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Urban Spatial Patterns and Mobility Interaction Model for the Cairo Metropolitan Area

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Abstract

In general, urbanization in less developed countries is often characterized as growth without development. In other words, urban growth is not accompanied by economic prosperity. Development may be brought about by technical progress, the spread of technology, capital accumulation, improved education, training of the labor force and improvement of market organization.

Recently, considerable attention has been given to the population issue and migration and mobility components of such models has given rise to the issue of urban settlement system planning. As a matter of fact, there are many scholars who have investigated the interaction model as to whether their dealing was direct or indirect (e.g. Mueller, 7, Isard, 20, Wilson, 32 and 3, etc.).

However, the main questions facing decision − makers in Cairo are related to its population growth and its relevant impacts. The fact is that the land required for housing, services, social and technical infrastructure, etc. will increase as the population and number of economic activities rise.

This paper focuses on the Egyptian urban governorates in order to identify the effects of socio − economic factors on the Cairo Metropolitan Area (CMA) through the new treatment of the gravity model. This model is called the Mobility Interaction Model (MIM).

Key Words : Urban Population, Gravity Model, Lowry Model, Gairn Lowry model, Gravity Potential Model, Logistic Model, Breaking Point, Mobility Interaction Model (MIM), Cairo Metropolitan Area (CMA).

1. INTRODUCTION

Several studies in different parts of the world have shown that there is a strong positive correlation between economic development and the level of urbanization. In other words, in any given area, economic efficiency decreases with an increase in the rural population (i.e. a decrease in urban population). On the other hand, the spatial concentration in one metropolis is not necessarily a prerequisite for economic prosperity. However, urbanization occurs as rural people assume urban ways of thinking and behaving, and also as urban institutions and services move towards rural settlements.

Population growth is often raised and characterized by rapid changes in work environment and society : from manufacturing to service industry, from local to global markets, from quantity to quality consideration, from national to multinational companies and enterprises. The relationship between population and environment can be shown as follows :

LEVEL OF POPULATION =

Population Size. Unit of Production. Environmental Impact

Recently the improvement of quality of life and conservation of nature is the main target for many studies. Practically, the phrase "Low Cost With High Quality of Life" summarizes the main problem which faces the the decision maker, especially in big cities (e.g. Cairo, Tokyo, New York, Frankfurt, etc.).

Therefore, when the level of urbanization is limited, the narrowing of opportunities may lead to a concentration of migration to the capital city, which is the case in Egypt.

However, the development of any type of urban system – the network of relations between several such units of concentration (e.g. activities, information, etc.) – requires constant availability of resources and the organization of their flow in relatively wide and diversified societal ecological frameworks through mutually reinforcing activities and mechanisms.

In brief, if you know where you are headed (GOAL), specific means (TECHNIQUE) will get you there (OUTPUT). On the contrary, if you do not know where you are headed (..) ,any road (..) will lead you there (..). That is true for social, economic and physical sciences.

One of the objectives of this paper is to present the Mobility Interaction Model (MIM). Also, in this paper the MIM is developed and presented in practical terms to help the decision maker when dealing with urban issues.

2. THE DEVELOPMENT PROBLEMS AND OBJECTIVES

2.1. DEVELOPMENT PROBLEMS

When a person moves to a city he is faced with the challenge of mobility within the new setting. This mobility may require a new life style, new attitudes and new behavioral patterns. Moreover, new and additional services in the destination area are required.

The movement is based on the weight of advantages and disadvantages. For instance, people who move to the city lose their kinship bonds and become individualistic. However, the movement is assumed to be motivated primarily by economic factors (A.M. Hesham, 15). In Egypt, as a consequence of the migration into the CMA the number of squatters represented about 20% of the total population in the year 1978 (Soliman A., 27).

The imbalance in the access to resources between regions, between villages and between families is at the core of understanding the phenomenon of mobility. The above points and related matters represent the main development constraints of the case study area. Figure 1 shows the schema of urban development problems.

2.2. OBJECTIVE OF THE STUDY

The major goals of our study are as follows :

(1) To measure the effects of socio – economic variables in the Cairo Metropolitan Area (CMA).

(2) To weigh the importance of such parameters in order to determine any positive

