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DECK KEY

Deck #1 FORTRAN Deck, sequence 0010 through 1790 in cc 77-80;
BAII in cc 73-75; 179 cards.

Deck #2 FORTRAN Deck, sequence 0010 through 1360 in cc 77-80;
SLCT in cc 73-76; 136 cards.

Deck #3 FORTRAN Deck, sequence 0010 through 1530 in cc 77-80;
INP in cc 73-75; 153 cards.

Deck #4 FORTRAN Deck, sequence 0010 through 0240 in cc 77-80;
SORT in cc 73-76; 24 cards.

Deck #5 FORTRAN Deck, sequence 0010 through 0550 in cc 77-80;
PRNT in cc 73-76; 55 cards.

Deck #6 Control cards, sequence 1 through 2 in column 80;
CONTROL in cc 73-79; 2 cards.

Deck #7 Object Deck, sequence 01 through 03 in cc 79-80;
ICLOCK in cc 73-78; 3 cards.

Deck #8 Control cards, sequence 3 through 4 in column 80;
CONTROL in cc 73-79; 2 cards.

Deck #9 Sample Problem Input; sequence 0001 through 0014 in cc 77-80;
DATA in cc 73-76; 14 cards.

SHARE PROGRAM LIBRARY SUBMITTAL FORM

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This form should be completed and submitted with the program package to the SHARE Program Library Agency at the address shown above. Standards and instructions for submitting programs are in the "SHARE Reference Manual".

(1) Program Number (to be filled in by SPLA)..... 360D-15.6.004

(2) System Type (machine)..... IBM 360/370

(3) Search Key..... Facility Layout

(4) Programming Systems/Languages..... IBM FORTRAN IV, OS ASSEMBLER

(5) Author's Name and Address..... P. Hicks & T. Cowan

(6) Direct Technical Inquiries to Name & Address (if different than Author) Mr. Troy E. Cowan
Contracts Div., ERDA
Box 5400
Albuquerque, NM 87115

(7) Title of Program..... Computerized Relative Allocation of Facilities Technique (Including Dept. Move Costs), CRAFT-M

(8) Submitter's Installation Membership Code.....

(9) Submitter's Own Program Identification and Suffix(Optional).. CRAFT-M

(10) Primary Subject Code..... 15.6

(11) Minimum System Requirements

(12) New or Revision Code (if revision, show prior Program Number in Item 1) New*

(13) Year Completed..... 1975

(14) Date of Submittal..... 6/76

(15) Documentation (number of original pages submitted)..... 16

(16) Abstract (should contain sufficient information for a reader to determine the value of the program). Listed on the reverse side of this form are subjects which may serve as a guide for a descriptive abstract.

Revised 4/74

*Major modification to SHARE Pgm. #360D-15.6.003 (Armour, Cartier, Fagnani; Completed 1967; Submitted 2/74)

SHARE PROGRAM LIBRARY SUBMITTAL FORM

Subject Guide:

a. Purpose
b. Programming Language used
c. Version and modification level or release number
d. Field of application
e. Type of routine (main program, subroutine, etc.)
f. Specific description of machine requirements

ABSTRACT

CRAFT is a computer program for heuristically determining the relative location of activities in a plant layout in an attempt to minimize the material handling cost of all products flowing between departments per unit time. Input consists of an initial layout of activity areas, and flow and material handling cost data. The program considers switching departments in an effort to reduce overall material handling cost.

CRAFT-M, an extension to CRAFT, requires additional inputs of 1) fixed cost, and variable cost per unit distance, to move each activity area, 2) interest rate and number of interest periods for prorating move costs over the life of the rearrangement, and 3) expected material handling cost reduction made possible by an activity area move. In CRAFT-M, departments are switched if the resulting material handling cost improvement more than covers the departmental move costs over the life of the rearrangement.

