in region J (manufacturing year $/year)

OOC(J) = Other sales office expenses in region J (manufacturing year $/year)

These four variables are computed as follows:

SALES OFFICE FACILITIES COST PARAMETERS			
SPP	=	Amount of office space per person (Square meters/person)	= 12.45
GAMMAO	=	Sales office utilities cost rate (% of capital cost/year)	= 12.6%
RHOO	=	Sales office utilities cost rate (1981 $/square meter)	= $1.89
OM	=	Sales office maintenance cost rate (% of capital cost/year)	= 1.0%
BETA	=	Sales office property tax rate (% of capital cost/year)	= 4.0%
MU	=	Insurance rate (% of capital cost/year)	= 1.0%

- <u>Office Rental Expense-ORC(J)</u>

ORC(J) = GAMMO*CAPO(J)

CAPO(J) = BJ(J)*KO(OS(J))*$(1+GH)^N$

where,

GAMMAO = Office facilities lease rate (% of capital cost)

BJ(J) = Facilities cost index for region J

OS(J) = Sales office size in region J (square meters)

KO(OS(J))= Sales office facilities capital cost function

GH = Facilities inflation rate (%/year)

N = (Manufacturing year) - (base price year)

SALES OFFICE CAPITAL COST FUNCTION			
Sales Office Size (Square Meters) OS			Total Office Capital Cost (1981 $) K(OS)
0 ≤ OS ≤ 185	K (OS)	=	+ 517.33*OS
185 < OS ≤ 278	K (OS)	=	40,107.13 + 300.53*OS
278 < OS ≤ 372	K (OS)	=	7,598.52 + 417.46*OS
372 < OS ≤ 557	K (OS)	=	30,625.99 + 355.56*OS
557 < OS ≤1115	K (OS)	=	4,636.98 + 402.23*OS
1115 < OS	K (OS)	=	34,980.74 + 375.01*OS

- Office Utilities Expense - OUC(J)

  OUC(J) = UJ(J)*RHOO*OS(J)*$(1+GE)^N$

  where,
  UJ(J) = Utilities cost index for region J

  RHOO = Sales office utilities cost rate ($/square meter)

  OS(J) = Sales office size in region J (square meters)

  GE = Utilities inflation rate (%/year)

  N = (manufacturing year) - (base price year)

- Office Maintenance Expense - OMC(J)

  OMC(J) = OM*CAPO(J)

  where,
  OM = Sales office maintenance cost rate (% of capital cost/year)

Although maintenance costs are more labor intensive than capital cost, it is assumed that the total maintenance requirement depends on the capital cost of the office facilities. Capital costs include materials, construction labor, and architectural and engineering design fees. Furthermore, office maintenance represents a relatively small portion of the total sales office facilities cost. Thus, the office maintenance expense is not adjusted by the labor cost index for differences in regional labor costs or by the labor cost inflation rate.

- Other Office Expense - OOC(J)

  OOC(J) = (BETA + MU)*CAPO(J)

  where,
  BETA = Sales office property tax rate (% of capital cost/year)

  MU = Sales office insurance rate (% of capital cost/year)

Sales Expenses: Sales expenses include:

- Office supplies
- Travel and entertainment
- Communications.

These expenses are assumed to vary with the type of customer and are computed as a function of the direct cost of salesmen.

SEC(J) = Annual sales expense cost in region J (manufacturing year dollars per year)

$$= \sum_{I=1}^{3} SAE(I)*SR(I,J)*CS(I)*LJ(J)*(1 + GB)^{N}$$

where,
SAE(I) = Sales expense rate associated with the salesmen who sell to customer type I

The following standard values for SAE are contained in the block data subprogram.

SALES AND ADVERTISING EXPENSE PARAMETERS

Customer/Product Type (I)	Average Order Quantitt Range AOQ(I) (Megawatts/Order)	Sales Expense Rate SAE(I)		Advertising Cost Rate ADE(I)	
		COLL.	PCU	COLL.	PCU
Household Products	0.00 - .05	20%	10%	2.0%	0.2%
Commercial Products	0.05 - 1.00	25%	12.5%	1.0%	0.1%
Central Power Stations	1.00 - 500	30%	15%	0.1%	0.01%

Advertising Expense: Since this is a supply side model, the intent of the advertising expenses submodel is to prescribe a reasonable estimate of the advertising budget rather than to model the optimal advertising budget. The impact of advertising is extremely difficult to model even for established products and is beyond the scope of this model.

Thus, the size of the advertising budget is computed as a function of the cost of the product for each customer type. This allows the user to specify different advertising rates for different types of customers.

SAC(J) = Annual advertising cost in region J (manufacturing year dollars per year)

$$= \sum_{I=1}^{3} ADE(I)*PRICE(I)*10^{6}*D(I,J)$$

where,

ADE(J) = Advertising rate (% of manufacturing price) for customer type I

PRICE(I) = Manufacturing price for customer product type I (manufacturing year $/watt)

D(I,J) = Annual demand in region J by all customers of type I (megawatts/year)

10^6 = Conversation factor (watts/megawatt)

Standard values to be used for the advertising rate, ADE, are contained in the block data subprogram. The standard rates vary inversely with the cost of the product. That is, the advertising budget rate for small residential customers is higher than for large central power station customers. For inverters it is assumed that the advertising level is significantly lower, namely at 10% of the solar collector level. The following rules of thumb were used to establish the standard values:

Companies typically allocate between 1% and 2% of sales to advertising. Of course, this varies among industries. The percentage was nearly 5% for tabacco companies and .7% for food retailers in 1977.

Total Annual Sales Costs: The total annual sales costs are computed as the sum of direct personnel, indirect sales personnel, office facility, sales expense, and advertising cost in region J.

TSC(J) = Total annual sales cost in region J (manufacturing year dollars/year)

TSC(J) = DSC(J) + CIS(J) + OFC(J) + SEC(J) + SAC(J)

where,

DSC(J) = Annual direct sales personnel cost in region J (manufacturing year dollars/year)

CIS(J) = Annual indirect sales personnel cost in region J (manufacturing year dollars/year)

OFC(J) = Annual office facility cost in region J (manufacturing year dollars/year)

SEC(J) = Annual sales expense cost in region J (manufacturing year dollars/year)

SAC(J) = Annual advertising cost in region J (manufacturing year dollars/year)

Total Sales Personnel: This is computed as the sum of salesman, direct support personnel, and indirect support personnel.

$$SPERSN(J) = \sum_{I=1}^{3} SR(I,J) + \sum_{KD=1}^{6} DSR(KD,J) + \sum_{KI=1}^{8} ISP(KI,J)$$

= Total sales personnel in region J

Marketing Price Estimate Calculation: Marketing prices in dollars per watt are computed as follows:

Step 1: Set MPRICE(I,J) = 0

Step 2: Salaries & Benefits (direct sales)

$$MPRICE(I,J) = LJ(J)*(1+GB)^{N}[SR(I,J)*(CS(I)+SSI(AOQ(I))* \sum_{KD=1}^{6} RC(KD)*AC(KD)]$$

Step 3: Salaries & Benefits (Indirect Sales)

$$MPRICE(I,J) = MPRICE(I,J)*[1 + \frac{CIS(J)}{DSC(J)}]$$

Step 4: Office Facilities Expenses

$$MPRICE(I,J) = MPRICE(I,J)*[1+ \frac{OFC(J)}{DSC(J) + CIS(J)}]$$

Step 5: Sales Expenses

$$MPRICE(I,J) = MPRICE(I,J) + SAE(I)*SR(I,J)*CS(I)*LJ(J)*(1+GB)^{N}$$

Step 6: Advertising Expenses

$$MPRICE(I,J) = MPRICE(I,J) + ADE(I)*D(I,J)*PRICE(I)*10^{6}$$

Step 7: Total Marketing Price

At this point,

MPRICE(I,J) = Total annual marketing expenses for customer type I (manufacturing year $/year)

To get price, divide by annual demand in watts/year

$$MPRICE(I,J) = MPRICE(I,J)/(D(I,J)*10^{6})$$

2. Distribution Submodel Equations

Following are the algorithms and calculations for the distribution submodel.

Annual Cost for Direct Factory to Customer Shipments: If there is a warehouse in region J (this is, if X(I,J)=1), all deliveries to customers of type I in region J go through the warehouse. All other customers (that is, if X(I,J)=0) are supplied directly from the factory.

The cost of supplying customers directly from the factory is given by the following relationship:

$$DC(J) = \sum_{I=1}^{3} [(D(I,J)/ADQ(I)]*[1-X(I,J)]*[C(S(JR,J),(ADQ(I)*WT)] * (1+GT)^{N}$$

where,

DC(J)	=	Annual distribution cost in region J for customers supplied directly from the factory in region JR (in manufacturing year dollars/year).
D(I,J)	=	Annual demand in region J by all customers of type I (megawatts/year).
X(I,J)	=	0 if customers of type I in region J are supplied directly from the factory.
	=	1 if customers of type I in region J are supplied from a warehouse in region J.
GT	=	Transportation inflation rate (%/year).
N	=	(manufacturing year) - (base price year)
ADQ(I)	=	Average delivery quantity for customers of type I (megawatts/delivery).
WT	=	Product weight (kilograms/megawatt).
Z=ADQ(I)*WT	=	Average shipment weight to a customer of type I (kilograms/delivery).
S(JR,J)	=	Average shipping distance from region JR to region J (kilometers). This is a table look-up function presented on the second page following this one.
C(Z,S) C(S(JR,J),Z)	=	Interregional transportation cost as a function of the shipment weight, Z, and distance, S. This is a table look-up function presented on the next page. The transportation mode is optimized by quantity ordered, but regional geography is not considered.

INTERREGIONAL TRANSPORTATION COST FUNCTION

Weight Class (kilograms)	Transportation Mode	Freight Charge Rate (1981 $ Per 100 Kilograms)
Less than 225	Truck	27.3170 + 0.02418*S
225 to 450	Truck	21.3791 + 0.02603*S
450 to 900	Truck	17.4860 + 0.02557*S
900 to 2250	Truck	15.0479 + 0.02325*S
2250 to 4500	Truck	9.2791 + 0.02418*S
4500 to 10800	Truck	7.7363 + 0.02464*S
10800 to 18000	Truck	7.1202 + 0.01488*S
more than 18000	Rail	0.9752 + 0.01203*S

Where S = Shipping distance in kilometers

*Rail rates have been adjusted to include delivery to and from the train depot and to reflect differences between rail distance and road distance. Thus, the freight charges represent door-to-door transportation costs.

INTERREGIONAL SHIPPING DISTANCES
(kilometers)

Origin Region \ Destination Region	I West Coast Los Angeles	II Rocky Mountain Phoenix	III North Central Omaha	IV Great Lakes Springfield	V North Eastern Syracuse	VI South Eastern Atlanta	VII South Central Dallas
I West Coast Los Angeles	----	640	2788	3057	4344	3540	2293
II Rocky Mountain Phoenix	640	----	2100	2782	3595	3036	1652
III North Central Omaha	2788	2100	----	644	1770	1609	1064
IV Great Lakes Springfield	3057	2782	644	----	1287	965	1207
V North Eastern Syracuse	4344	3595	1770	1287	----	1529	2414
VI South Eastern Atlanta	3540	3036	1609	965	1529	----	1287
VII South Central Dallas	2293	1652	1064	1207	2414	1287	----

Annual Cost for Factory-Warehouse Transshipments: The cost of supplying demand in region J from a regional warehouse is composed of three parts:

- Factory-Warehouse Transportation Cost: The cost of transporting the product in bulk from the factory in region JR to the warehouse in region J. This is a function of the distance and the economic shipment quantity and includes the cost of processing the order.

- Warehousing Costs: This consists of inventory carrying costs, warehouse operating costs, and warehouse capital costs.

- Local Delivery Costs: This is the cost of distributing individual units from the warehouse to the customers.

Given the total demand in region J by each type of customer, D(I,J), the first two cost functions must be optimized to determine the economic warehouse order quantity. This balances the number of shipments with the size of the warehouse. It is assumed that the penalty cost associated with stockouts is sufficiently high that stockouts are not allowed. (This would be the likely case, for example, if the customer - not merely the sale - were lost if the product could not be delivered on time.)

The annual demands, D(I,J), the average delivery quantities, ADQ(I), and the product weight, WT, are input variables whose values are specified by the user.

The transportation cost function is a piecewise linear function of the quantity shipped and the distance traveled. X(I,J) is a decision variable whose value is determined to minimize total annual distribution costs. This determines which customers are supplied from the factory and which are supplied from the regional warehouse.

IC(J) = Total annual distribution cost for region J warehouse transshipments from the factory in region JR as a function of the warehouse order quantity Q(J) (in manufacturing year dollars/year).

$$= T(J,Q(J)) + W(J,Q(J)) + L(J)$$

where,

T(J,Q(J))= Annual transportation cost for shipments from the factory to the warehouse in region J as a function of the order quantity (Q(J) (in manufacturing year dollars/year).

W(J,Q(J)) = Annual warehousing cost in region J as a function of the order quantity Q(J) (in manufacturing year $/year).

L(J) = Annual local delivery cost in region J (in manufacturing year dollars)

These three transshipment cost parameters are computed as follows:

- Factory-Warehouse Transportation Cost

$$T(J,Q(J)) = \sum_{I=1}^{3} [(D(I,J)*X(I,J))/Q(J)]* [OP + C(Q(J)*(JR,J))WT,S] *(1 + GT)^N$$

where,

Q(J) = Factory warehouse shipment quantity in region J (megawatts/shipment).