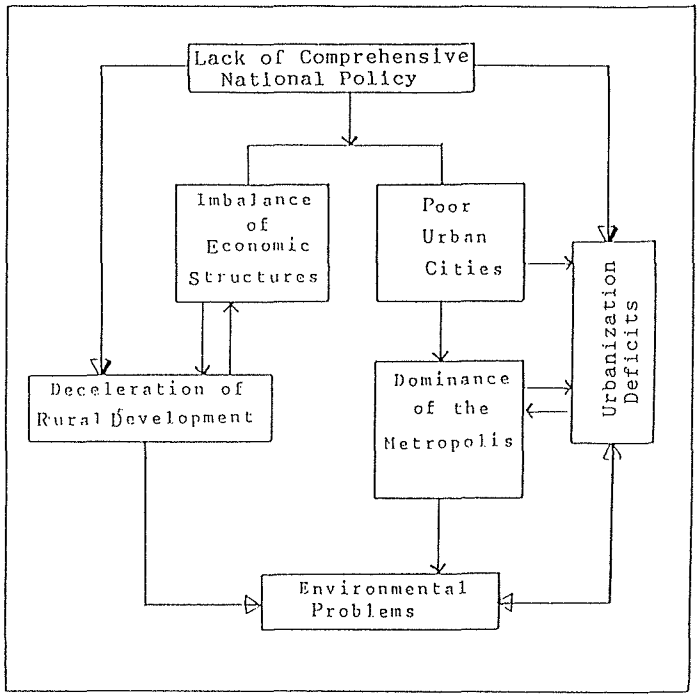

Figure. 1 A Schema of Urban Development Problems

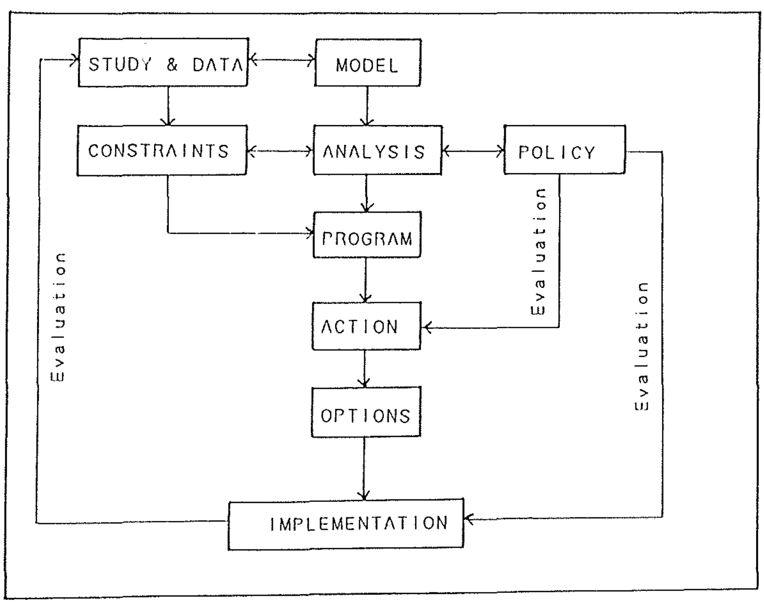

Figure. 2 The Basic Premise of Modelling and Implementation Procedures

interactions between urban governorates of Egypt and the CMA.

Figure 2 shows the basic premise of modeling and implementation procedures. This structure of a positive action loop is of great value in achieving comprehensive planning and helping decision makers.

3. URBAN SPATIAL PATTERNS AND STUDY AREA

3.1. URBAN POPULATION STRUCTURE

The administration boundaries of Egypt include 26 governorates. Egypt is divided into three major areas. The first area is called Old Valley (17 governorates – Lower & Upper Egypt Governorates). The second is called Frontier Governorates (5 governorates). The third area is called Urban Governorates which includes Cairo, Alexandria, Port Said and Suez.

Table 1 shows the urban and rural population and some demographic indicators of Egypt from 1897 to the year 2000, whereas table 2 shows the total population, area and population density of the urban governorates in the year 1976.

The urban populations represented 43.9 per cent of the total population of Egypt in the year 1976, while the total population of urban governorates in the year 1976 represented 20.5 per cent of the total population of Egypt. On the other hand, the Cairo governorate represented 64.6 per cent of the total population of urban governorates. This situation

Table 1 The Population Structure of Egypt from 1897 to 2000

Year	Population in 1000s		Total	Urban %	Rural %	Index No. 1897=100	Between Census Increase Rate %	Males %	No. of Families (1000s)	Average Family Size
	urban	rural								
1897	–	–	9669			100		50.8	1593	6.06
1907	2132	9058	11190	19	81	116	1.47	50.2	1934	5.78
1917	2689	10080	12719	21	79	132	1.29	50.1	2185	5.82
1927	3810	10368	14178	27	73	147	1.09	49.8	2671	5.30
1937	4492	11429	15921	28	72	165	1.16	50.0	3187	4.99
1947	6363	12604	18967	34	66	196	1.78	49.5	4022	4.71
1960	9864	16120	25984	38	62	268	2.38	50.3	5177	5.01
1966	12091	17756	29847	41	59	309	2.54	50.4	5689	5.24
1970	13895	19188	33083	42	58	342	2.41	50.4	6449	5.13
1975	16315	40764	37079	44	56	383	2.31	50.4	7372	5.03
1980	11187	22543	41710	46	54	481	2.38	50.4	8495	4.91
1985	22600	24483	47083	48	52	487	2.45	50.5	9912	4.75
1990	26504	26504	53008	50	50	548	2.40	50.5	11498	4.61
1995	30254	29068	59322	51	49	614	2.28	50.6	13301	4.46
2000	34293	31655	65948	52	48	682	2.14	50.7	15266	4.32

Sources: 1) Ministry of Housing and Reconstruction (Cairo, 1975)
2) Author's Arrangement and Order

reflects the imbalance of urban system hierarchy (A.M.Hesham, 17). Figure 3 depicts the ideal hierarchy of rural and urban systems.

Table 2 The Population Density in Urban Governorates in 1976

Urban Governorate	Total Population	Area in km^2	Density Person/km^2
Cairo	5,074,016	214.2	23,688
Alexandria	2,317,705	314.4	7,372
Port Said	262,760	72.1	3,644
Suez	193,933	306.9	632

3.2. CAIRO AT A GLANCE

Cairo today gathers together old history and modern Egypt. In other words, Greater Cairo embraces within its peripheral roads relics of the most ancient capitals of Egypt from Pre – dynastic times (5,000 – 3,100 B.C., Oan) up till the end of the old kingdom (3,100 – 2,181 B.C.) of the pharaonic era (Memphis with an area of 3.4 km^2). In Egypt, Cairo represents an unique city in terms of population, social and technical infrastructures and institutions.

Moreover, the population of Greater Cairo has increased from 3.7 million people in 1960 to 9.0 million people in 1976. Therefore, the population density of Cairo has increased from 19,593 people/km^2 in 1966 to 28,284 people /km^2 in 1986. This represents a quarter of the nation's population. About 55 per cent of the agglomeration extends on agricultural land.