(Please attach additional pages if necessary).....Total pages attached

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(17) Signature of Submitter and Date Philip E. Hicks May 27, 1976

(18) Signature of Installation Addressee

CRAFT-M

Computerized Relative Allocation of Facilities Technique (Including Department Move Costs)

Philip E. Hicks

Industrial Engineering Department

New Mexico State University

Las Cruces, New Mexico

June, 1976

TABLE OF CONTENTS

1.0 Introduction

CRAFT-M is an extension to the Fagnani (1) CRAFT-IV program submitted in February, 1974. CRAFT-M additionally considers the prorated cost of moving departments over the projected life of a layout rearrangement as well as material handling improvements (reductions) made possible by moving departments.

The following, excerpted from the original article (2) concerning CRAFT-M, describes the change in decision criteria employed in the CRAFT heuristic:

Comparison of CRAFT-IV and CRAFT-M

CRAFT-M incorporates departmental move cost and material handling improvement factors in the decision logic. Thus, CRAFT-M produces a layout that will pay for the required department moves within the estimated lifetime of the rearrangement, based on user supplied input parameters.

The following describes more explicitly the difference in decision criteria employed in CRAFT-IV and CRAFT-M. CRAFT-IV selects from the set of possible interchanges the exchange that will give the largest savings in material handling cost (MHC) in relation to the previous iteration. This stepwise process continues until none of the possible interchanges would result in a savings. This decision criteria may be written as:

$$\text{Max} \left(\sum_{i=1}^{n} X\,(i,j-1) - \sum_{i=1}^{n} X\,(i,j) \right)$$

where X(i,j) is the MHC between Department "i" and all other departments, 1 through n, based on department locations in the jth iteration. X(i,j) is calculated as a function of material flow, departmental distances, and unit costs per distance between departments.

In contrast, CRAFT-M selects the desired interchange based on the following decision criteria:

$$\text{Max} \left(\sum_{i=1}^{n} X'(i,j-1) - \sum_{i=1}^{n} X'(i,j) \right)$$

where

$$X'(i,j) = X(i,j) - \Big(X(i,j) * HR(i)\Big) + \left(CF(i) + \Big(CM(i) * ZZZ(i,j)\Big)\right) * XINT$$

The new variables are defined as follows:

HR(i) is the operating cost improvement factor to account for methods or equipment improvements in Department "i" made possible by moving "i" user inputed as an estimated percentage of the material handling costs of the department. It is zero if Department "i" has not moved from its original location.

CF(i) is the fixed costs component of moving Department (i). This is also zero if the department does not move.

CM(i) is the cost per unit distance to move Department "i".

ZZZ(i,j) is the rectilinear distance that Department "i" will be moved from its initial location to the location in the jth iteration. This is also zero if the department does not move from its original

location.

XINT is the capital recovery factor for prorating the total move cost of Department "i" over the life of the rearrangement. It is internally computed from a user supplied period interest rate and a number of periods of the estimated rearrangement life.

An April, 1976 revision of the Fagnani program by T. L. Ward (3) "corrects several problems that limited full use of the input options [contained in the Fagnani program] (3)". Unfortunately, CRAFT-M, as of this date, is an extension to the Fagnani program and not its latest revision.

2.0 How to Use the Program

A complete data deck is required for each problem, but the user may insert as many decks as desired in a given run. The nth data deck is placed behind the nth-1 deck.

Two alternate deck set-ups are available. Set-up number 1 is for a job shop or similar layout with many flow relationships:

1A - Title Card
2A - Control Card(s) [Contains CRAFT-M additional input.]
3A - Flow Matrix
4A - Cost per Unit Distance Matrix
5A - Interspatial Array Matrix

CRAFT-M Additional Input
5.5A - Move Data Inputs

6A - Department List (optional)
7A - "END" Card

Set-up number 2 is for a more restricted flow pattern.

1B - Title Card
2B - Control Card(s) [Includes CRAFT-M additional input.]
3B - I, J Element List
4B - 9999 Card
5B - INTERSPATIAL ARRAY Matrix

CRAFT-M Additional Input
5.5B - Move Data Inputs

6B - Department List (optional)
7B - "END" Card

Set-up number 2 allows more input flexibility and is recommended for all but problems with many interdepartmental flows.

1A and 1B - TITLE CARD FORMAT (10A6)

This card is the first card in any data set. It has a 60-column limitation and is used for problem identification. The project title will be reprinted on the summary sheet exactly as it appears on this card.