D(I,J) = Annual demand by all customers of type I in region J (megawatts/year).

X(I,J) = 0 if customers of type I region J are supplied directly from the factory.
= 1 if customers of type I in region J are supplied from a warehouse in region J.

OP = Order processing cost ($/shipment).

WT = Product weight (kilograms/megawatt).

S(JR,J)= Average shipping distance from region JR to region J (kilometers).

C(Q(J)(JR,J))*WT,S = Interregional transportation cost as a function of the shipment weight and distance.

GT = Transportation inflation rate (%/year).

N = (manufacturing year) - (base price year).

- Warehouse Costs

W(J,Q(J))= Annual warehousing cost in region J as a function of the order quantity Q(J) (in manufacturing year dollars/year).

= CC(Q(J)) + OC(J,Q(J)) + LC(J,Q(J))

CC(Q(J)) = Annual inventory cost as a function of the warehouse order quantity in region J (in manufacturing year dollars/year).

OC(J,Q(J))= Annual warehouse operating cost in region J as a function of the warehouse order quantity, Q(J) (in manufacturing year dollars/year).

LC(J,Q(J))= Annual warehouse leasing cost in region J as a function of the warehouse order quantity, Q(J) (in manufacturing year dollars/year).

Inventory Carrying Cost: Q(J)/2 = Average inventory level assuming zero safety stock and uniform demand over time. Given a deterministic demand, this assumption minimizes the warehouse costs.

$$CC(J) = (Q(J)/2)* \sum_{I=1}^{3} \frac{PRICE(I)*D(I,J)*X(I,J)}{\sum_{I=1}^{3} D(I,J)*X(I,J)} *PHI*10^6$$

where,

Q(J) = Factory-warehouse shipment quantity in region J (megawatts).

PRICE(I) = Manufactured product price for customer type I i.e., the unit value of inventory (manufacturing year dollars/watt).

PHI = Annual inventory carrying charge (% of unit value).

10^6 = Conversion factor (watts/megawatt).

Inventory Carrying Charge Rate: Inventory carrying charges represent the cost of capital tied up in inventories. The model computes this cost by multiplying the average inventory value by the carrying charge rate, PHI. The standard value of PHI is computed as follows:

$$PHI = \text{Inventory Carrying Charge Rate}$$

$$= DIB \left[\frac{LAMDA - 1}{LAMDA}\right] + RHO \left[\frac{1}{LAMDA}\right]\left[\frac{1}{1 - TAU}\right] + MUW$$

where,

DIB = debt interest rate = .105

LAMDA = Leverage ratio = $\frac{\text{Total capital}}{\text{Total equity}}$ = 1.2

RHO = Rate of return on equity = .21

TAU = Effective income tax rate = .51

MUW = Inventory insurance rate = .01

The values listed above yield PHI = 37.75%

Warehouse Operating Cost: Operating costs include personnel, utilities, maintenance, property tax, and insurance on the building and equipment.

$OC(J,Q(J)) = PC(J) + UC(J) + MCC(J) + XSC(J)$

$PC(J)$ = Personnel cost.

$= LJ(J)*(1 + GB)^N *P(F(J))$

$UC(J)$ = Utilities cost.

$= UJ(J)*(1 + GE)^N*RHOW*F(J)$

$XCS(J)$ = Other warehouse operating cost

$= (BETAW + MUW) *[EJ(J)*KE(F(J))*(1 +GJ)^N+ BJ(J)*KB(F(J))*(1 + GH)^N]$

$MCC(J)$ = Maintenance cost.

$= M* [EJ(J)*KE(F(J))*(1 + GJ)^N+ BJ(J)*KB(F(J))*(1 + GH)^N]$

where,

$LJ(J)$ = Labor cost index for region J.

GB = Labor inflation rate (%/year).

$UJ(J)$ = Utility cost index for region J.

GE = Utilities inflation rate (%/year).

$EJ(J)$ = Equipment cost index for region J.

GJ = Equipment inflation rate (%/year).

$BJ(J)$ = Building cost index for region J.

GH = Facilities inflation rate (%/year).

$RHOW$ = Utility cost rate ($/square meter/year).

MUW = Insurance rate (% of capital cost/year).

M = Maintenance cost rate (% of capital cost/year).

$F(J)$ = Warehouse size in region J as a function of the warehouse order quantity (square meters). This is a piecewise linear function of the order size, Q, and is derived below.

$P(F(J))$ = Personnel cost function ($/year) includes both wages and benefits.

KE(F(J)) = Equipment capital cost function.

KB(F(J)) = Building capital cost function.

N = (manufacturing year) - (base price year)

Warehouse Size: The size of the regional warehouses is a function of the economic or optimal factory-warehouse order quantity, Q*, the physical volume of the solar product, V, and the warehouse space utilization factor.

F(J) = Warehouse size in region J (square meters).

= ALPHA*V*Q(J)

where,

Q(J) = Factory-warehouse shipment quantity in region J. (megawatts)

V = Solar product volume (cubic meters/megawatt)

ALPHA = Warehouse space utilization factor

The warehouse space utilization factor is used to compute the total amount of warehouse space required, based on the maximum inventory quantity and the physical volume of the solar products.

The multiplier includes the stacking height and allows for circulation and office areas. The standard value is based on the following assumptions:

- The inventory is stacked on pallets five meters high.
- A single factory shipment occupies 80% of the total warehouse area. This is the maximum inventory level with no space for safety stock. The remaining 20% of the warehouse is occupied by aisles, office areas, and restrooms.

ALPHA = Warehouse space utilization factor.

$$= \frac{100\%}{80\%} \left(\frac{1 \text{ square meter of warehouse floor}}{5 \text{ cubic meters of product}} \right)$$

= .25/meter

Building Capital Cost Function: The capital cost for construction of a warehouse depends on the size and location of the facility. A TB&A engineering cost analysis yielded the following average 1981 warehouse construction costs for Springifeld, Illinois.

Warehouse Size (Square Meters)	Average Construction Cost* ($/square meter)
250	334.51
1000	317.67
2500	300.85
25000	247.41

*Expressed in 1981 dollars for Springfield, Illinois.

To account for regional differences in construction costs, the cost relations should be adjusted using the regional construction cost index.

BUILDING CAPITAL COST FUNCTION

Warehouse Size F (Square Meters)	Total Land and Building Cost (1981$)
$0 \leq F \leq 250$	KB(F) = 347.19*F
$250 \leq F \leq 1000$	KB(F) = 5,825.17 + 323.89*F
$1000 < F \leq 2500$	KB(F) = 29,102.23 + 300.61*F
$2500 < F$	KB(F) = 154,060.02 + 250.63*F

Equipment Capital Cost Function: Warehouse equipment consists of forktrucks, conveyors, lifts, carts, pallets, and other materials handling equipment. The cost of items are approximated as a function of the size of the warehouse. The function yields economies of scale (that is, decreasing costs per square meter) for larger warehouses. The rationale for this phenomena is that larger warehouses are able to substitute capital for labor making automated equipment more economical.

EQUIPMENT CAPITAL COST FUNCTION

Warehouse Size F (Square Meters)	Equipment Capital Cost (1981$)
$0 \leq F \leq 1000$	KE(F) = 34.1*F
$1000 \leq F \leq 25000$	KE(F) = 6,554 + 27.5*F
$2500 < F$	KE(F) = 13,108 + 24.9*F

Warehouse Personnel Cost: The number of warehouse personnel required per square meter of space varies with the size of the warehouse. This reflects the assumption that larger warehouses will operate more efficiently and hence require fewer people per square meter. The following tables indicate the type of personnel and the quantity required for different warehouse sizes.

WAREHOUSE PERSONNEL COST

Personnel Description	Percent of Total Personnel	Annual Cost* (1981$)
Warehouse Supervisor	10%	$29,182.5
Forklift Operator	50%	14,965.4
Inventory Clerk	20%	18,380.2
Material Handler	20%	22,856.2
Total Weighted Average	100%	$18,648.2

*The annual cost for personnel includes both wages and benefits and is based on a nationwide survey. The costs should be multiplied by the appropriate labor cost index to reflect regional conditions.

Warehouse Size F (Square Meters)	Total Personnel
$F < 1$	PEOPLE = 0.00
$1 \leq F < 2000$	PEOPLE = 2.00
$2000 \leq F < 5000$	PEOPLE = 0.66 + 0.00067 * F
$5000 \leq F < 15000$	PEOPLE = 1.00 + 0.00060 * F
$15000 \leq F$	PEOPLE = 2.50 + 0.00050 * F

The annual cost for personnel includes both wages and benefits based on a nationwide survey. The amounts are expressed in 1981 dollars and should be multiplied by the appropriate labor cost index to reflect regional conditions. The following table presents equations (corresponding to the above table) for computing the annual personnel cost as a function of the warehouse size.

PERSONNEL COST FUNCTION

Warehouse Size F	Annual Personnel Cost (1981 $)
$0 < F \leq 2000$	$P(F) = 37{,}296.44$
$2000 < F \leq 5000$	$P(F) = 12{,}432.15 + 12.4321*F$
$5000 < F \leq 15000$	$P(F) = 18{,}648.22 + 11.1889*F$
$15000 < F$	$P(F) = 46{,}620.56 + 9.3241*F$

F = Warehouse size (square meters).

P(F) = Annual warehouse personnel cost (1981 $/year).

Maintenance Cost Rate: Maintenance costs for a warehouse can be approximated as a percent of the capital cost of the building and equipment.

M = Maintenance cost rate (% of capital cost/year).

M = 1%/year

Utility Cost Rate: For a warehouse, the major utility expense is the electric power cost. Hence, only electricity costs are computed directly. Other utility expenses (telephone, water, sewage disposal, fuel oil, etc.) are assumed to be a multiple of the total electricity cost. Since utility expenses are a small portion of the total warehouse operating cost, this simplifying assumption will not affect the end results significantly. Following are the assumptions for computing the annual utility cost rate per square meter of warehouse space:

Electric Power Cost:

$$\text{Capacity} = \left[.5 \frac{\text{watts}}{\text{square foot}}\right] * \left[\frac{1 \text{ square foot}}{.0929 \text{ square meters}}\right]$$

$$= 5.38 \text{ watts/square meter}$$

$$\text{Demand} = 40\% \left[365 \frac{\text{days}}{\text{year}}\right] \left[24 \frac{\text{hours}}{\text{day}}\right]$$

$$= 3504 \text{ hours/year}$$

Rate = $.052/kilowatt-hour (in 1981 dollars)

$$\text{Cost} = 5.38 \frac{3504}{1000} * (\$.052)$$

$$= \$.980/\text{square meter}$$

Total Utility Cost:

RHOW = Warehouse Utility Cost

RHOW = 1.93*(electric power cost)

RHOW = $1.89/square meter/year

The electricity cost rate is from Springfield, Illinois in Region II in 1981. The utility cost index must be used to obtain the cost for other regions, and the utility inflation rate must be used to adjust for other years.

Insurance Rate: The cost of insurance for a warehouse is assumed to be 1% of the original book value of the warehouse building and equipment.

MUW = Insurance Rate (% of capital cost/year)

MUW = 1%/year

Warehouse Leasing Cost: Annual warehouse leasing costs are computed separately for plant and equipment based on the economic lives and the lessor rate of return.

LC(J,Q(J))	=	Annual warehouse leasing cost in region J as a function of the warehouse order quantity, Q(J).
	=	GAMMAE*KE(F(J))*EJ(J)*(1 + GJ)^N + GAMMAB*KB(F(J))*BJ(J)*(1 + GH)^N
EJ(J)	=	Equipment cost index for region J.
BJ(J)	=	Building cost index for region J.
GAMMAE	=	Annual lease rate for equipment (percent of capital cost/year).
GJ	=	Equipment inflation rate (%/year).
N	=	(manufacturing year) - (base price year)
GAMMAB	=	Annual lease rate for building (percent of capital cost/year)
GH	=	Facilities inflation rate (%/year).
F(J)	=	Warehouse size in region J (square meters) as a function of the order quantity Q(J).
KE(F(J))	=	Equipment capital cost function.
KB(F(J))	=	Building and land capital cost function.

Equipment Lease Rate

$$GAMMAE = \frac{(1-s)}{\frac{1-(1+i)^n}{i}}$$

where,

s = Salvage value fraction of purchase price = .10

(1-s) = Effective replacement cost fraction (that is, purchase price minus salvage value)

n = Economic life = 5 years

i = Lessor's rate of return = 12.5%

GAMMAE= .25

Building Lease Rate

$$GAMMAB = \frac{(1-s)}{\frac{1-(1+i)^n}{i}}$$

where,

s = Salvage value fraction = 0

n = Economic life = 40 years

i = lessor's rate of return = 12.5%

GAMMAB= .126

- Customer Delivery Costs

Based on an analysis of local freight carriage costs in different regions of the U.S., transportation costs from the warehouse to the customers can be minimized when the company owns and operates a fleet of delivery trucks. The costs of owning and operating a delivery truck are divided into fixed and variable components. Fixed costs include drivers' wages and benefits, vehicle capital charges, depreciation, and insurance. Variable costs per kilometer consist of gas, oil, and maintenance. The following are formulas for computing these costs and fleet size required.