Figure 4 depicts the evolution of urban and built – up areas of Cairo from 1850 until 1982. Also, the urban centers of Lower Egypt Governorates and Urban Governorates of Egypt in the year 1976 are shown in figure 5.

Concerning the migratory patterns, the volume of gross migration is certainly large. For instance, over 26 per cent of Cairo's population was born outside the metropolis (A. M. Hesham, 16). In fact, the migration issue has negative impacts on both human beings and the environment, in addition to the increasing demands on urban facilities and social services.

3.3. MOBILITY AND MIGRATORY MOVEMENTS

THE MOBILITY TERM :

In this study, mobility is defined as the phenomenon of people moving from one area to another for a temporary period (not for a lifetime). When those people achieve their goals such as leisure or money, etc., they return to their place of origin. The return to the place of origin was decided in their mind before any move towards the destination. So, they accept any job (no any meaningful contribution to the GNP), any shelter (in the form of shanty towns, slum areas, etc.). However, the term mobility differs from term migration.

Migration may be defined as the physical transition from one geographical area to another.

Migration represents a person crossing boundaries, whereas mobility represents the

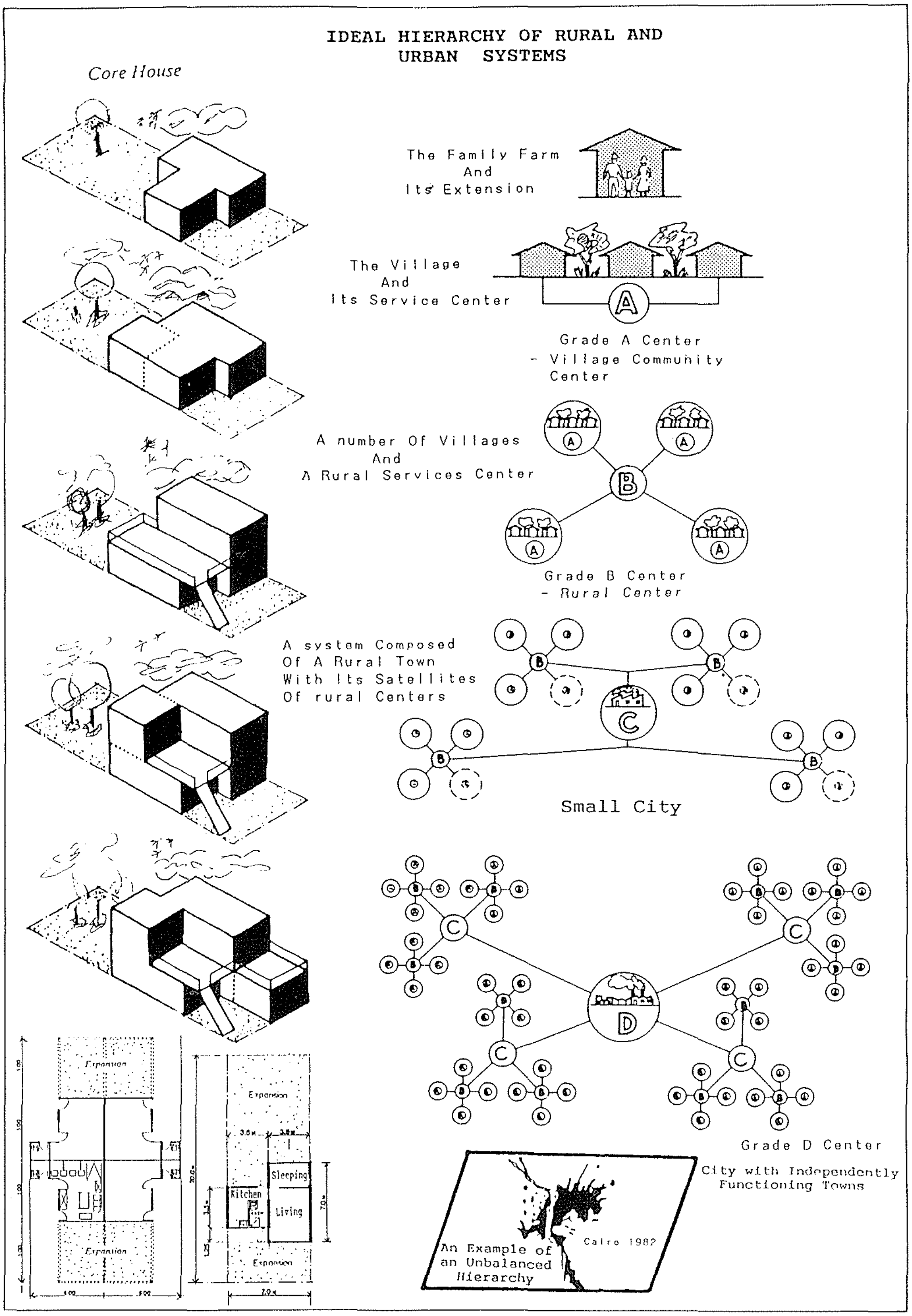

Figure. 3 Ideal Hierarchy of Rural and Urban Systems

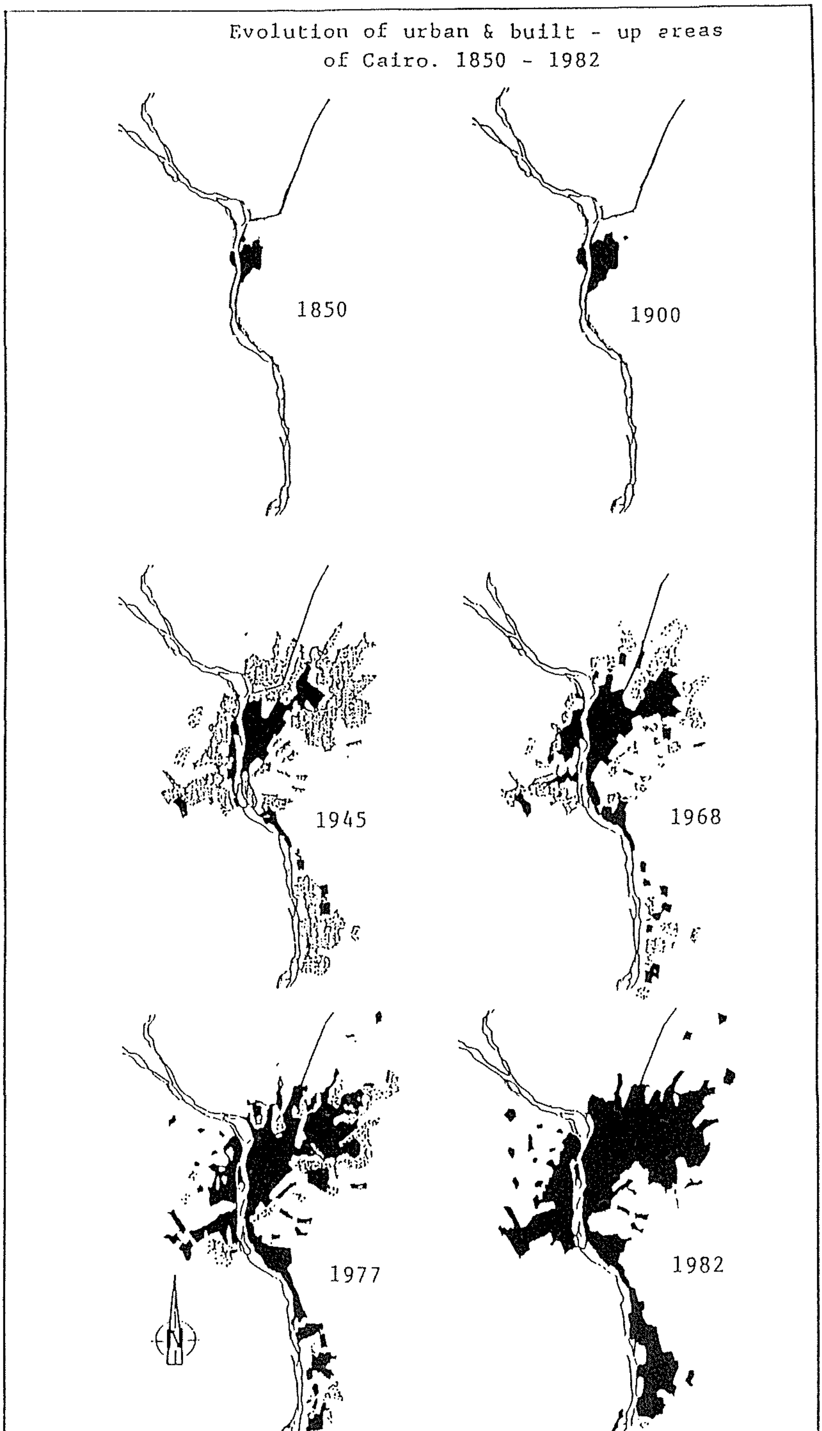

Figure. 4 Evolution of Urban & Built — Up Areas of the CMA from 1850 until 1982

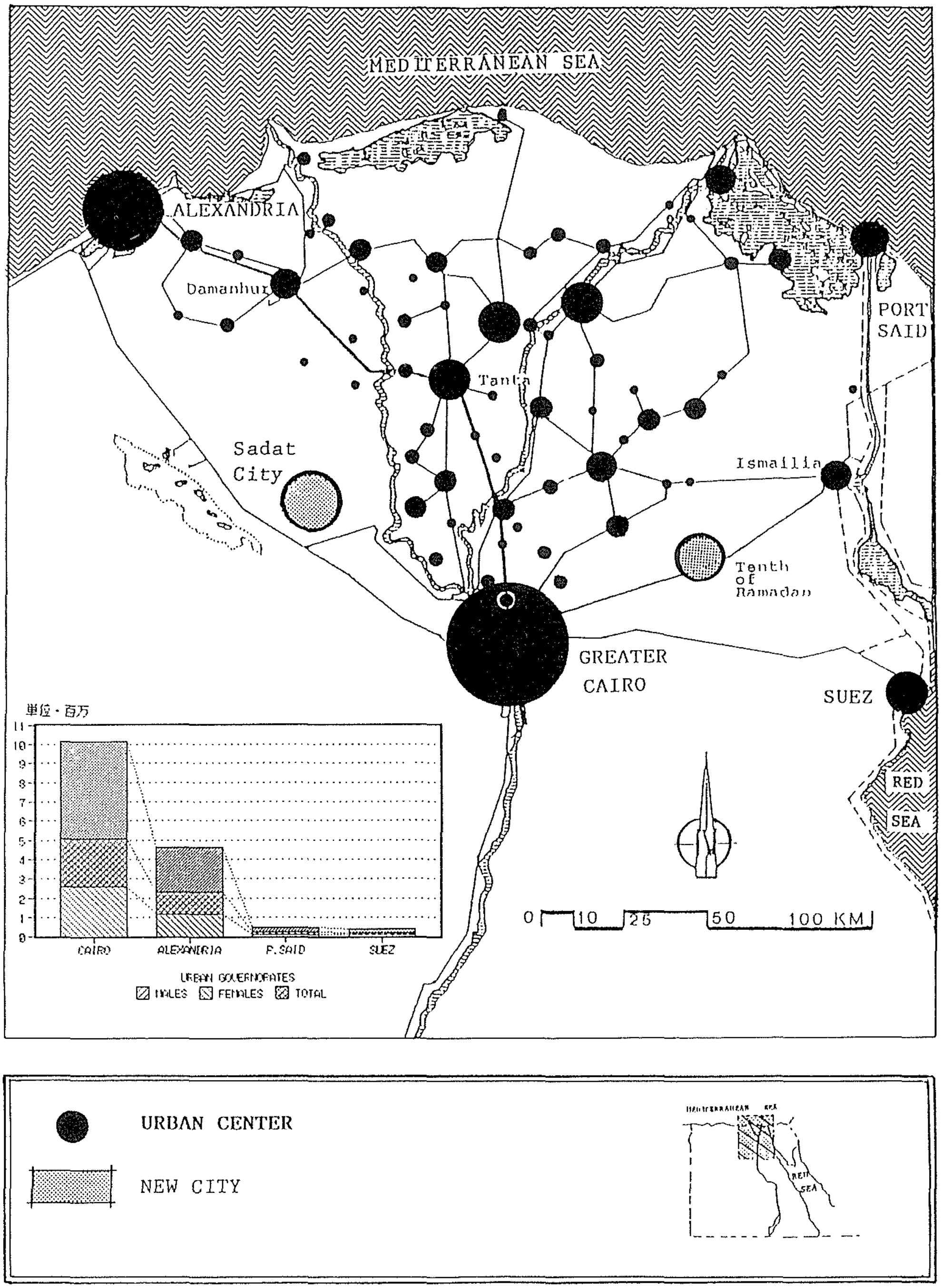

Figure. 5 Urban Governorates in 1976

movements within boundaries. The boundaries may be political, physical (e.g. mountain, river, etc.), visual (e.g. historical zone, recreation area, religious zone ,etc.), ethnic ferment groups , administrative borders (Figure 5, for example) or others.

Generally, many people move in response to changes in conditions (or in their perception of conditions), either in the villages of their origin or at the places of destination.

The classification of movements can be summarized under the following headings :

(1) Rural — Rural Movement

