Mansoura Engineering Journal (MEJ) Vol.15.No,2.Dec 1990. C-1

# A NEW APPROACH OF USING THE TRANSPORTATION MODEL FOR EVALUATING HOUSING PROJECTS

مدخل جديد لاستخدام البرمجه الخطيه
(بطريقة النقل) في تقييم مشروعات الاسكان

**Dr. Mostafa Al-Ahwal, Ph.D.**

Assistant Professor, Civil Engineering Dept.
Faculty of Technological Studies, Kuwait

يهدف البحث الى تطويع استخدام البرمجه الخطيه بطريقة النقل في التقييم الاقتصادي لمشاريع الاسكان ولدراسة الجدوى الاقتصاديه لتلك المشاريع وهذه الطريقه يمكن استخدامها للمفاضله بين البدائل المختلفه او المشاريع المطروحه للتقييم الاقتصادي نظرا لاختلاف طرق التصميم او التخطيط او التنفيذ لتلك المشاريع - كما يمكن استخدامها في ايجاد افضل الحلول المقدمه والتي تحقق اعلى ربح ممكن او اقل تكلفه ممكنه وهذا البحث هو خاتمه الابحاث التي قام بها الباحث في استخدام طرق البرمجه الخطيه للتقييم الاقتصادي للمشاريع

ABSTRACT - Most of the Large Housing Projects have different dwelling units designs. The optimum project from the economical point of view depends on different constraints such as cost of the site planning, dwelling design, project locations, etc. This paper discusses a new approach for maximizing the profits or minimizing the cost of each design, using the Transportation Model.

## 1. INTRODUCTION

The Transportation Model requires the allocation of dwelling units subjected to a number of constraints, e.g., design, site planning, cost, etc. in order to optimize the cost of the project/or to maximize its profit) (see Table 1).

Mathematically, the problem is defined in the following manner:

The objective function equation is :

$$\sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \qquad (1)$$

which is subject to the constrains :

$$\sum_{i=1}^{n} X_{ij} = a_i, \; (i = 1, 2, \ldots\ldots m) \qquad (2)$$

$$\sum_{i=1}^{m} X_{ij} = b_i, \; (j = 1, 2, \ldots\ldots m) \qquad (3)$$

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_1 \qquad (4)$$

If these amounts of originals or constraints are not equal in eq. (4), a dummy may be introduced to satisfy eq. (4).

$$X_{ij} \quad 0 \text{ for all i and j} \qquad (5)$$

Table 1. TABULAR FORM OF THE TRANSPORTATION MOOEL

| Origin | Destination | | | | | Supply |
|---|---|---|---|---|---|---|
| | I | II | .... | n-1 | n | |
| 1 | $x_{11}$ $c_{11}$ | $x_{12}$ $c_{12}$ | . . | $x_{1j}$ $c_{1j}$ | $x_{1n}$ $c_{1n}$ | $a_1$ |
| 2 | $x_{21}$ $c_{21}$ | $x_{22}$ $c_{22}$ | . . | $c_{2j}$ | $x_{2n}$ $c_{2n}$ | $a_1$ |
| . | . . | . . | . . | . . | . . | . |
| i | $x_{i1}$ $c_{i1}$ | $x_{i2}$ $c_{i2}$ | . . | $x_{ij}$ $c_{ij}$ | . . | $a_i$ |
| m | $x_{m1}$ $c_{m1}$ | $x_{m2}$ $c_{m2}$ | . . | $x_{mj}$ $c_{mj}$ | $x_{mn}$ $c_{mn}$ | $a_m$ |
| Require-ments | $b_1$ | $b_2$ | ... | $b_j$ | $b_n$ | $a_m$=$b_n$ |

where:

$X_i$ : is the amount of allocation from original to the destinations (constraints) j

$C_{ij}$ : is the cost or profit of allocating 1 unit from original i to constraints j

$a_i$ : is the amount available at each origin

$b_j$ : is the amount required at each constraint.

## 2. ARCHITECTURAL PROBLEM

Suppose there are three different types of residential projects with different designs (I, II, III, IV). Each dwelling unit has different cost according to the project type as shown in Table (2). The problem is to determine the number of dwelling units in each project to achieve the minimum cost.

Table ( 2 )

| Project \ Design | I | II | III | IV | Supply (Flat) |
|---|---|---|---|---|---|
| | costs/D.U. (XLE. 1000) | | | | |
| 1 | 70 | 60 | 60 | 60 | 8 |
| 2 | 50 | 80 | 60 | 70 | 10 |
| 3 | 80 | 50 | 80 | 60 | 5 |
| Requirements (dwelling units) | 5 | 4 | 6 | 4 | 23<br>19 |

## 3. SOLUTION PROCEDURES FOR MINIMIZING THE PROJECT COST

a) Set up the matrix of the problem according to the initial allocation, as shown in Table (1). The supply and requirement values have been multiplied by $10^{-3}$ to make the computations easier. In this example a dummy column is necessary to satisfy (eq. 4) because the supply is greater than the demand. The matrix also contains the costs, requirements (dwelling units and supplies (number of projects).