L(J) = Total annual local or intraregional delivery cost in region J (in manufacturing year dollars)

$$= [TK(J)*FC + VC*KM]*(1 + GT)^N$$

where,

TK(J) = Vehicle fleet size in region J.

FC = Annual fixed cost per vehicle ($/vehicle-year).

VC = Variable operating cost per vehicle-kilometer ($/kilometers).

KM = Total distance traveled by all vehicles (kilometers/year).

GT = Transportation inflation rate (%/year).

N = (manufacturing year) - (base price year)

Fleet Size Submodel: The fleet size and total distance traveled are given by the following relationship: The number of regional delivery trucks required is computed by dividing the total travel distance by the vehicle distance capacity.

$$TK = \frac{KM}{MC} \quad \text{(rounded up to an integer value}$$

Travel Distance Submodel: The total travel distance by all delivery trucks in a given region is computed as follows:

KM = Total distance traveled by all vehicles (kilometers/year)

= (#Tours) * (Distance per tour)

$$= \frac{(\#\text{Customers})}{(\#\text{Customers/Tour})} * (\text{Distance per tour})$$

$$\#\text{Customers} = \sum_{I=1}^{3} \frac{D(I,J)*X(I,J)}{ADQ(I)}$$

$$\#\text{Customers/Tour} = \frac{WC}{Q(I)*WT} \sum_{I=1}^{3} \frac{WC}{ADQ(I)*WT}$$

$$\text{Distance/Tour} = Y(I,J)*\left(\frac{WC}{ADQ(I)*WT}\right) + Y(I,J)$$

$$KM = \sum_{I=1}^{3} [(D(I,J)/ADQ(I)]*X(I,J)*Y(I,J)*[(1+ADQ(I))*WT/WC]$$

X(I,J = 0 if customers of type I in region J are supplied directly from the factory.
= 1 if customers of type I in region J are supplied from a warehouse in region J.

WC = Vehicle load capacity (kilograms/shipment).

WT = Product weight (kilograms/megawatt).

Y(I,J) = Average distance from the warehouse to the delivery location and between consecutive customers for customer type I in region J (kilometers)

The average delivery distance, Y(I,J), is specified as input by the user and can be used to model differences in the customer location distribution between regions and/or types of customers.

Following is a list of delivery cost parameters for a conventional truck. A heavy duty truck with a capacity of 4,000 kg of low density collectors (3 lb/ft or 49 kg/m) was selected for the base case.

- Vehicle Distance Capacity
  Assuming 250 days per year and 300 kilometers per day
  MC = 75,000 kilometers/vehicle/year

- Vehicle Load Capacity
  WC = 8,000 kilograms/delivery

- Annual Fixed Cost Per Vehicle
  Purchase cost, net $50,000

Capital recovery (5 year life, 20% salvage)	$ 8,000
Annual interest (@12%)	1,000
Annual return of equity (17.2% of equity)	7,200
Where Financial Leverage = Total Capital / Equity Capital = 1.2	$16,200
Debt = Total capital /6	
Annual amortization of tax saving @51%	(4,590)
Net capital cost	$11,610
Insurance	6,700
Driver's wages and benefits	13,700
FC = Annual Fixed Cost per Vehicle =	$31,510

- Variable Operating Cost per Vehicle Kilometer

Gas	$.096/kilometer
Oil and maintenance	.029/kilometer
VC = variable operating cost per vehicle kilometer =	$.125/kilometer

* All costs are expressed in 1981 dollars per year.

Total Annual Distribution Cost: The total annual distribution cost is found by minimizing the following function over all possible shipping combinations indicated by X(I,J) which equals 0 if customers of type I in region J are supplied directly from the factory and equals 1 if they are supplied from the warehouse.

$$TAC(J) = \underset{X(I,J)}{\text{MINIMUM}} \left[DC(J) + \underset{Q(J)}{\text{MINIMUM}} \ (IC(J))\right]$$

The cost of direct factory to customer shipments is DC(J) and the cost of indirect factory-warehouse transshipments is IC (J). The latter is minimized over all possible values of W*(J) to determine the economic factory warehouse shipping quantity.

3. Financial Submodel Equations

Following are the algorithms and calculations for the financial submodel:

Chart of Accounts - Income Statement: The purpose of the financial submodel is to compute the delivered price per watt for the solar products. To do this, it is necessary to prepare a pro-forma income statement to arrive at sales revenues. The resulting revenues can then be divided by the quantity sold to compute the delivered price. The income statement consists of the following chart of accounts.

Sales:
- Household Products
- Commercial Products
- Central Power Stations
  - Total sales

Cost of Goods Sold:
- Household Products
- Commercial Products
- Central Power Stations
  - Total Cost
  - Gross Profit

Expenses:
- Distribution (Schedule A)
- Marketing (Schedule B)
  - Total Expenses

Net Profit Before Tax

Net Income Tax
- Net Profit After Tax

Schedule A: Distribution Expenses	Schedule B: Marketing Expenses
Salaries and Benefits	Salaries and Benefits
Transportation	Sales Expenses
Warehouse Facilities:	Office Facilities:
Lease	Lease
Utilities	Utilities
Other Expenses	Other Expenses
Total Warehouse Expenses	Total Office Expenses
Inventory Carrying Charges	Advertising
Total Distribution Expenses	Total Marketing Expenses

The cost of goods sold represents the manufacturing cost, computed as the product of the manufacturing costs and the demand distribution. These are specified as inputs by the model user.

The annual marketing and distribution expenses listed in Schedules A and B are provided by the marketing and distribution models.

Income taxes and the net profit after tax are computed from the working capital requirement and normative profit equation based on the required revenue condition.

Required Revenue Condition: The required revenue condition states that the revenues must equal costs where costs include a reasonable return on equity. The only capital invested in the firm is working capital required for inventories and for cash to cover expenses during slump periods. Facilities and equipment are assumed to be rented.

Annual Revenue = Annual Cost

Price * Quantity = Manufacturing Cost of Goods Sold
+ Marketing Expenses
+ Distribution Expenses
+ Income Taxes
+ Net Profit After Tax

This equation is solved for price to derive price estimates for delivered product. First, net profit after tax is computed from the normative profit equation based on the working capital requirement.

Working Capital Requirement: Working capital is required for cash tied-up in inventories and for cash to cover expenses during slump periods.

AVERAGE WORKING CAPITAL = AVERAGE INVENTORY VALUE + AVERAGE CASH RESERVE

AWC(I,J) = Average working capital for customer type I in region J (manufacturing year dollars).

$$= \frac{ALFA}{12} * CGS(I,J) + \frac{BETAF}{12} *(TDX(I,J) + TMX(I,J))$$

where,

ALFA = Average inventory turnover time in months (ratio of inventory value to manufacturing cost of goods sold per month).

BETAF = Average expense coverage time in months (ratio of cash reserve to marketing and distribution expenses per month).

CGS(I,J) = Annual manufacturing cost of goods sold for customer type I in region J (manufacturing year dollars per year).

TDX(I,J) = Annual distribution expense for customer type I in region J (manufacturing year dollars per year).

TMS(I,J) = Annual marketing expense for customer type I in region J (manufacturing year dollars per year.

Normative Profit Equation: The normative profit equation assumes that net profit after taxes must provide a specified rate of return on the equity portion of working capital.

NPA(I,J) = Net profit after income tax for customer type I in region J.

$$= \frac{RHO}{LAMDA} * AWC(I,J)$$

where,

AWC(I,J) = Average working capital in region J (manufacturing year dollars).

RHO = Required minimum rate of return on equity.

LAMDA = Financial leverage ratio = $\frac{\text{Total Capital}}{\text{Total Equity}}$

Revenue

REV(I,J) = Total annual revenue from customer type I in region J (manufacturing year dollars/year).

REV(I,J) = CGS(I,J) + TDX(I,J) + TMX(I,J) + TAX(I,J) + NPA(I,J)

where,

TDX(I,J) = Annual distribution expense for customer type I in region J (manufacturing year dollars/year).

TMX(I,J) = Annual marketing expense for customer type I in region J (manufacturing year dollars/year).

TAX(I,J) = Annual income tax expense for customer type I in region J (manufacturing year dollars/year).

NPA(I,J) = Net profit after income tax for customer type I in region J (manufacturing year dollars/year.

Cost of Goods Sold

CGS(I,J) = Total annual manufacturing cost of goods sold in region J (manufacturing year dollars/year).

= D(I,J) * PRICE(I) * 10^6

where,

D(I,J) = Annual demand in region J by all customers of type I (megawatts/year).

PRICE(I) = Manufacturing price for customer type I (manufacturing year dollars/watt).

Gross Profit

GRO(I,J) = Annual gross profit for customer type I in region J (manufacturing year dollars/year).

= REV(I,J) - CGS(I,J)

Income Tax

TAX(I,J) = Annual income tax expense for customer type I in region J (manufacturing year dollars/year).

$$TAX(I,J) = \frac{TAU}{1-TAU} * NPA(I,J)$$

where,

TAU = Effective income tax rate.

NPA(I,J) = Net profit after income tax in region J (manufacturing year dollars/year).

Delivered Price Estimates: The delivered solar equipment prices expressed in dollars per watt are computed by dividing the total annual revenues by the total annual demand and deflating to report year dollars.

The prices include the manufacturing cost, marketing expense, distribution expense, income tax, and profit.

PPRICE(I,J)= Delivered price estimate for customer type I in region J (1980 dollars/watt).

= REV(I,J)/D(I,J)

where,

REV(I,J) = Annual sales revenue for customer type I in region J (manufacturing year dollars/year).

D(I,J) = Total annual demand for product I in region J (megawatts per year).

Key Financial Indicators: Four key financial indicators are provided to assist the financial community in interpretation of the results.

- Rate of Return of Eqity (Input)

  The rate of return on equity is the minimum required specified as input.

  RHO = Minimum required rate of return on equity.

  It is related to profit, leverage, and working capital as follows:

  $$RHO = NPA(I,J) * LAMDA * \frac{1}{AWC(I,J)}$$

- After Tax Cost of Capital (Computed from Input)

  The after tax cost of capital is the weighted average of debt and equity. This is computed from input parameters.

  $$ACAP = (1 - TAU)\left[1 - \frac{1}{LAMDA}\right] + DIB * \frac{RHO}{LAMDA}$$

  where,

  TAU = Effective income tax rate.

  DIB = Debt interest rate.

  1/LAMDA = Equity fraction of total capital.

- Markup (Computed from Output)
  Markup is the ratio of revenue less manufacturing cost to manufacturing cost.

  $$MARK(J) = \frac{\sum_{I=1}^{3} (REV(I,J) - CGS(I,J))}{\sum_{I=1}^{3} CGS(I,J)}$$

- Profit Margin (Computed from Output)
  The profit margin is the ratio of net profit after taxes to total revenue.

  $$PROF(J) = \frac{\sum_{I=1}^{3} NPA(I,J)}{\sum_{I=1}^{3} REV(I,J)}$$

I=1

FINANCIAL SUBMODEL STANDARD PARAMETERS

TAU	Effective income tax rate (%/year)	51%
RHO	Minimum required rate of return on equity (%/year)	21%
LAMDA	Financial leverage ratio (total capital/equity capital)	1.2
ALFA	Average inventory turnover time (months)	1.5
BETAF	Average expense coverage time (months)	6.0
DIB	Debt interest rate (%/year)	10.5%
PHIF	Inventory carrying charge rate (%/year)	37.75%

INFLATION RATES

CODE	INFLATION CLASS	MEASURE	ANNUAL RATE
GA	Raw Materials	Crude materials price index	11%
GB	Labor	Manufacturing labor	8%
GC	Chemicals	Industrial chemicals	13%
GD	Commodities	Producer finished goods	8%
GE	Energy & Utilities	Electric power	12%
GG	Land	Springfield real estate	4%
GH	Facilities	Factory and commercial buildings	9%
GI	Construction	Construction and contract labor	8%
GJ	Equipment	Machinery and equipment	7%
GF	Resources	Natural resources	15%
GT	Transportation	Transportation	7%

Sources: (a) Survey of Current Business Statistics (1967 = 100) published by the U.S. Department of Commerce.

(b) Bureau of Labor Statistics.

(c) Springfield Illinois Chamber of Commerce.

REGIONAL COST INDICES

REGION J	Labor LJ	Energy and Utilities UJ	Facilities BJ	Construction CJ	Equipment EJ
West Coast	1.103	1.320	1.062	1.062	1.062
Rocky Mountain	1.088	.820	.969	.969	.969
North Central	1.014	.900	1.052	1.052	1.052
Great Lakes	1.161	.900	1.000	1.000	1.000
North Eastern	.998	1.300	1.114	1.114	1.114
South Eastern	.858	.950	.938	.938	.938
South Central	.937	1.200	.927	.927	.927
National Average	1.000	1.000	1.041	1.041	1.041

Sources: Forbes, Business Week, Bureau of Labor Statistics, Data Resource Institute, National Bureau of Economic Research, Business School Professional, Engineering New Record, Census of Wholesale Trade, California Bureau of Labor Statistics, and Site Selection Handbook.