Rural mobility generally increases in response to heavy labor demand at the time of the harvesting. Laborers often take up harvest work outside their home villages.

In the case of Egypt, growth of village industries and the occupational diversity that usually follows creates additional work in the village and can thereby reduce the impact on mobility of factors such as land scarcity.

Possibly the more diversified villages in Egypt are close to the Nile River, or roads leading to cities, which can open up the option of commuting instead of out — migration (A.M. Hesham, 15).

(2) Rural — Coast Movement

The main targets of this movement are economic (e.g. fishing, sea port services, etc.).

The people flee from a rural environment which offers nothing, but lack clear objectives in terms of job specifics. Sometimes the decision — making has clear objectives either to maximize household income or to achieve a specific goal.

(3) Rural — Urban Movement

Under this issue the question that may be raised is : does a person prefer place [B] to place [A] because place [B] is selected or because place [A] is rejected, (A.M. Hesham, 18).

Also, how does distance impede migration and mobility, Distance is not an absolute concept in its own right ,but rather "effective distance," — the geographical space which can determine how far a migrant may travel — is a product of the adequacy and price of the communications network across that space.

(4) Urban — Urban Movement

The number of people moving from Alexandria to Cairo contribute about 46.3 per cent, whereas Suez contribute about 36.4 per cent and Port Said represent about 17.3 per cent of the total number of people who move to Cairo.

Additionally, we assume that the distance between any place and itself is positive.

In short, the factors entering into the decision to move and the process of mobility and migration can be summarized as follows :

(1) Factors associated with the area of origin.
(2) Factors associated with the area of destination.
(3) Intervening obstacles (e.g. the compulsory migration from Suez and Port Said governorates during the wars of 1956 and 1973).
(4) Factors concerning individual choice.

3.4. CAIRO METROPOLITAN AREA AS A DESTINATION