2A and 2B - FIRST CONTROL CARD FORMAT (8[12, 1X], 2[F5.0, 1X])

The Control Card is used to describe limiting parameters of the problem. It also specifies program internal processing options.

Columns			Variable
1-2	Number of Departments	MAX 45	NDEPT
4-5	Number of rows in the spatial configuration	MAX 40	IROW
7-8	Number of columns in the spatial configuration	MAX 40	ICOL
10-11	Analyzer control 00 two department moves only 01 three department moves only 02 two department moves followed by three department moves 03 three department moves followed by two department moves 04 choose best of two or three department moves at each iteration (recommended)		

Columns		Variable
13-14	Input/output control 00 print first and last layout 01 print first layout and for each iteration the most favorable layout found during the iteration	IOCTL
16-17	Debugging parameter 00 no failure messages 01 write exchange failure and no cost reduction messages 02 same as above but also prints results of search for best move	ICHK
19-20	Number of departments to be fixed in place NOTE: The actual departments to be fixed are placed on the second control card IF(IFIX.EQ.0), omit the second control card	IFIX

SECOND CONTROL CARD FORMAT (40I2)

Columns		Variable
1-2	Department number of first department to be fixed in place, right justified	IDFIX (I)
3-80	Same as above 2 columns for each additional department to be fixed in place	

2A and 2B - FIRST CONTROL CARD CONTINUED

Columns		Variable
22-23	00 or blank specified job set-up number one (refer to original CRAFT write-up) 02 specifies use of element list (refer to Appendix C for explanation of element list	IPTS
25-29	Percent of department size variability FORMAT (F 5.0)	PCNT

FOR EXAMPLE: 00.05 = 5% (refer to Appendix C [(1)] for explanation of this feature)

31-35 Cost limiting factor EPSLN

FORMAT (F 5.0)

FOR EXAMPLE: 45.00 = $45.00, all actual exchanges must be greater than $45 (EPSLN) to be accepted (refer to Appendix C for further information)

CRAFT-M Additional Input (First Control Card Continued)

52-55 Number of periods in layout rearrangement life

FORMAT (I4)

FOR EXAMPLE: 10 = ten year expected life of the rearrangement

57-61 Interest rate

FORMAT (F 5.0)

FOR EXAMPLE: 00.10 = 10% minimum acceptable rate of return on investment (interest) to be employed. Include decimal point

3A FLOW MATRIX

Flow volumes are punched for every interdepartment relationship. Each department (row of the volume matrix (department from)) is started on a new card. Twenty paired department volume relationships may be punched per card. (e.g., for the first card punches in cols. 9-12 would input the volume flowing from department 1 to department 3.)

If more than 20 departments are specified, use additional cards. Volumes are treated uniquely on both sides of the diagonal in order that volumes in different directions can be represented at different travel costs. (See cost per unit distance array below). If travel cost is the same for both directions of flow, place 1/2 of the volume on each side of the diagonal.

There should be as many sets of cards for the array as is indicated in columns 1-2 of the control card. There should be the same number of fields utilized per set as is indicated in columns 1-2 of the control card. There is one card per set if the number of departments (col. 1-2 of control card) is 20 or less. There are two cards per set if the number of departments (col. 1-2 of control card) is greater than 20 and less than 46.

The decimal point is not punched. A decimal point will be considered to immediately follow the right most digit of each field for purposes of computation.

4A COST PER UNIT DISTANCE MATRIX FORMAT (20F4.0)

This array is punched on a one to one relationship with the flow array. (e.g., for the first card of the first act punches in Cols. 9-12 would input the unit cost of moving a unit load a unit distance from department number 1 to department number 3. Include the decimal point. For example, 6.0 in columns 10-12 of the first cost per unit distance matrix card indicates a relative cost of 6 for a unit of flow between departments 1 and 3 per unit distance.