APPENDIX C
ERROR MESSAGES

Variable Name	Array Dimension	Variable Definition	Lower Bound	Upper Bound	Data Format
D(I,J)	I=1,3 J=1,7	total annual demand in region J by all customers of type I (megawatts per year)	0.0	100000.0	F8.2
AOQ(I)	I=1,3	average order quantity for customer type I (megawatts per order)	0.0	100.0	F6.3
ADQ(I)	I=1,3	average delivery quantity for customer type I (megawatts per shipment)	0.0	100.0	F6.3
PRICE(I)	I=1,3	manufacturing price of product for customers of type I (manufacturing year $/watt)	0.0	10.0	F5.3
TM	-	manufacturing year	1980	2000	I6
TR	-	report year for which dollars are reported on output reports	1980	2000	I6
WT	-	product weight (kilograms/ megawatt)	1000.0	10,000,000	F8.0

APPENDIX C
ERROR MESSAGES

Variable Name	Array Dimension	Variable Definition	Lower Bound	Upper Bound	Data Format
V	-	product volume (cubic meters/ megawatt)	100.0	100,000.0	F9.3
JR	-	factory location region	1	7	I2
XXX(J)	J=1,7	warehouse constraint indicator for region J 0 = compute optimal alternative 1 = cannot have warehouse 2 = must have warehouse	0	2	I1
RUNTYP	-	determines which subprograms should be executed: 1 = marketing only 2 = distribution only 3 = both marketing and distribution	1	3	I4
PRODUC	-	product type indicator 1 = PCU or inverter 2 = collector	1	2	I4

APPENDIX D: INPUT DATA FORMS

M&D MODEL INPUT DATA

GENERAL INFORMATION

- Manufacturing Year
  (the steady-state year for which the marketing costs are computed) _____

- Report Year
  (the year in which dollars are expressed on the output reports) _____

- Run Type (check one)

  _____ 1. Distribution only

  _____ 2. Marketing only

  _____ 3. Marketing, Distribution, & Financial

- Demand by Customer Type and Region (megawatts per year)

MARKET REGION	CUSTOMER TYPE		
	RESIDENTIAL HOUSEHOLD	COMMERCIAL INTERMEDIATE	PUBLIC UTILITY CENTRAL STATION
WEST COAST	_____	_____	_____
ROCKY MOUNTAIN	_____	_____	_____
NORTH CENTRAL	_____	_____	_____
GREAT LAKES	_____	_____	_____
NORTH EASTERN	_____	_____	_____
SOUTH EASTERN	_____	_____	_____
SOUTH CENTRAL	_____	_____	_____

- Manufacturing Price by Customer Type
  (manufacturing year dollars per watt)

  Residential/Household _____

  Commercial/Intermediate _____

  Public Utility/Central Station _____

MARKETING

- Average Order Quantity by Customer Type (megawatts per order)

  Residential/Household _____

  Commercial/Intermediate _____

  Public Utility/Central Station _____

DISTRIBUTION

- Solar Product Volume (cubic meters per megawatt) _____

- Solar Product Weight (kilograms per megawatt) _____

- Factory Location Region (check one)

  _____ West Coast _____ North Eastern

  _____ Rocky Mountain _____ South Eastern

  _____ North Central _____ South Central

  _____ Great Lakes

- Average Delivery Quantity by Customer Type (megawatts per shipment)

  Residential/Household _____

  Commercial/Intermediate _____

  Public Utility/Central Station _____

- Use of a warehouse (put a 0 in each region for which the program should determine if a warehouse is wanted; 1 for each region which is forbidden to have a warehouse; and 2 for each region which must have a warehouse)

  _____ West Coast _____ North Eastern

  _____ Rocky Mountain _____ South Eastern

  _____ North Central _____ South Central

  _____ Great Lakes

- Solar Product Type 1. _____ Power Conditioning Unit
  2. _____ Collector

APPENDIX E: INTERREGIONAL TRANSPORTATION COST FUNCTION

Objectives:

To analyze the interregional transportation cost function used for direct shipments from the factory to the customer.

Assumptions:

- The model assumes that the product is picked up at the factory and delivered to the final customer's site. The cost varies with shipping distance and shipment weight, but not with the number of shipments per year.
- The same rates are applied for all products including power conditioning units, flat-plate photovoltaic collectors and concentrator photovoltaic collectors. However, the rates do vary with the different weights of these products.
- The model assumes that a common or route carrier uses trucks for all shipments under 18,000 kilograms (40,000 lbs) independent of the origin and destination. Rail is the mode for all shipments exceeding 18,000 kg.

Results:

Pages 58 and 59 present the equations and a graph of the cost function. The lines on the graph of shipping cost ($/kilogram) versus shipping distance (kilometers) represent the cost equations for different weight levels. Note that two of the lines do intersect. This implies that the cost per kilogram will be slightly less for a smaller shipment of the same distance.

The tables on Page 60 show how the direct shipping cost function varies with shipping distance and shipment weight for three types of products: power conditioning unit, concentrator collector and flat-plate collector. The tables show the economies of scale for heavier shipments while the results are strictly linear for longer distances.

The four graphs of cost per shipment versus shipment weight for four different distances display the piecewise linear function. As the graphs indicate, in some cases the cost per shipment is less for larger shipments of the same distance. For example, consider the case of Phoenix to Los Angeles. A distance of 640 kilometers (397.7 miles):

10,000 kg	22,000 lbs	$2351/shipment
12,000 kg	26,400 lbs	$1997/shipment
18,000 kg	39,600 lbs	$1561/shipment

Thus, it is more economical to ship 39,600 lbs than 22,000 lbs. This may not be a realistic representation of the economies of scale.

Conclusions:

The shipping rates should be updated at some point in the future to eliminate the intersecting equations and the excessive economies of scale. However, these anomallies will not distort the results significantly.

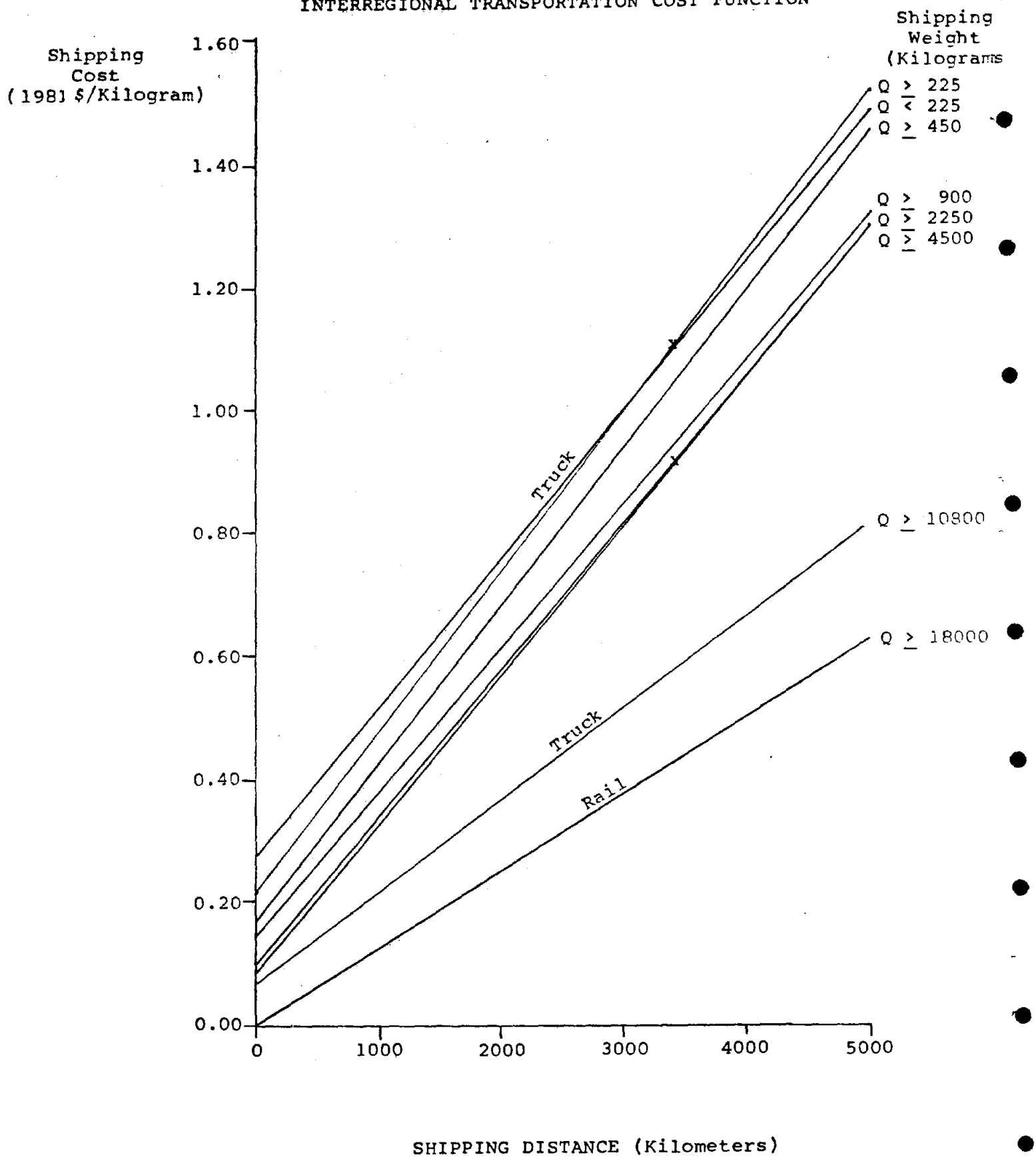
INTERREGIONAL TRANSPORTATION COST FUNCTION

Shipping Mode	Shipment Weight (Kilograms)	Equation 1981 $/100 Kilograms
TRUCK	$Q < 225$	$C(S,Q) = 27.3170 + 0.02418 \ast S$
TRUCK	$Q \geq 225$	$C(S,Q) = 21.3791 + 0.02603 \ast S$
TRUCK	$Q \geq 450$	$C(S,Q) = 17.8960 + 0.02557 \ast S$
TRUCK	$Q \geq 900$	$C(S,Q) = 15.0479 + 0.02325 \ast S$
TRUCK	$Q \geq 2250$	$C(S,Q) = 9.2791 + 0.02418 \ast S$
TRUCK	$Q \geq 4500$	$C(S,Q) = 7.7363 + 0.02464 \ast S$
TRUCK	$Q \geq 10800$	$C(S,Q) = 7.1202 + 0.01488 \ast S$
RAIL	$Q \geq 18000$	$C(S,Q) = 0.9752 + 0.01203 \ast S$

CONVERSION FACTORS:
2.200 lbs/kilogram
0.6214 miles/kilometer

SYMBOLS:
C(S,Q) = Cost Per Shipment Function ($/100 kilograms)
S = Shipping Distance (km)
Q = Shipment Weight (kg)

INTERREGIONAL TRANSPORTATION COST FUNCTION



INTERREGIONAL TRANSPORTATION COST FUNCTION

Four example cases of different shipment distances were analyzed to illustrate how the interregional cost function is applied for direct shipping for three different solar products.

SHIPPING DISTANCES

		KILOMETERS	MILES
Case A	Phoenix to Phoenix	50.0	31.07
Case B	Phoenix to Los Angeles	640.0	397.7
Case C	Phoenix to Dallas	1652.0	1026.6
Case D	Phoenix to Atlanta	3036.0	1886.6

POWER CONDITIONING UNIT
1981 $/shipment

Shipment Size	0.006 MW	0.060 MW	0.600 MW	6.000 MW
Distance	611 lbs	6109 lbs	61090 lbs	610896 lbs
A. 31.07 miles	$ 62.87	$290.73	$ 437.06	1777.41
B. 397.70 miles	105.62	687.38	2408.71	21964.49
C. 1026.6 miles	178.77	1366.86	5789.28	56585.19
D. 1886.6 miles	195.73	2296.12	10412.52	03862.09

CONCENTRATOR COLLECTOR
1981 $/shipment

Shipment Size	0.005 MW	0.050 MW	0.500 MW	5.000 MW
Distance	5091 lbs	50908 lbs	509080 lbs	090800 lbs
A. 31.07 miles	$242.69	$364.85	$1483.74	14837.37
B. 397.70 miles	572.81	2007.26	18303.74	83037.40
C. 1026.6 miles	1139.05	4824.40	47154.32	71543.22
D. 1886.6 miles	1913.44	8677.10	86610.06	66100.58