The value of mobility and immigration to the CMA is certainly large and represents one of the main development problems. For instance, in 1976 the total number of migrants to Cairo was 1,401,476 persons.

It may be that the social facilities of the city and other economic factors are important incentives to people to move towards Cairo.

The people express their first movements to city as "having a fling" and often return with no, or very small financial gains.

Hence, the reason for this so – called "target" mobility is to build up an adequate amount of capital, or sufficient capital to buy a farm or a house , and then return to the place of origins.

But in the case of the CMA, the people prefer to stay under any conditions (e.g. no shelter, jobless, etc.), as long as possible, enjoying the services and facilities available and waiting for other chances to improve conditions. The decision to return is related to the level of economic or social opportunity in the origin areas.

The fact is that this decision is closely related to the availability of particular kinds of jobs in the origin.

3.4.1. THE MIGRATION TO THE CMA ACCORDING TO VARIOUS FACTORS

The following arguments distinguish the influence of various factors on the movements to the CMA.

(1) AGE GROUP

Migration is concentrated extremely heavily in the population aged 15 – 45 (males represent 58.1% whereas females represent 41.9%).

(2) PURPOSE OF MIGRATION

Accompanying (co -migration of dependents) as a purpose represented the highest percentage of migrants (43.7%), while work represented 33.8 per cent of the total migrants. The purpose of marriage represented 11.2 per cent of the total migrants. As illustrated in table 3 work and marriage contributed about 45 per cent of the total migrants to Cairo in

Table 3 The Purpose of Immigration to Cairo in the Year 1976

Purpose	Male	Famale	Total	%
Work	438,524	35,501	474,025	33.8
Education	37,629	11,790	49,419	3.5
Marriage	15,512	14,508	157,020	11.2
Return After Compulsory Migration	14,489	9,079	23,568	1.7
Change of Residence	32,198	12,192	44,390	3.2
Accompanying as a Dependent	174,210	438,806	613,016	43.7
Others	20,218	19,820	40,038	2.9

1976, whereas the purpose of education represented only about 3.5 per cent.