3B - I, J ELEMENT LIST

Replaces - 3A and 4A in set-up number two

FORMAT (2[I2,1X], 2[F5.0, 1X])

Variables: I, J, DST, CVL

I= Department from which product is emerging
J= Department destination of product flow emerging from I
DST= The quantity of flow from Department I to Department J
CVL= The cost to move this flow one grid square (i.e., cost per unit distance

EXAMPLE:

01, 05, 010.0, 00.20

Flow from department #1 to department #5 of 10 units, at a cost of $.20 a unit for each grid square moved.

Each card represents one from I to J move relationship. Every such non-zero relationship must be represented by one card. No specific order is required in this section of the data set except the requirement of a 9999 card (4B in deck set-up), to signal termination of this section.

4B - "9999" CARD

A card having the number "9999" in its first 4 columns, signals termination of I, J ELEMENT LIST

5A - 5B INTER SPATIAL ARRAY MATRIX FORMAT (40I2)

Maximum grid size is 40 x 40.

Punch each row of the array on a separate card. Department numbers of the departments occupying each space are punched on the card in two column fields. The array is punched by rows. There should be as many cards punched as is specified in columns 4-5 of the control card. There should be as many fields punched on each card as is specified in columns 7-8 of the control card.

Department numbers are converted by the program to alphabetic characters for print out (e.g., 01 = A, 02 = B,..., 26 = Z, 27 = AA, 28 = EB, etc.).

Irregularities in building configuration should be filled in by adding artificial departments until a rectangular building configuration is achieved. These artificial departments may be held fixed. See control card.

The maximum number of times that any one department may be punched is 150. No department may be disjointed. Each department which appears in more than one field or card must be punched so that when the keypunched spatial array is listed each department number has a like department number immediately adjacent in the same row or column. Departments may have multiple indentations along one axis but not along both axes. A department may not completely aurround another department on all sides.

CRAFT-M Additional Input

5.5A - 5.5B MOVE DATA INPUT

One card for each department, cards in any order.

Columns

1-5 Department number

FORMAT (I5)

FOR EXAMPLE: 01 - First department in flow matrix or cost per unit distance matrix

6-15 Fixed cost of department move

FORMAT (F10.0)

FOR EXAMPLE: 2000.0 = $2,000 fixed cost for moving this department. Include decimal point.

16-25 Variable cost of department move

FORMAT (F10.0)

FOR EXAMPLE: 300.0 = $300 variable cost per unit distance for this department. ZZZ gives number of grid unit distances moved. Include decimal point.

26-35 Handling reduction percentage

FORMAT (F10.0)

FOR EXAMPLE: .075 = 7.5% reduction in material handling cost expected following relocation of this department. Include decimal point.

6A - 6B DEPARTMENT LIST (OPTIONAL)

Any number of cards may be placed between the last card of section 5A-5B and the "END" card (7A or 7B). All 80 fields of each card may be used. The information is read under an Alphanumeric Format and reproduced at the end of SMRY exactly as it appears on the cards.

7A - 7B "END" CARD

A card having the letters E, N, D in columns three, four, and five respectively, signals the termination of a data set.

3.0 Testing

The submittal includes a test deck shown below in Figure A. This test deck duplicates the data employed in the Hicks and Cowan article (2), for

which below figures 1, 2, 3, 4, 5 and 7 from that article are duplicated.

4.0 Additional Program Information

The source deck is serialized in columns 76-80 beginning with 00010 and ending with 30212. Columns 73-75 have alphabetic coding as follows:

Columns 73-75 Coding	Description
CFT, RAF, CFZ, DFT	CRAFT-IV program
NMS	Card changes made at New Mexico State University to get CRAFT-IV to run on the NMSU system
M	CRAFT-M cards (May include some NMS type cards)
D	CRAFT-M data cards

5.0 Tape Key

This volume contains two files and two tape marks arranged as follows:

File 1. FORTRAN Source Deck
EBCDIC
Sequence 00010 through 30212 in columns 76-80, above designations in columns 73-75, 2195 cards.
2195 card images blocked 80 per block.
28 blocks of 6400 characters each.
T/M

File 2. Sample Data Input
EBCDIC
Sequence 1-32 in columns 73-74, D in column 72, 32 cards.
32 card images blocked 80 per block.
1 block of 6400 characters each
T/M
T/M