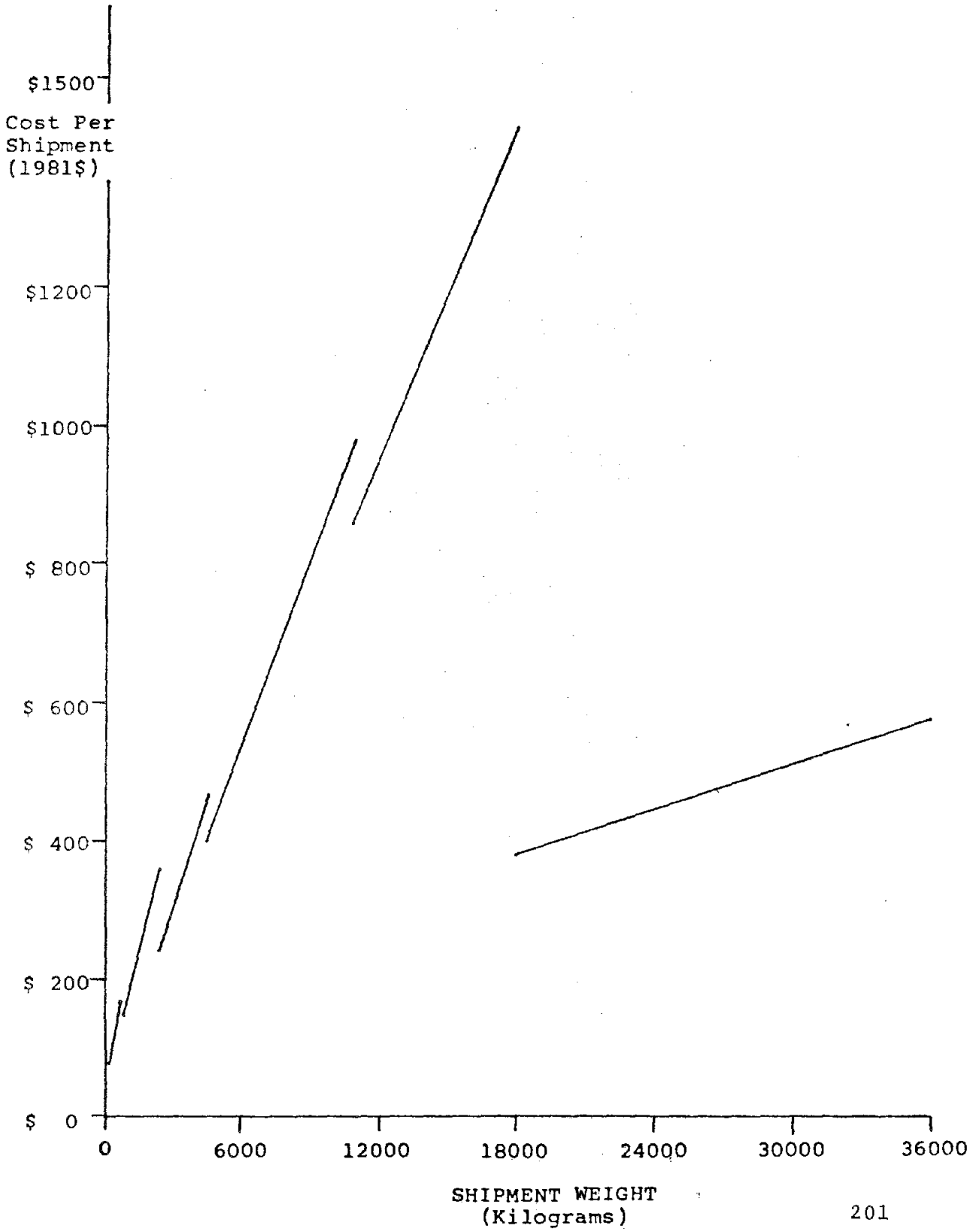
FLAT-PLATE COLLECTOR
1981 $/shipment

Shipment Size	0.005 MW	0.050 MW	0.500 MW	5.000 MW
Distance	1715 lbs	17152 lbs	171516 lbs	715164 lbs
A. 31.07 miles	$146.29	$699.19	$ 499.89	4998.92
B. 397.70 miles	263.91	1832.57	6166.79	61667.94
C. 1026.6 miles	465.65	3776.60	15886.97	58869.72
D. 1886.6 miles	741.55	6435.24	29180.18	91801.79

The cost per shipment functions corresponding to each shipping distance are also presented graphically on the following four pages.

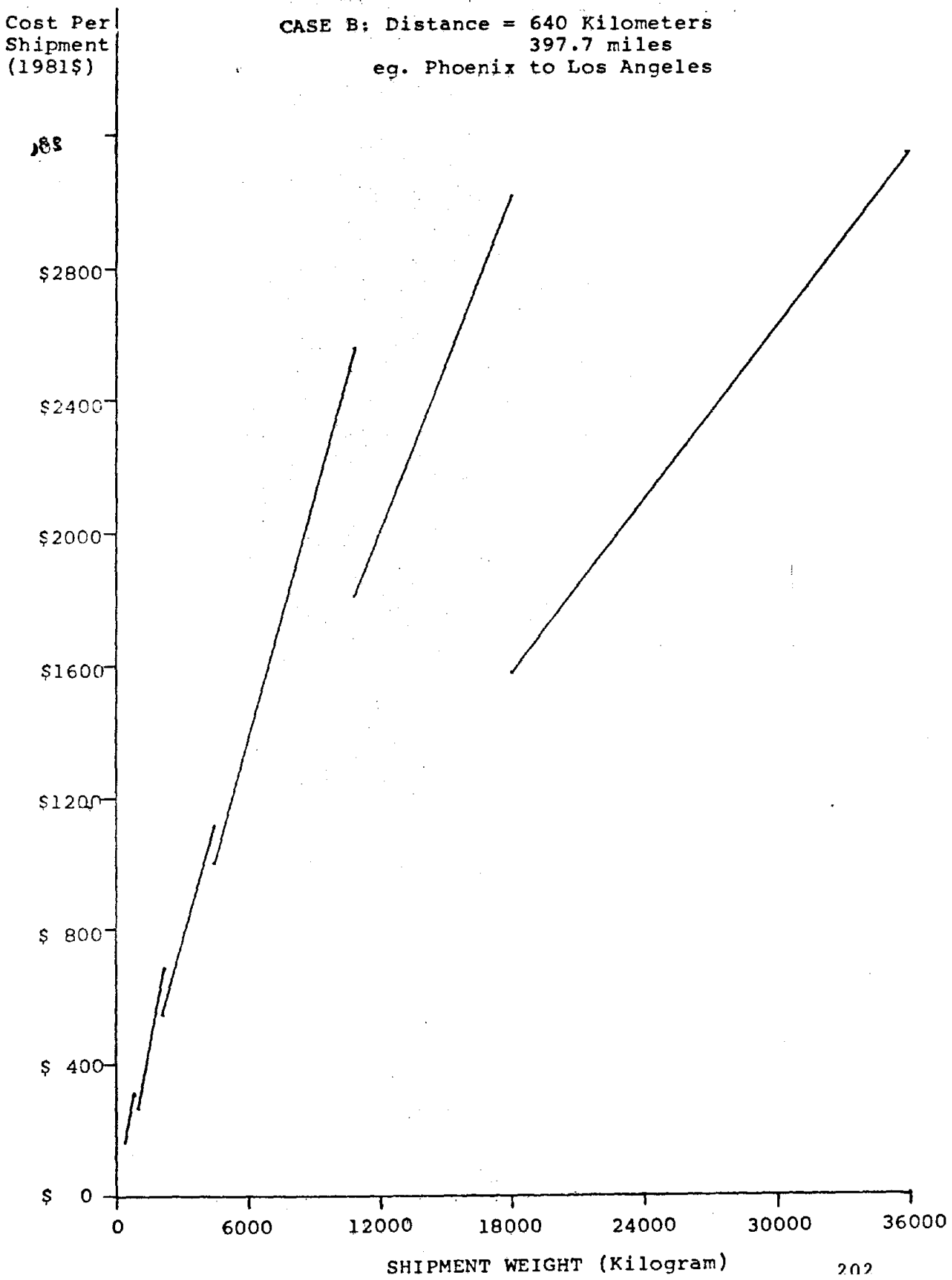
INTERREGIONAL TRANSPORTATION COST FUNCTION

CASE A: Distance = 50 Kilometers
31.07 miles
eg. Phoenix to Phoenix

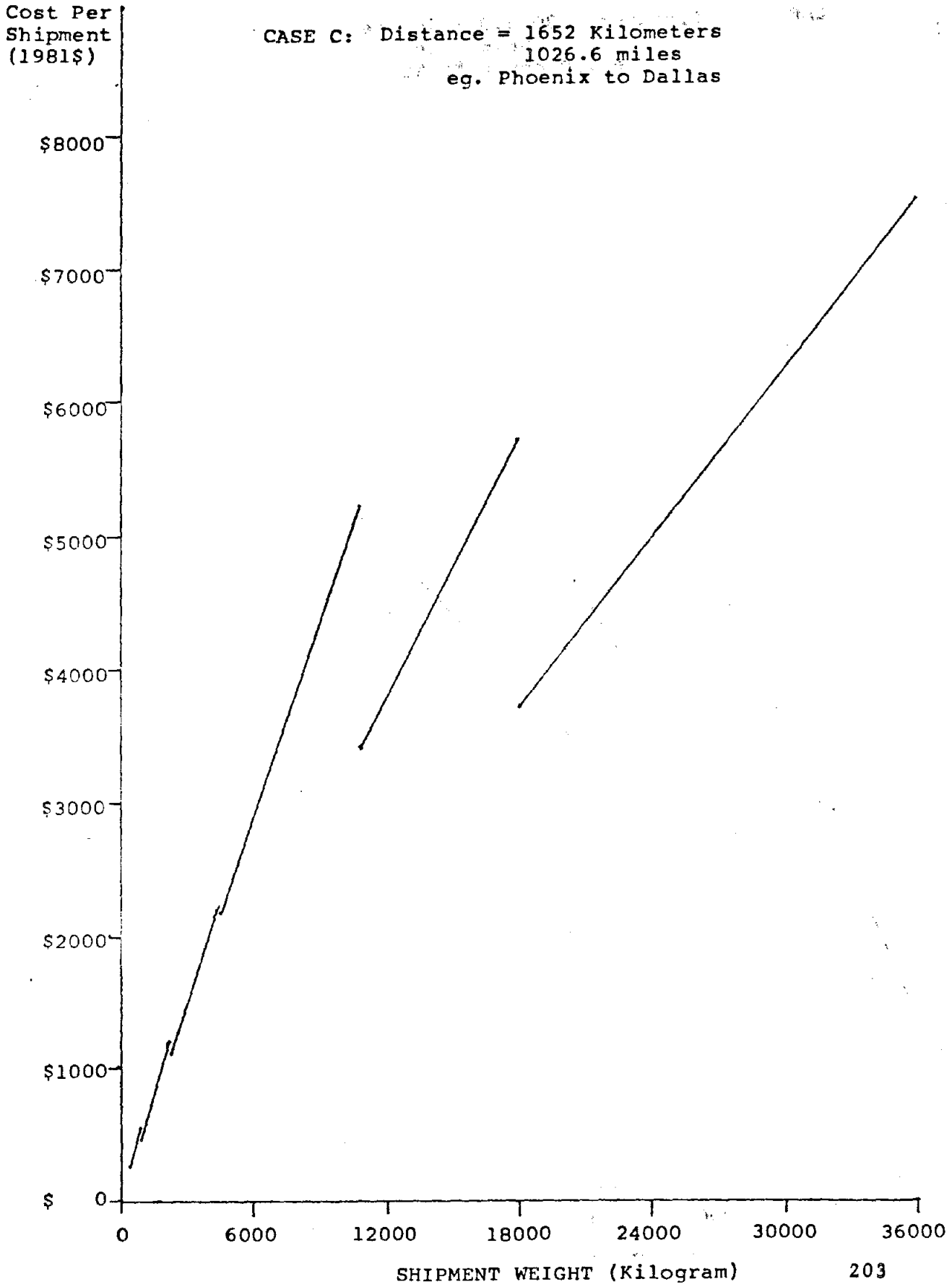


INTERREGIONAL TRANSPORTATION COST FUNCTION

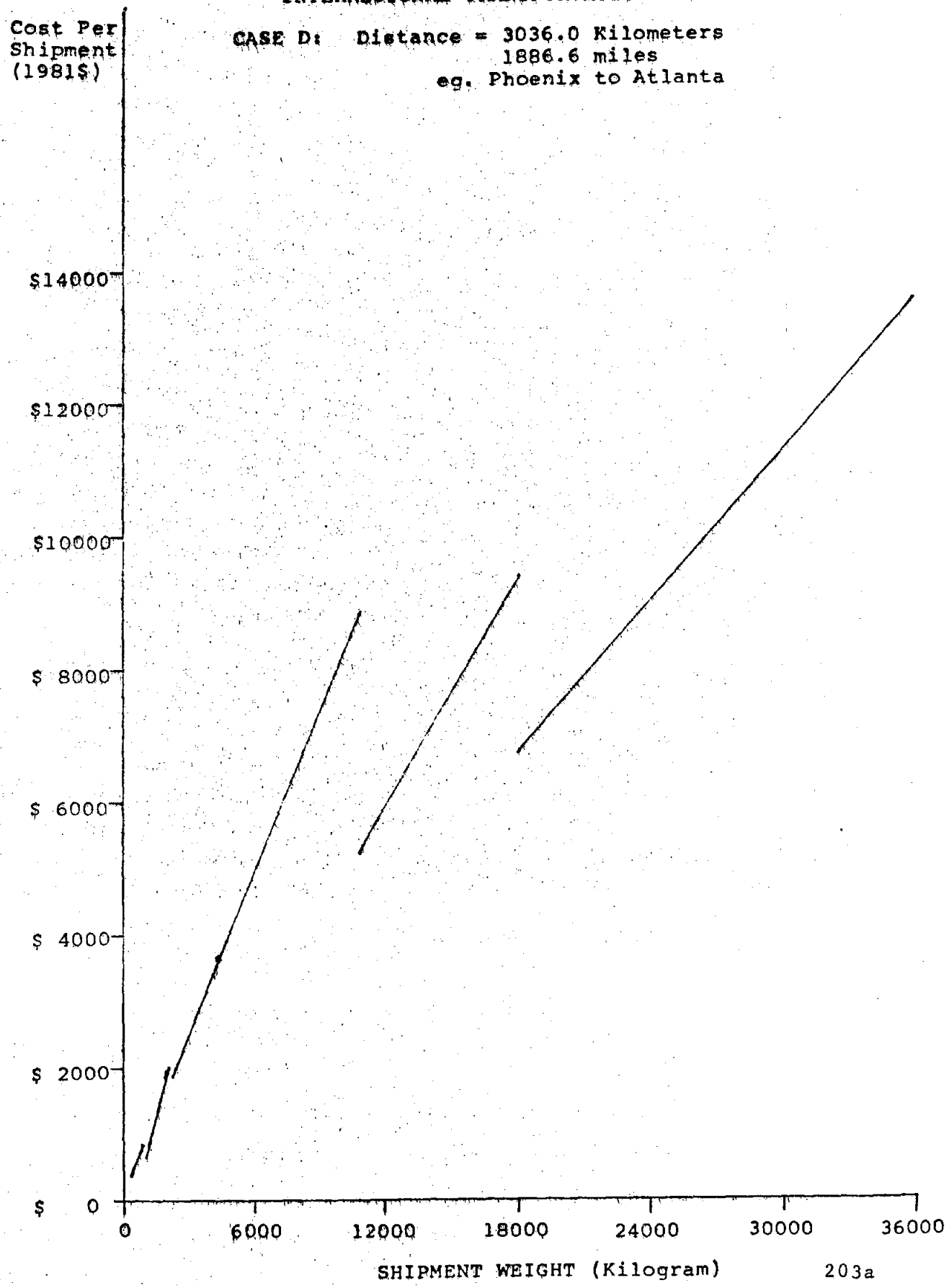
CASE B: Distance = 640 Kilometers
397.7 miles
eg. Phoenix to Los Angeles



INTERREGIONAL TRANSPORTATION COST FUNCTION



INTERREGIONAL TRANSPORTATION COST FUNCTION



INTERREGIONAL TRANSPORTATION COST FUNCTION

These tables contain the data points that are plotted on the preceeding four graphs.