(3) DISTANCE

There are two major standards in the field of study of migration and mobility. One is concerned with the transfer of labor from rural to urban areas. The second is concerned with the effects of distance and the choice of destination on the geographical and spatial patterns. Concerning the distance factor, the Egyptian governorates are divided into four groups.

These groups are as follows :

(a) Short distance (0 – 135km). This means the travel time is 1.30 hours (max. speed equals 90km/h).
(b) Medium distance (136 – 360km). Travel time is 4.0 hours.
(c) Long distance (361 – 630km). Travel time equals 7.0 hours.
(d) Very long distance (over 630km).

Short distance migrants represented the highest percentage of migrants (38.6%), whereas the very long distance represented the lowest percentage (2.5%) of the migrants. That means when the distance is short and close to the city, the desire of migration increases. Figure 6 shows the relationship between distance and migration.

(4) ADMINISTRATION BOUNDARY

As we mentioned before, Egypt is divided into three major areas. These areas are Old Valley, Frontier Governorates and the Urban Governorates. The urban governorates are populated areas in which non – agricultural economic activities are concentrated.

The Lower Egypt governorates (north Cairo) represented 50.7 per cent of the total migrants in the year 1976, whereas, the frontier governorates represented 1.6 per cent of the total migrants (Figure 7). That means the heavy people movements to Cairo are concentrated in the north of Cairo.

(5) DEMOGRAPHIC INFLUENCES

(5.1) Males & Females

The number of females migrants in Lower Egypt governorates is high compared with Upper Egypt governorates. This phenomena is due to social values and norms, especially

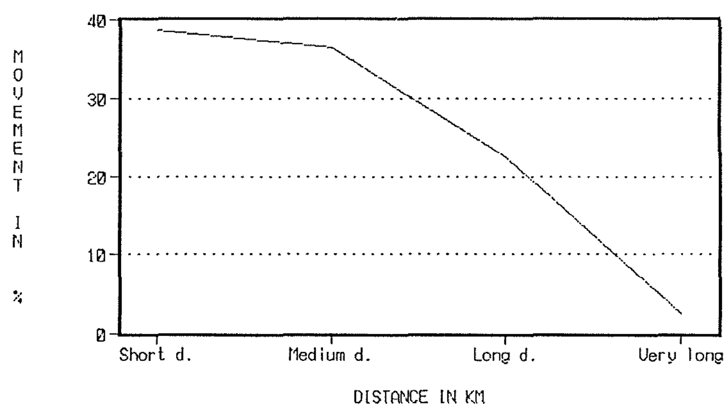

Figure. 6 The Relationship Between Distance and Movement

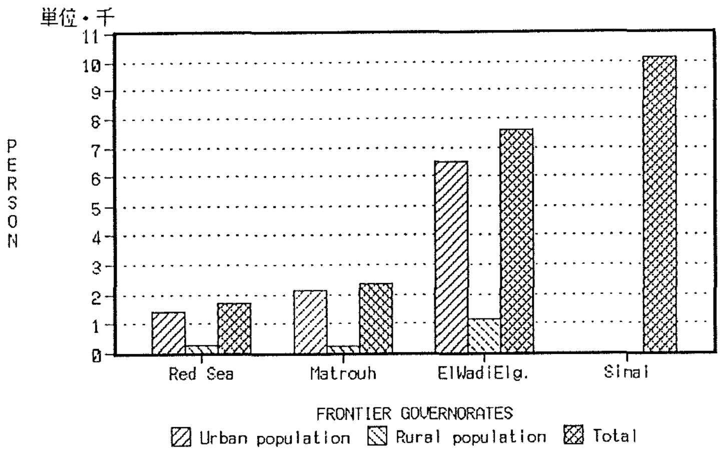

Figure. 7 The Migration from Frontier Governorates to Cairo in the Year 1976

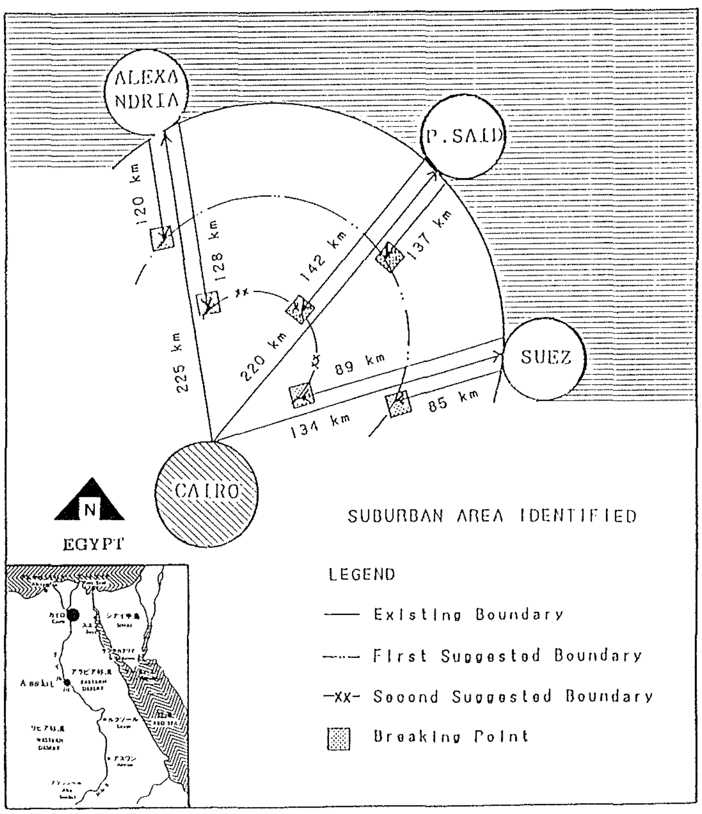

Figure. 8 Identification of Suburban Areas

religious determinants.