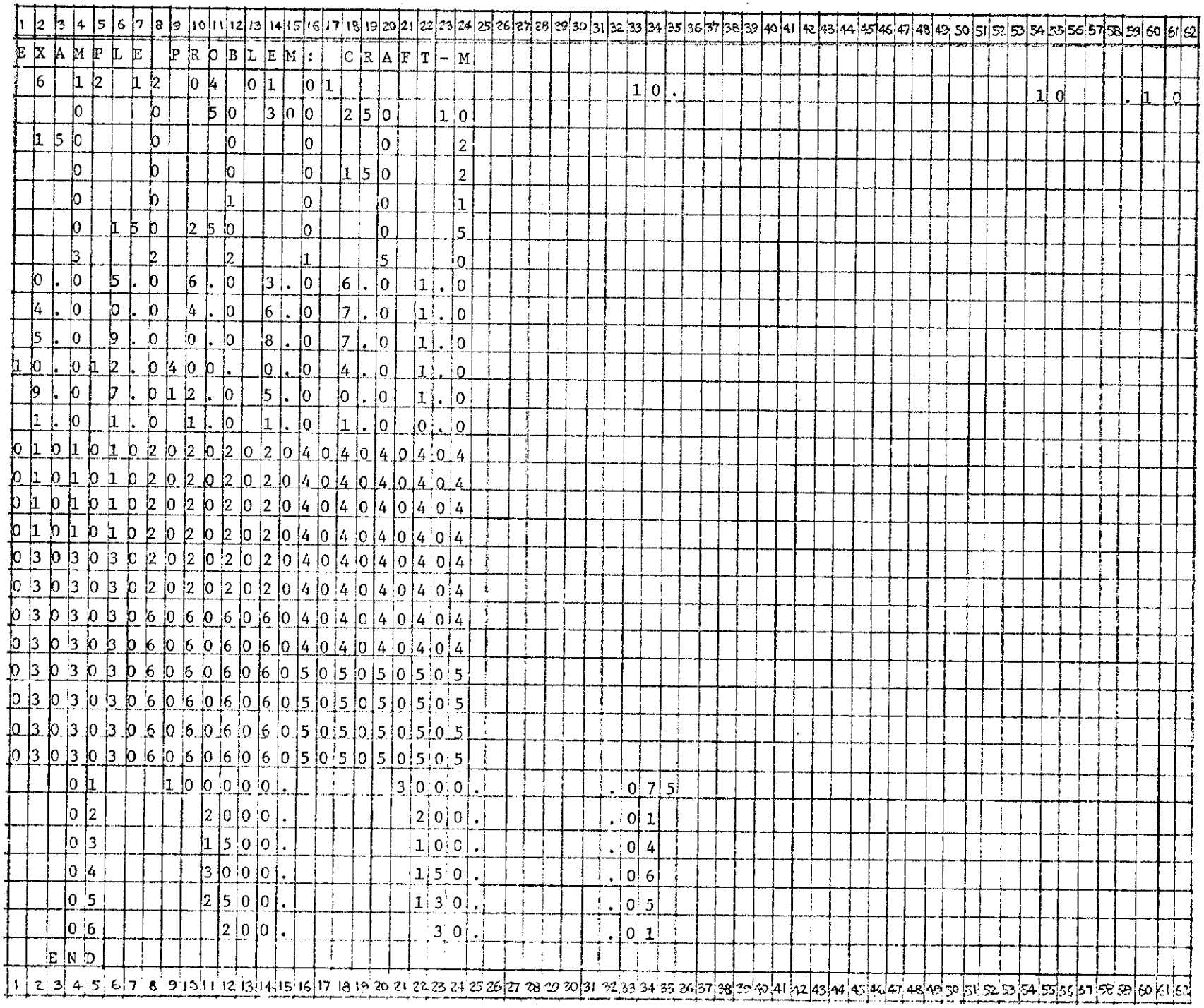

Figure A. Test Deck

Product	Volume	Department sequence
I	100	ADCEBA
II	200	ADC
III	250	AEC
IV	50	ACEBA

Departments

A: Shipping and Receiving

B: Processing Department #1

C: Processing Department #2

D: Processing Department #3

E: Processing Department #4

F: Office

Figure 1. Data for example problem.