CASE A: S = DISTANCE = 50 Kilometers (31.07 miles)

$/kg	Q kg	C(S,Q) $/ship	Q kg	C(S,Q) $/ship
.28	100	28	225	64
.23	225	51	450	102
.19	450	84	900	169
.16	900	146	2250	365
.10	2250	236	4500	472
.09	4500	404	10800	969
.08	10800	849	18000	1416
.02	18000	284	36000	568

CASE B: S = DISTANCE = 640 Kilometers (397.7 miles)

$/kg	Q kg	C(S,Q) $/ship	Q kg	C(S,Q) $/ship
.43	100	43	225	96
.38	225	85	450	171
.34	450	152	900	305
.30	900	269	2250	673
.25	2250	557	4500	1114
.24	4500	1058	10800	2539
.17	10800	1797	18000	2996
.09	18000	1561	36000	3123

CASE C: S = DISTANCE = 1652 Kilometers (1026.6 miles)

$/kg	Q kg	C(S,Q) $/ship	Q kg	C(S,Q) $/ship
.67	100	67	225	151
.64	225	145	450	290
.60	450	269	900	538
.53	900	481	2250	1203
.49	2250	1108	4500	2215
.48	4500	2180	10800	5232
.32	10800	3424	18000	5706
.21	18000	3753	36000	7506

CASE D: S = DISTANCE = 3036 Kilometers (1886.6 miles)

$/kg	Q kg	C(S,Q) $/ship	Q kg	C(S,Q) $/ship
1.00	100	100	225	225
1.00	225	225	450	450
.95	450	428	900	856
.86	900	771	2250	1927
.83	2250	1861	4500	3721
.82	4500	3714	10800	8915
.52	10800	5648	18000	9413
.37	18000	6750	36000	13500

APPENDIX F: LOCAL DELIVERY COST FUNCTION

Objectives:

To analyze the local delivery cost function for shipments within a region from the warehouse to the customer.

Assumptions:

- The model assumes the purchase of trucks and the hiring of drivers to handle all local deliveries.

- Values of the following standard parameters have a significant impact of the results:

  -Fixed cost per vehicle - $31,510.20/year
  -Variable cost - $0.125/kilometer
  -Vehicle distance capacity - 75,000 kilometers/year
  -Vehicle load capacity - 8000 kilometers/shipment

  These parameters can be modified by the model user to represent a specific situation.

- The average shipping distance from the warehouse to the customer is assumed to be 50 kilometers (31 miles). This is also a standard parameter which can be changed by the user.

Page 68 presents the M&D model equations for the local delivery cost function.

Result:

An example case for a photovoltaic concentrator demonstrates the use of the model. The detailed results presented on pages 69 and 70 are summarized below.

- For low shipping volumes (below 10 shipments per year), the cost per shipment is extremely high due to the high fixed cost of $31,510.20 per year for the driver and truck. For the concentrator example, the cost per shipment is as follows:

1 shipment	$31,697
10 shipments	3,338
50 shipments	817

  In this case, fifty shipments per year is the capacity limit of a single truck. Consequently, $817 per shipment is the minimum cost.

- For high shipping volumes (over 500 shipment/year), the cost per shipment is constant or independent of volume, as the function approaches the minimum cost corresponding to the capacity limit of the truck. That is, as volume increases more trucks are added with a decreasing impact on cost per shipment. For this example, the capacity limit is $817/shipment. The cost is relatively constant above 500 shipments per year with 10 or more trucks.

- At intermediate volumes (between 50 and 500 shipments/year), the discontinuity of the function causes some diseconomies of scale at the points where the function adds another truck. For the example, one truck is required for up to 50 shipments per year. The cost per shipment is $817. For 51 shipments, two trucks are required and the cost per shipment is $1423.

Conclusions:

At low volumes, it is more economical to ship via common carrier directly from the factory than to employ a local delivery truck.

The results are extremely dependent on the values of the standard parameters used. The type and size of delivery truck used should be modified to match the product, average delivery size, and total demand. Also, the average shipping distance of customers from the warehouse may vary significantly from one region to the next.

LOCAL DELIVERY COST FUNCTION

Annual Cost = Fixed Cost + Variable Cost

$$LC = FC * TK + VC * KM$$

where

LC = annual cost for local deliveries

TK = number of delivery trucks

$$TK = \text{integer}\left(\frac{KM}{MC} + .9\right)$$

KM = total delivery distance (kilometers/year)

$$KM = \frac{D}{ADQ} * Y * \left(1 + \frac{ADQ * WT}{WC}\right)$$

FC = fixed cost/vehicle/year = $31,510.20/year

VC = variable cost = $0.125/kilometer

MC = vehicle distance capacity = 75000 kilometers/vehicle/year
= 46605 miles/vehicle/year

WC = vehicle load capacity = 8000 kilograms/shipment
= 17600 lbs/shipment

Y = average shipping distance = 50 kilometers/shipment
= 31 miles/shipment

D = annual demand (megawatts)

ADQ = average delivery quantity (megawatts/delivery)

LOCAL DELIVERY COST FUNCTION

The following example case for a photovoltaic concentrator collector illustrates the local delivery cost function.

CONCENTRATOR COLLECTOR

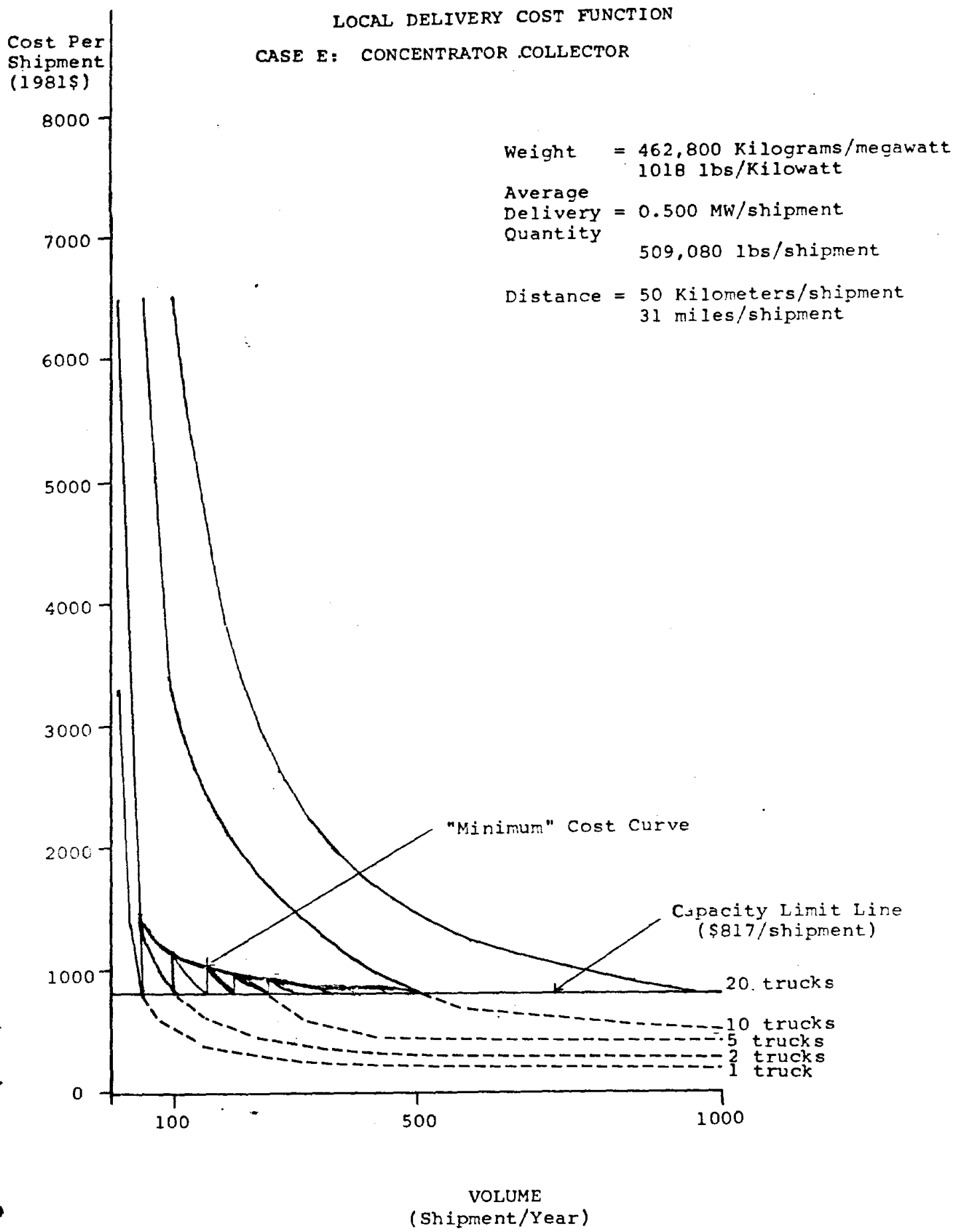
Weight = WT = 462,800 kg/MW (1018 lbs/kilowatt)
Average delivery = .500 MW (509,080 lbs)
(29 truckloads/customer)

$$KM = V * 50 \left(1 + \frac{.5 * 462{,}800}{8000}\right) \text{ kilometers/year}$$
$$= 1496.25 \text{ kilometers/shipment} * V$$

VOLUME	1	10	100	1000	shipments
KM	1,49625	14,9625	149,625	1,496,250	kilometers
TRUCKS	1	1	2	20	trucks
COST/SHIP	$31697	$3338	$817	$817	1981 $/shipment

COST (1981 $/SHIPMENT)

SHIPMENTS PER YEAR	1 TRUCK	2 TRUCKS	10 TRUCKS	20 TRUCKS
1	31697	63207	315289	630391
10	3338	6489	31716	63207
50	817	1447	6489	12791
100	502	817	3338	6489
500	250	313	817	1447
1000	218	250	502	817
TRUCK CAPACITY (SHIPMENTS PER YEAR)	50	100	501	1002


LOCAL DELIVERY COST FUNCTION
CASE E: CONCENTRATOR COLLECTOR
Cost Per Shipment (1981$)
8000
7000
6000
5000
4000
3000
2000
1000
0
Weight = 462,800 Kilograms/megawatt
1018 lbs/Kilowatt
Average Delivery Quantity = 0.500 MW/shipment
509,080 lbs/shipment
Distance = 50 Kilometers/shipment
31 miles/shipment
"Minimum" Cost Curve
Capacity Limit Line ($817/shipment)
20 trucks
10 trucks
5 trucks
2 trucks
1 truck
100
500
1000
VOLUME
(Shipment/Year)

APPENDIX G: WAREHOUSE TRANSSHIPMENT COST FUNCTION

Objectives:

To analyze economic order quantity and shipping frequency for transshipments from the factory through a warehouse to the customer.

Assumptions:

Given the total demand in a particular region, the model computes the economic order quantity to be shipped from the factory to the warehouse and the corresponding warehouse size. The economic order quantity is selected to minimize the total annual distribution cost which consists of three components:

- factory/warehouse transportation cost
- warehousing cost
- local delivery cost

The first component decreases with increasing order quantities as the cost per shipment is lower for larger less frequent shipments. It also includes an order processing cost which is a fixed charge for handling and paperwork. This charge is assumed to be independent of the order size. The interregional transportation cost function is used for shipping to the warehouse.

The second component involves warehouse operating costs and inventory carrying charges. These increase with the order quantity because the average inventory level is assumed to be higher for less frequent shipments.