(5.2) Rural and Urban

Within the Lower Egypt governorates, Monoufiya Governorate represented the highest number of migrants (29.3%), whereas Kafr – El – Sheikh Governorate represented the lowest percentage (2.2%) of total migrants of the lower Egypt governorates.

On the other hand, Souhag Governorate represented the highest number of migrants (20.9%) within the Upper Egypt governorates, whereas Aswan Governorate represented the lowest percentage (6.1%) of total migrants of the Upper Egypt governorates.

4. BRIEF REVIEW OF THE SPATIAL INTERACTION MODELS

4.1. GRAVITY MODEL

The gravity model derives its name and basic premise from Isaac Newton's law of gravity

$$F=\frac{m_1m_2}{D^2} \qquad [4.1]$$

Newton's law states that the attractive force between any two bodies is directly related to the masses of the bodies and inversely related to the square distance between them.

However, the gravity model offers a simple methodology for estimating and measuring the possible interaction that can occur between various areas. In other words, this model states that the intensity of interaction between two areas is directly proportional to the number of people living in them and inversely proportional to the intervening distance. The gravity formula is given by

$$I=\frac{P_1P_2}{D^2} \qquad [4.2]$$

where

I is a measure of interaction

P_1 and P_2 are the populations of the areas $_1$ & $_2$

D^2 is the distance between them

4.2. JOCHIM MODEL

Jochim has developed a useful gravity model to analyze the interaction between a human population and several preferred resources. His modified Model is

$$I=G\ \ R \qquad [4.3]$$

where

G is a constant and R is the dietary proportion of a resource. The density of each resource is expressed by

$$mc=w\ \ h\ z \qquad [4.4]$$

where mc is the mass of a resource cluster, w is the weight of an individual, h is the number of individuals and z is the area. According to Jochim (Karl *W*. Butzer, 23), the gravity model can be reformulated to include distance between a group and a dietary resource :

$$I=\frac{P\ w\ h\ z}{D^2} \tag{4.5}$$

where P is the population and D is the distance between the population and resource.

Therefore,

$$D=\sqrt{\frac{P\ w\ h\ z}{G\ R}} \tag{4.6}$$

The equation [4.6] is also called resource gravity model. In order to obtain a practicable relationship, the constant G and the population P can be ignored. Then, the resource gravity model will appear as follows :

$$D^2=\frac{whz}{R} \tag{4.7}$$

4.3. LOWRY MODEL

Given the location of basic employment, or even assuming changes in industrial location, the problem may be seen as one of discovering where the population would live in relation to the employment opportunities provided. Also, it may be presented as one of discovering the desired pattern of development.

In the original Lowry model, population was distributed using a potential model, in which the amount of population allocated to any one zone was determined by the sum of the inter – zonal potentials for that zone. This pattern is shown in the following formula

$$P_j=\mathrm{sc}\sum_{j=1}^{n}\frac{B_i}{D_{ij}} \tag{4.8}$$

where

P_i is the amount of population allocated to j

B_i is the basic employment in i

D_{ij} is the impediment factor between i and j

sc is a scaling factor to ensure that $\sum_j P_j$ equal to the total growth forecast

(For further details, see C.S.Bertuglia, Leonadri, 3).

and,

$$B_i=E_i-S_i \tag{4.9}$$

where E_i represents the total employment in i and S_i represents the service employment in i.

4.4. GARIN MODEL

The Garin model is the most widely used version of the Lowry model. The Garin model is also based on the gravity model and is shown as follows :

$$T_{ij}=C_i(A_iP_jD_{ij}^{-1}) \tag{4.10}$$

where

T_{ij} is the amount of activity allocated from zone i to zone j

C_i is the total amount of activity to be allocated from zone i to zone j

The expression

$$(A_iP_jD_{ij}^{-1}) \quad [4.11]$$
$$\{\text{where} \quad A_i=((P_jD_{ij}^{-1}))^{-1}\} \quad [4.12]$$

is the probability of interaction between zones i and j, with P_j being a measure of the attraction of zone j. The total number of workers living in any one zone j is therefore

$$\sum_{i=1}^{n} T_{ij} \qquad (i=1,2,..,n) \quad [4.13]$$

Also, the total amount of population living in any zone then becomes :

$$P_j=\alpha\sum_{i=1}^{n} T_{ij} \qquad (i=1,2,..,n) \quad [4.14]$$

where

$$\alpha=P/E \quad [4.15]$$

where P is the total population and E is the total employment.

4.5. GARIN LOWRY MODEL

The residential location component of the Garin − Lowry model can be presented as follows :

$$T_{ij}=C_i(A_iP_jD_{ij}^{-g}) \quad [4.16]$$
$$\{\text{where} \quad A_i=((P_jD_{ij}^{-g}))^{-1}\} \quad [4.17]$$

where g is a parameter.