LOCATION PATTERN

	1	2	3	4	5	6	7	8	9	10	11	12
1	A	A	A	B	B	B	B	D	D	D	D	D
2	A		A	B			B	D				D
3	A		A	B			B	D				D
4	A	A	A	B			B	D				D
5	C	C	C	B			B	D				D
6	C		C	B	B	B	B	D				D
7	C		C	F	F	F	F	D				D
8	C		C	F			F	D	D	D	D	D
9	C		C	F			F	E	E	E	E	E
10	C		C	F			F	E				E
11	C		C	F			F	E				E
12	C	C	C	F	F	F	F	E	E	E	E	E

Figure 2. Present arrangement of departments.

INTERDEPARTMENT PRODUCT FLOW

FROM \ TO	A	B	C	D	E	F
A	0.0	0.0	50.000	300.000	250.000	10.000
B	150.000	0.0	0.0	0.0	0.0	2.000
C	0.0	0.0	0.0	0.0	150.000	2.000
D	0.0	0.0	1.000	0.0	0.0	1.000
E	0.0	150.000	250.000	0.0	0.0	5.000
F	3.000	2.000	2.000	1.000	5.000	0.0

Figure 3. Product flow between departments.

INTERDEPARTMENT MOVE COST
PER UNIT LOAD PER UNIT DISTANCE

		TO A	B	C	D	E	F
FROM	A	0.0	5.000	6.000	3.000	6.000	1.000
	B	4.000	0.0	4.000	6.000	7.000	1.000
	C	5.000	9.000	0.0	8.000	7.000	1.000
	D	10.000	12.000	400.000	0.0	4.000	1.000
	E	9.000	7.000	12.000	5.000	0.0	1.000
	F	1.000	1.000	1.000	1.000	1.000	0.0

Figure 4. Unit material handling costs between departments.

```
PERIODS =     10
INTEREST =  0.100

 DEPT   CMOVE        CFIX        HRED
   1    0.30E 04    0.10E 06    0.75E-01
   2    0.20E 03    0.20E 04    0.10E-01
   3    0.10E 03    0.15E 04    0.40E-01
   4    0.15E 03    0.30E 04    0.60E-01
   5    0.13E 03    0.25E 04    0.50E-01
   6    0.30E 02    0.20E 03    0.10E-01
```

Figure 5. CRAFT-M input.

LOCATION PATTERN

	1	2	3	4	5	6	7	8	9	10	11	12
1	A	A	A	B	B	B	B	B	B	B	B	B
2	A		A	B	B	B	B					B
3	A		A	D	D	D	B	B	B	B	B	B
4	A	A	A	D		D	D	D	E	E	E	E
5	D	D	D	D			D	E	E			E
6	D		D	D	D	D	D	E				E
7	D		D	F	F	F	F	E	E	E	E	E
8	D		D	F			F	C	C	C	C	E
9	D		D	F			F	C			C	C
10	D		D	F			F	C				C
11	D		D	F			F	C				C
12	D	D	D	F	F	F	F	C	C	C	C	C

Figure 7. CRAFT-M final layout.

References

1. Fagnani, Roger A., "Computerized Relative Allocation of Facilities Technique," IBM SHARE Program #360D-15.6.003, Share Program Library Agency, Triangle Universities Computation Center, P.O. Box 12076, Research Triangle Park, North Carolina 27709, submitted February, 1974.

2. Hicks, Philip E. and Troy E. Cowan, "CRAFT-M for Layout Rearrangement," Industrial Engineering, Vol. 8, No. 5, May, 1976, pp. 30-35.

3. Ward, L. L., "Computerized Relative Allocation of Facilities Technique," April, 1976 revision to IBM SHARE Program #360D-15.6.003, Share Program Library Agency, Triangle Universities Computation Center, P.O. Box 12076, Research Triangle Park, North Carolina 27709, submitted April, 1976.