The third component, local delivery cost, depends only on the total demand and the average delivery quantity. It is assumed to be independent of the quantity shipped to the factory. This represents the cost of shipping from the warehouse to the final customer. The local delivery cost function is used.

Results:

The following results reveal the interrelationship between these variables for three different solar products: a power conditioning unit, a flat-plate photovoltaic collector and a concentrator collector.

For each product the following assumptions hold:

- Factory in Phoenix
- Warehouse in Dallas
- Average Delivery Size 0.005 MW/delivery
- Manufacturing Year = Report Year = 1981

The model generated the following results for two levels of annual demand: 5 MW and 50 MW.

ANNUAL DEMAND (MW)	ORDER QUANTITY (MW)	SHIPPING FREQUENCY	WAREHOUSE SIZE (ft^2)	COST PER DELIVERY 1981$
		POWER CONDITIONING UNIT		
5	0.417	monthly	157	$139
50	0.962	weekly	362	$ 84
		FLAT-PLATE COLLECTOR		
5	0.192	biweekly	731	$268
50	0.192	daily	731	$202
		CONCENTRATOR COLLECTOR		
5	0.096	weekly	2635	$591
50	0.192	daily	5270	$530

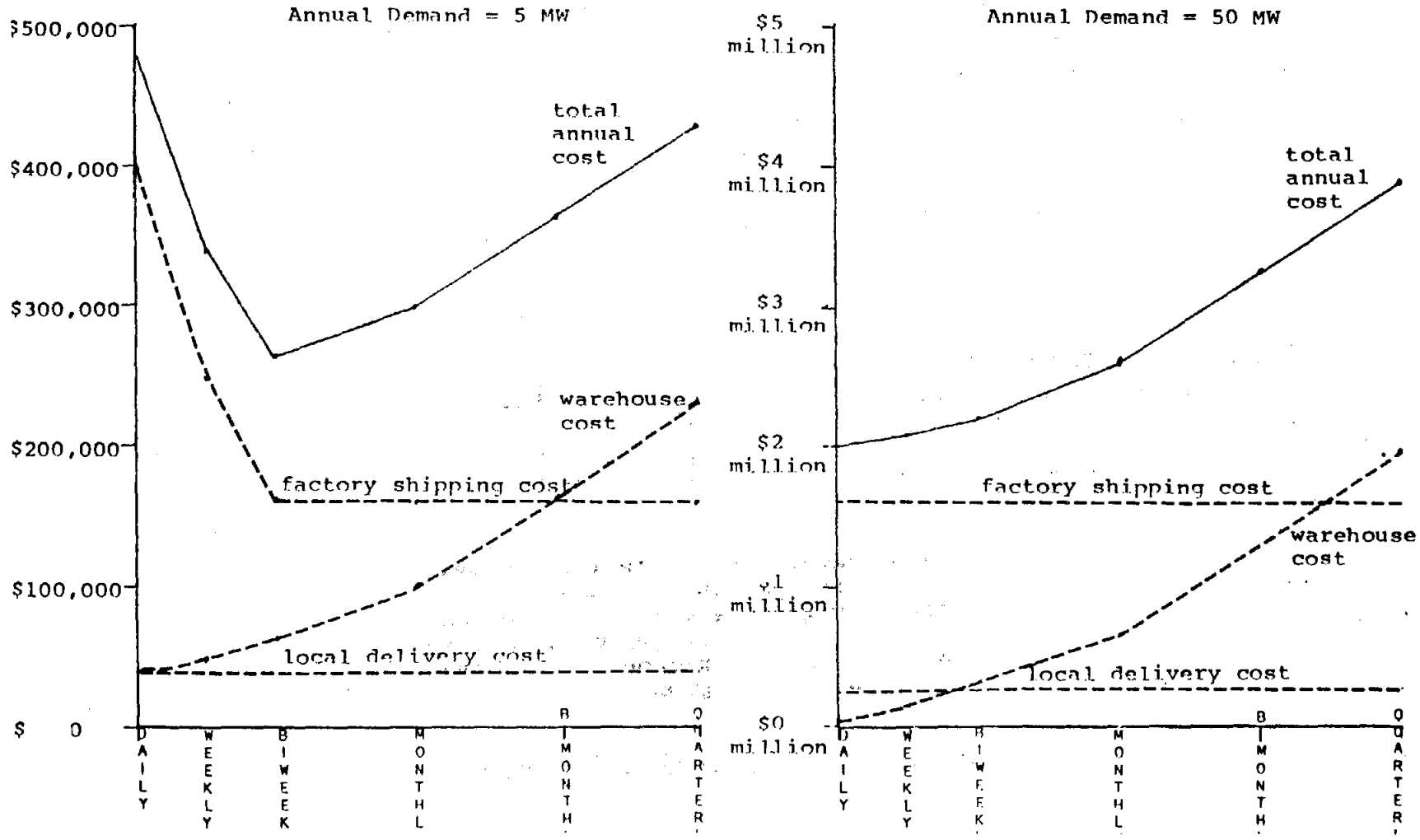
Conclusions:

At high volumes, the economic shipping frequency becomes unrealisticly short because the factory-warehouse transportation cost is relatively constant. Meanwhile, warehousing costs increase significantly with less frequent shipments or larger orders. Consequently, the model indicates that shipments should be made daily or even more frequently. Two things can be done to modify this situation. Number one, the model can be constrained with a minimum shipping frequency of two weeks so that more frequent shipments are not allowed. Second, the order processing cost can be increased to $6000 per order in high volume situations.

The computer program currently constrains the shipping frequency to a minimum of two weeks and uses an order processing cost $68 per order.

WAREHOUSE TRANSSHIPMENT COST FUNCTION

Flat-Plate Photovoltaic Collector
Factory in Phoenix
Warehouse in Dallas
Average Delivery Size 5 KW



WAREHOUSE TRANSSHIPMENT COST ANALYSIS

Total Demand = 5 MW/Year
Factory in Phoenix = 1652 kilometers
Warehouse in Dallas
Average Order Size = 0.005 MW/Order
1000 Deliveries/Year
Manufacturing Year = 1981/Report Year = 1981

SHIPMENTS/YEAR	260	52	26	12	6	4
ORDER QUANTITY	0.0192MW	0.0962MW	0.192MW	0.417MW	0.833MW	1.25MW

POWER CONDITIONING UNIT (Weight 46,280 kg/mw Volume = 140m^3/mw Price = $.20/watt)

	Daily	Weekly	Biweekly	Monthly	Bimonthly	Quarterly
Factory-Warehouse Cost	155890	117441	114058	49060	48652	48516
Warehousing Cost	35721	38819	41916	51725	68503	85281
Local Delivery Cost	37941	37941	37941	37941	37941	37941
Total Annual Cost	229552	194201	193915	138726	155096	171738

FLAT-PLATE COLLECTOR (Weight 155,925 kg/mw Volume = 1415.805m^3/mw Price = $.70/watt)

	Daily	Weekly	Biweekly	Monthly	Bimonthly	Quarterly
Factory-Warehouse Cost	401446	250692	164310	163358	162950	162814
Warehousing Cost	37977	50099	65252	100607	166087	231155
Local Delivery Cost	38369	38369	38369	38369	38369	38369
Total Annual Cost	477793	339161	267931	302335	367406	432338

CONCENTRATOR COLLECTOR (Weight 462,800 kg/mw Volume = 10200 m^3/mw Price = $.70/watt)

	Daily	Weekly	Biweekly	Monthly	Bimonthly	Quarterly
Factory-Warehouse Cost	1138618	485976	484208	483256	482848	482712
Warehousing Cost	41015	65288	94663	162778	285163	412049
Local Delivery Cost	39568	39568	39568	39568	39568	39568
Total Annual Cost	1219201	590832	618440	685602	807580	934329

WAREHOUSE TRANSSHIPMENT COST ANALYSIS

Total Demand = 50 MW/Year
Factory in Phoenix = 1652 kilometers
Warehouse in Dallas
Average Order Size = 0.005 MW/Order
10000 Deliveries/Year
Manufacturing Year = 1981/Report Year 1981

SHIPMENTS/YEAR	260	52	26	12	6	4
ORDER QUANTITY	0.0192MW	0.0962MW	0.192MW	0.417MW	0.833MW	1.25MW

POWER CONDITIONING UNIT (Weight 46,280 kg/mw Volume = 140m^3/mw Price = $.20/watt)

	Daily	Weekly	Biweekly	Monthly	Bimonthly	Quarterly
Factory-Warehouse Cost	1138618	485976	484208	483256	482848	482712
Warehousing Cost	42691	73666	112384	202728	370342	537538
Local Delivery Cost	284879	284879	284879	284879	284879	284879
Total Annual Cost	1466188	844521	881472	970864	1138070	1305130

FLAT-PLATE COLLECTOR (Weight 155,925 kg/mw Volume = 1415.805m^3/mw Price = $.70/watt)

	Daily	Weekly	Biweekly	Monthly	Bimonthly	Quarterly
Factory-Warehouse Cost	1643102	1628957	1627189	1626238	1625830	1651563
Warehousing Cost	65252	186108	336264	683810	1332640	1977970
Local Delivery Cost	320672	320672	320672	320672	320672	320672
Total Annual Cost	2029025	2135738	2284126	2630720	3279142	3924337

CONCENTRATOR COLLECTOR (Weight 462,800 kg/mw Volume = 10200 m^3/mw Price = $.70/watt)

	Daily	Weekly	Biweekly	Monthly	Bimonthly	Quarterly
Factory-Warehouse Cost	4842084	4827939	4826171	4825219	4824811	4824675
Warehousing Cost	94663	326181	611317	1268992	2479260	3681883
Local Delivery Cost	364170	364170	364170	364170	364170	364170
Total Annual Cost	5300917	5518290	5801658	6458381	7668241	8870728

APPENDIX H: COMPARISON OF INTERREGIONAL AND LOCAL DELIVERY COST FUNCTION

Objectives:

To compare the interregional cost function with the local delivery cost model for shipments to customers in the same region as the factory.

Assumptions:

- The local delivery model purchases a truck and hires a driver. The size of the truck and cost of owning and operating it are standard data parameters to be specified by the user. For this analysis the following values were used:

  - vehicle load capacity = 800 kilograms/shipment
    = (17600 lbs)

  - vehicle distance capacity = 75000 kilometers/year
    = (46800 miles)

  - fixed cost = $31,510.20/vehicle/year

  - variable cost = $0.125/kilometer ($.20/mile)

- The average shipping distance per customer is 50 kilometers or about 31 miles from the factory.

- The interregional cost function for direct shipments assumes that a common carrier is used and the cost per shipment varies with the shipping distance and the shipping weight but not with the volume of shipments per year. The same rates are applied for all products. Rail is assued for all shipments over 18,000 kilograms (40,000 lbs) and truck for higher shipments.

Results:

Following are the breakeven volumes of shipments per year at which the local delivery model becomes more cost effective than the interregional cost function.

Power Conditioning Unit

average delivery quantity (mw)	0.006	0.060	0.600	6.000
shipment weight (lbs)	611	6109	61090	610896
breakeven volume (shipment/year)	920	204	97	75

Concentrator Collector

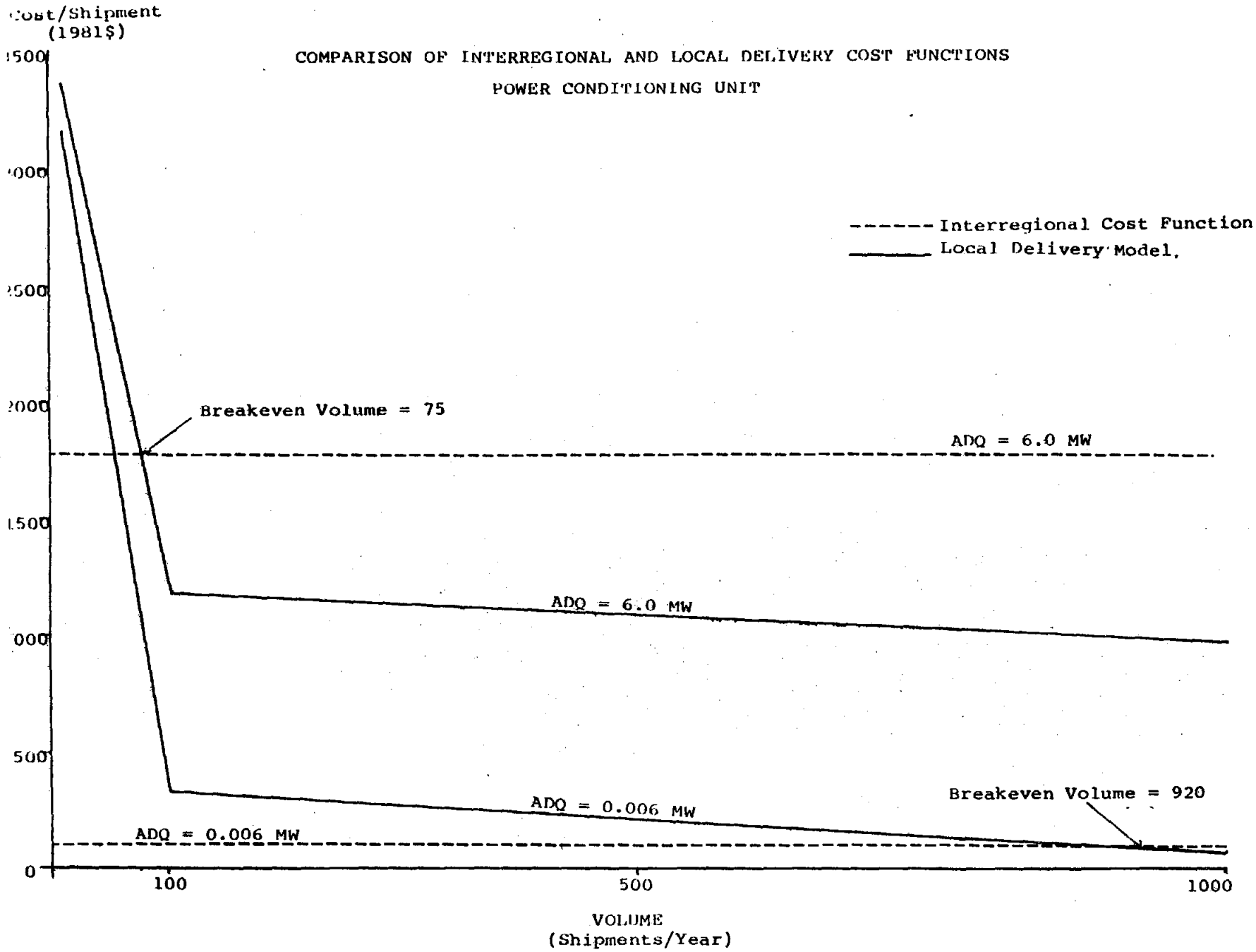
average delivery quantity (mw)	0.005	0.050	0.500	5.000
shipment weight (lbs)	5091	50908	509080	5090800
breakeven volume (shipment/year)	354	99	76	8