Table ( 3 )

| Project \ Design | I | II | III | IV | Dummy | Supply (Flat) |
|---|---|---|---|---|---|---|
| | costs/ D.U. (XLE. 1000) | | | | | |
| 1 | 70 | 60 | 60 | 60 | 0 | 8 |
| 2 | 50 | 80 | 60 | 70 | 0 | 10 |
| 3 | 80 | 50 | 80 | 60 | 0 | 5 |
| Requirements | 5 | 4 | 6 | 4 | 4 | 23 |

b) Put the value of dummy column in the sequence of row of maximum value (A, Table 4). Then put the other values of the dummy column in other spaces (B & C, Table 4).

c) Distribute the other values of the columns taking into account the number of projects (horizontally) and units (vertically) and by choosing the minimum $C_{ij} \times X_{22}$ to achieve the minimum total costs. Each step is represented by alphabetic letter as shown in Table 4.

d) Calculate the total cost according to equation (1). (see Table 4). Therefore the minimum costs = (5 x 60) + (3 x 60) + (5 x 50) + (1 x 60) + (4 x 60) + (1 + 50) = 300 + 180 + 250 + 60 + 240 + 50 = LE.1, 080, 000

## 4. SOLUTION PROCEDURES FOR MAXIMIZING THE PROJECT PROFIT

The above mentioned procedures applied for minimizing the cost is also applicable for maximization the project profit choosing the cells of maximum numbers as shown in the following example Table (5); and its solution is shown in Table (6).

Table (5)

| Project | I | II | III | IV | Supply |
|---|---|---|---|---|---|
| | Profit/DU (LE. 1000) | | | | |
| 1 | 7 | 6 | 6 | 6 | 8 |
| 2 | 5 | 8 | 6 | 7 | 10 |
| 3 | 8 | 5 | 8 | 6 | 5 |
| Requirements | 8 | 5 | 8 | 6 | 23 |

Table (6)

| Project | I | II | III | IV | Dummy | Supply |
|---|---|---|---|---|---|---|
| | Profit/DU (LE.1000) | | | | | |
| 1 | 4 [7] D | 0 [6] E | 0 [6] F | 0 [6] J | 4 [0] A | 0 |
| 2 | 0 [5] K | 4 [8] Q | 2 [6] O | 4 [7] P | 0 [0] B | 10 |
| 3 | 1 [8] L | 0 [5] R | 4 [8] M | 0 [6] N | 0 [0] C | 5 |
| Requirements | 5 | 4 | 6 | 4 | 4 | 23 |

Then the max. profite = (4 x 7) + (4 x 8) + (2 x 6) + (4 x 7)
+ (1 x 8) + (4 x 8) =
= 28 + 32 + 12 + 28 + 8 32
= 140,000 LE

Finally, it must be mentioned that the previous technique of Transportation Model which is using the Column & Row Method, (CRM) is not achieving the best solution for minimizing cost/or maximizing profits of construction projects. There are another technique of Transportation Model called Vogal Approximation Method (VAM) by which can be achieved more maximum profits/or less cost than the CRM technique. The VAM has the CRM procedures, but choosing the minimum costs/or maximum profits of variables, and then choosing the dummy variables. Tables 7 & 8 shows the minimum and maximum solutions of the same provious solutions of CRM. Table (9) shows the differences between the CRM and VAM techniques.

Table (7) Solution steps of minimization case

| Project type / Flat type | I | II | III | IV | Dummy | Supply |
|---|---|---|---|---|---|---|
| | Dwelling costs x LE 1000 | | | | | |
| 1 | 0 / 70 / M | 0 / 60 / N | 5 / 60 / K | 3 / 60 / L | 0 / 0 / O | 8 |
| 2 | 5 / 50 / F | 0 / 80 / I | 1 / 60 / J | 0 / 70 / J | 4 / 0 / H | 10 |
| 3 | 0 / 80 / C | 4 / 50 / A | 0 / 80 / D | 1 / 60 / B | 0 / 0 / E | 5 |
| Requirements | 5 | 4 | 6 | 4 | 4 | 23 |

First solution of (VAM): For minimizing the project cost:

minimum cost of project = (5 x 50) + (4 x 50) + (5 x 60) + (1 x 60) + (3 x 60) + (1 x 60) = 1,050,000 LE

Table (8) Second solution of VAM: for minimizing the project profit

| Project type / Flat type | I | II | III | IV | Dummy | Supply |
|---|---|---|---|---|---|---|
| | Dwelling costs x LE 1000 | | | | | |
| 1 | 5 / 7 / J | 0 / 6 / M | 0 / 6 / C | 0 / 6 / N | 3 / 0 / O | 8 |
| 2 | 0 / 5 / K | 4 / 8 / H | 1 / 6 / B | 4 / 7 / I | 1 / 0 / L | 10 |
| 3 | 0 / 8 / D | 0 / 5 / S | 5 / 8 / A | 0 / 6 / F | 0 / 0 / G | 5 |
| Requirements | 5 | 4 | 6 | 4 | 4 | 23 |

Max. project profit = (5 x 7) + (4 x 8) + (1 x 6) + (1 x 6) + (5 x 8) + (4 x 7) = 157,000 LE

## CONCLUSION

The Transportation Model with CRM or VAM techniques can be developed for evaluating the economies of housing projects with multi variables of dwelling designs, project locations, dwelling costs, etc. This model will help in the feasibility studies of these projects. These techniques can also be computerized and then use them if the projects have many variables/or constraints, e.g., designing, planning, cost, profits, locations, etc.

## REFERENCES

1. Bunday, B. D. and G. R. Garside, LINEAR PROGRAMMING IN PASCAL, Edward Arnold, London (1988).

2. Bunday, B. D. and G. R. Garside, OPTIMIZATION METHODS IN PASCAL, Edward Arnold, London (1988).

3. Walsh, G. R., AN INTRODUCTION TO LINEAR PROGRAMMING, Hoet Rinehart and Winston (1971).