Flat-Plate Collector

average delivery quantity (mw)	0.005	0.050	0.500	5.000
shipment weight (lbs)	1715	17152	171516	1715164
breakeven volume (shipment/year)	658	88	96	10

Conclusions:

Since the breakeven volumes are relatively high, the model should assume that a common carrier is used for all shipments within the factory region. Stated another way, the interregional transportation cost function is more appropriate for the shipping of photovoltaic products to customers close to the factory.


Cost/Shipment
(1981$)
COMPARISON OF INTERREGIONAL AND LOCAL DELIVERY COST FUNCTIONS
POWER CONDITIONING UNIT
Interregional Cost Function
Local Delivery Model
Breakeven Volume = 75
ADQ = 6.0 MW
ADQ = 6.0 MW
ADQ = 0.006 MW
Breakeven Volume = 920
ADQ = 0.006 MW
0
100
500
1000
VOLUME
(Shipments/Year)

LOCAL DELIVERY COST FUNCTION

Standard Data:

8000.0 Kilograms/Shipment = Vehicle Load Capacity
75000.0 Kilometers/Vehicle = Vehicle Distance Capacity
$31510.20/Year = Fixed Cost/Vehicle/Year
$0.125/KM = Variable Cost = $.20/Mile
50 Kilometers/Customer = Average Distance = (31.07 miles)

POWER CONDITIONING UNIT
46,280 kilograms/megawatt

1981 $/shipment

Shipment Size	0.006 MW	0.060 MW	0.600 MW	6.000 MW
Annual Volume	611 lbs	6109 lbs	61090 lbs	610,896 lbs
A. 1 shipment	$31516.67	$31518.62	$31538.14	$31733.39
B. 10 shipments	3157.49	3159.44	3178.96	3374.21
C. 100 shipments	321.57	323.52	343.05	1168.49
D. 1000 shipments	37.98	39.93	122.47	979.43

CONCENTRATOR COLLECTOR
462,800 kilograms/megawatt

1981 $/shipment

Shipment Size	0.005 MW	0.050 MW	0.500 MW	5.000 MW
Annual Volume	5091 lbs	50908 lbs	509080 lbs	5090800 lbs
A. 1 shipment	$31518.26	$31534.53	$31697.23	$33324.26
B. 10 shipments	3159.08	3175.35	3338.05	8116.10
C. 100 shipments	323.16	339.43	817.24	8116.10
D. 1000 shipments	39.57	118.89	817.24	7927.04

FLAT-PLATE COLLECTOR
155,924 kilograms/megawatt

1981 $/shipment

Shipment Size	0.005 MW	0.050 MW	0.500 MW	5.000 MW
Annual Volume	1715 lbs	17152 lbs	171516 lbs	1715164 lbs
A. 1 shipment	$31517.06	$31522.54	$31577.36	$32125.53
B. 10 shipments	3157.88	3163.36	3218.18	3766.35
C. 100 shipments	321.96	327.44	382.26	2821.04
D. 1000 shipments	38.37	75.36	319.24	2695.00

CONVERSION FACTORS:

2.200 lbs/kilogram
0.6214 miles/kilometer

INTERREGIONAL TRANSPORTATION COST FUNCTION

Local Distance
Phoenix to Phoenix 50 kilometers or 31.07 miles

POWER CONDITIONING UNIT
46,280 kilograms/megawatt

1981 $/shipment

Shipment Size	0.006 MW	0.060 MW	0.600 MW	6.000 MW
Annual Volume	611 lbs	6109 lbs	61090 lbs	610,896 lbs
A. 1 shipment B. 10 shipments C. 100 shipments D. 1000 shipments	$62.87	$290.73	$473.06	$1777.41
	(independent of volume of shipments/year			

CONCENTRATOR COLLECTOR
462,800 kilograms/megawatt

1981 $/shipment

Shipment Size	0.005 MW	0.050 MW	0.500 MW	5.000 MW
Annual Volume	5091 lbs	50908 lbs	509080 lbs	5090800 lbs
A. 1 shipment B. 10 shipments C. 100 shipments D. 1000 shipments	$242.69	$364.85	$1483.74	$14837.37
	(independent of volume of shipments/year)			

FLAT-PLATE COLLECTOR
155,924 Kilograms/megawatt

1981 $/shipment

Shipment Size	0.005 MW	0.050 MW	0.500 MW	5.000 MW
Annual Volume	1715 lbs	17152 lbs	171516 lbs	1715164 lbs
A. 1 shipment B. 10 shipments C. 100 shipments D. 1000 shipments	$146.29	$699.19	$499.89	$4998.92
	(independent of volume of shipments/year)			

CONVERSION FACTORS:
2.200 lbs/kilogram
0.6214 miles/kilometer

APPENDIX I: COMPARISON OF DIRECT SHIPPING WITH TRANSSHIPPING

Objectives:

To compare costs for direct shipping with transshipping from the factory through a regional warehouse to the customer.

Assumptions:

- For direct shipping the model assumes that the product is picked up at the factory and delivered to the final customer's site. The cost varies with shipping distance and shipment weight, but not with the number of shipments per year. The same freight rates are applied to all types of solar products. The model assumes a rail carrier for all shipments weighing more than 18,000 kilograms (40,000 lbs).

- Transshipping costs consist of three components:

  - transportation from the factory to the warehouse
  - warehouse cost
  - local delivery cost

  The transportation component is exactly the same function as for direct shipping except that an order processing cost is added on. The cost varies with the order quantity. This order quantity also determines the warehouse size required and the associated warehousing costs. The local delivery cost function assumes that drivers are hired and trucks are purchased to deliver the product from the warehouse to the customers. The following parameters determine the number required and the cost:

  - vehicle load capacity 8000 kilograms/load
  - vehicle distance capacity 75,000 kilometers/year
  - average distance per customer 50 kilometers
  - fixed cost per vehicle $31,510.20/year
  - variable operating cost $0.125/kilometer

  Different values of these parameters can be specified by the user and the results will vary accordingly.

Results:

The following results compare the two distribution alternatives for three types of products:

- Power Conditioning Unit
- Flat-Plate Collector
- Concentrator Collector

The analysis is based on a factory in Phoenix, Arizona and two warehouse locations. The first case involves a warehouse in Atlanta, Georgia. The corresponding shipping distance is 3036 kilometers (1887 miles). The second case examines a warehouse in Los Angeles 640 kilometers (397.7 miles) from the factory.

The following breakeven volumes (shipments/year) indicate the level at which transshipping through a warehouse becomes more economical than direct shipping.

CASE X: Phoenix to Atlanta

System Delivery Size	BREAKEVEN VOLUMES (shipments/year) 0.001 MW	0.010 MW	0.100 MW
PCU (46,280 kg/mw)	100,000	635	75
Flat-Plate (155,924 kg/mw)	989	96	79
Concentrator (462,800 kg/mw)	602	72	--

CASE Y: Phoenix to Los Angeles

System Delivery Size	BREAKEVEN VOLUMES (shipments/year) 0.001 MW	0.010 MW	0.100 MW
PCU (46,280 kg/mw)	--	989	509
Flat-Plate (155,925 kg/mw)	7954	680	295
Concentrator (462,800 kg/mw)	979	464	-

Conclusions:

The breakeven volume for warehousing to be cost effective decreases significantly as the distance of the warehouse from the factory increases.

Transhipments through a warehouse are never more economical for large systems over 18,000 kg (4000 lbs). For example it is more economical to ship large concentrator systems over 100 kw directly from the factory to the customer.

CASE X : COMPARISON OF DIRECT SHIPPING WITH TRANSSHIPPING COST

Distance: Phoenix to Atlanta 3036 kilometers (1887 miles)

POWER CONDITIONING UNIT

(Weight = 46,280 kilograms/megawatt, Volume 140 m^3/mw, Price =$.20/watt)

Shipments Per Year	0.001 MW/ship Indirect $/ship	0.001 MW/ship Direct $/ship	0.010 MW/ship Indirect $/ship	0.010 MW/ship Direct $/ship	0.100 MW/ship Indirect $/ship	0.100 MW/ship Direct $/ship
10	3286	47	3725	440	6740	3820
100	378	47	680	440	2699	3820
1000	105	47	276	440	1965	3820
10000	52	47	221	440		
100000	47	47				
	102 lbs		1018 lbs		10182 lbs	

FLAT-PLATE COLLECTOR

Weight = 155,924 kilograms/megawatt, Price = $.70/watt)

Shipments Per Year	0.001 MW/ship Indirect $/ship	0.001 MW/ship Direct $/ship	0.010 MW/ship Indirect $/ship	0.010 MW/ship Direct $/ship	0.100 MW/ship Indirect $/ship	0.100 MW/ship Direct $/ship
10	3425	157	4752	1335	11540	8154
100	481	157	1159	1335	7125	8154
1000	153	157	718	1335	6562	8154
10000	96	157	681	1335		
100000	92	157				
	343 lbs		3430 lbs		34303 lbs	

CONCENTRATOR COLLECTOR

(Weight = 462,800 kilograms/megawatt, Volume = 10200, Price = $.70/watt)

Shipments Per Year	0.001 MW/ship Indirect $/ship	0.001 MW/ship Direct $/ship	0.010 MW/ship Indirect $/ship	0.010 MW/ship Direct $/ship	0.100 MW/ship Indirect $/ship	0.100 MW/ship Direct $/ship
10	3706	440	6507	3820	23119	17354
100	656	440	2633	3820	19236	17354
1000	269	440	1929	3820	18722	17354
10000	217	440	1896	3820		
100000	214	440				
	1018 lbs		10182 lbs		101816 lbs	

*All costs stated in 1981$

CASE Y : COMPARISON OF DIRECT SHIPPING WITH TRANSSHIPPING COST

Distance: Phoenix to Los Angeles 640 kilometers (397.7 miles)

POWER CONDITIONING UNIT

(Weight = 46,280 kilograms/megawatt, Volume 140 m^3/mw, Price =$.20/watt)

Shipments Per Year	0.001 MW/ship Indirect $/ship	0.001 MW/ship Direct $/ship	0.010 MW/ship Indirect $/ship	0.010 MW/ship Direct $/ship	0.100 MW/ship Indirect $/ship	0.100 MW/ship Direct $/ship
10	4173	20	4382	157	5670	1088
100	444	20	573	157	1459	1088
1000	94	20	152	157	642	1088
10000	40	20	89	157		
100000	33	20				
	102 lbs		1018 lbs		10182 lbs	

FLAT-PLATE COLLECTOR

Weight = 155,924 kilograms/megawatt, Price = $.70/watt)

Shipments Per Year	0.001 MW/ship Indirect $/ship	0.001 MW/ship Direct $/ship	0.010 MW/ship Indirect $/ship	0.010 MW/ship Direct $/ship	0.100 MW/ship Indirect $/ship	0.100 MW/ship Direct $/ship
10	4245	67	4800	467	8010	2595
100	486	67	807	467	2735	2595
1000	118	67	279	467	2090	2595
10000	52	67	233	467		
100000	48	67				
	343 lbs		3430 lbs		34303 lbs	

CONCENTRATOR COLLECTOR

(Weight = 462,800 kilograms/megawatt, Volume = 10200, Price = $.70/watt)

Shipments Per Year	0.001 MW/ship Indirect $/ship	0.001 MW/ship Direct $/ship	0.010 MW/ship Indirect $/ship	0.010 MW/ship Direct $/ship	0.100 MW/ship Indirect $/ship	0.100 MW/ship Direct $/ship
10	4367	157	5621	1088	10890	4015
100	568	157	1410	1088	6083	4015
1000	147	157	614	1088	5491	4015
10000	86	157	574	1088		
100000	82	157				
	1018 lbs		10182 lbs		101816 lbs	

*All costs stated in 1981$

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