4.6. GRAVITY POTENTIAL MODEL

The Gravity Potential Model can be expressed symbolically as

$$T_{ij}=O_iG_j(f_{ij}) \quad [4.18]$$

Where

T_{ij} is the expected movement of people from i to j

O_i the origin

G_i is the destination

f_{ij} is the function which measures the separation between i and j

The most widely used type of spatial interaction model takes the following form :

$$M_{ij}=r_{ij}O_i^{\alpha}G_j^{\beta}f(d_{ij}) \quad [4.19]$$

where M_{ij} is the flow from origin i to destination j, O_i is the size variable pertaining to the origin i, G_j is a size variable pertaining to the destination j, d_{ij} is a variable reflecting the difficulty of contact between i and j, r_{ij}, α and β are parameters of the model and f_{ij} is a chosen function which often takes a quadratic or exponential form (David Batten, 9).

4.7. GRAVITY MODEL IN TERMS OF REGIONAL INCOME

The formulation of this model may be written as follows :

$$M_{ij}=q\,\frac{(Y_iY_j)^{\alpha}}{D_{ij}^{\beta}} \qquad [4.20]$$

Where

M_{ij} is total commodity flow between region i and region j
Y_i is the output of region i
Y_j is the output of region j
D_{ij} is the distance between i and j
q and β are constants, and α denotes the regional income elasticity

The value of α is defined as percentage change in commodity flow divided by percentage change in regional output.

Also, the following formula is used to determine the proportion of flow of commodity in one region with respect to another.

$$F_i^n=\frac{Y_i^n}{Y_j^n}\cdot F_j^n \qquad [4.21]$$

where

F_i^n is intraregional flow of commodity n in region i
F_j^n is intraregional flow of commodity n in region j
Y_i^n is the output of sector n region i
Y_j^n is the output of sector n region j

To apply the above equation numerous data are required which may be not easily available in many parts of developing countries.

4.8. LOGISTIC MODEL

This model examines the relationships between mutually exclusive and exhaustive probabilities of movement and a set of conditioning variables.

The polytomous logistic model describes the probability, p, that an individual residing in location i will decide to move to location j given the vector of characteristics concerning origin and destination (Daniel Shefer, 8). This model is expressed symbolically as

$$P_{ij}=e^{Z_{ij}}/\sum_{i=1}^{n}e^{Z_{ij}} \qquad [4.22]$$

where

$$\Sigma P_{ij}=1 \qquad (i,\ j=1,2,3,..,n) \qquad [4.23]$$

$$0<P_{ij}<1, \text{ and} \qquad [4.24]$$

e is the natural logarithm
Z_{ij} is the linear function

$$Z_{ij}=\alpha+\sum_{i=1}^{n}\beta\ln X_i+\sum_{j=1}^{n}\lambda\ln X_j+\delta\ln d_{ij} \qquad [4.25]$$

$$(i,\ j=1,2,..,n)$$

where

X_i is the origin
X_j is the destination
d_{ij} is the distance between them.
α, β, λ, and δ are parameters

Nonetheless, it would be impossible in one paper to give a detailed account on all interaction models. But previous models have either direct or indirect relationship with the MIM.

5. THE MOBILITY INTERACTION MODEL (MIM)

5.1. THE FIRST FORM OF THE MIM

One form of the MIM is

$$MM(ij)=L_i=\frac{E_jf(ij)}{\sum_{j=1}^{n}E_jf(ij)} \qquad [5.1]$$

where

$MM(ij)$ = No. of people moving from zone i to zone j
L_i = No. of people leaving zone i
E_i = No. of people entering zone j
$f(ij)$ = The friction factor(e.g. impediment distance) between zone i and zone j
n = No. of zones

Generally, impediment is a weighted sum of various types of times (e.g. waiting time, walking time, etc.) and types of cost (e.g. parking cost, bus fares, etc.).

The model also appears as follows :

$$MM(ij)=E_i\frac{L_jf(_{ij})}{\sum_{j=1}^{n}L_jf(ij)} \qquad [5.2]$$

Equation [5.1]$\neq$ equation [5.2]

If socio − economic factors are included, the model becomes :

$$M\overline{M}(ij)=E_i\frac{L_jf(ij)K_{ij}}{\sum_{j=1}^{n}L_jf(ij)K_{ij}} \qquad [5.3]$$

where

K_{ij}= Parameters

and

$$M\overline{M}(ij)=L_j\frac{E_jf(ij)K_{ij}}{\sum_{j=1}^{n}E_jf(ij)K_{ij}} \qquad [5.4]$$

equation [5.3]$\neq$ equation [5.4]

Look at each part of equations [5.3] and [5.4]

The first model states that the number of persons leaving in zone i

L_i

will be distributed over each other zone j

$MM(ij)$

according to the relative accessibility of each zone j as defined by

$$\frac{E_j}{\sum_j E_j} \qquad [5.5]$$

and the relative accessibility of each zone j as defined by

$$\frac{f_{ij}}{\sum f_{ij}} \qquad [5.6]$$

The friction factor is defined as

$$f_{ij}=\frac{1}{d_{ij}^2} \qquad [5.7]$$

or

$$f_{ij}=\frac{1}{d_{ij}} \qquad [5.8]$$

Thus, when the value of f is large, there will be more people who want to move from one place to another.

5.2. THE SECOND FORM OF THE MIM

The variables which have been selected in this section are chosen to be consistent with our model in order to achieve our objective.

The MIM which has been developed is shown as follows :

$$MM(ij)=S\left[L_{ij}\left(\frac{Q_j}{Q_i}\cdot\frac{U_i}{U_j}\right)\left(\frac{B_i^{\alpha_1}B_j^{\alpha_2}W_i^{\beta_1}W_j^{\beta_2}H_i^{\lambda_1}H_j^{\lambda_2}E_i^{\eta_1}E_j^{\eta_2}}{D_{ij}^{\theta}}\right)\right] \qquad [5.9]$$

where

$MM(ij)$ is the mobility interaction from i to j

Q_i is the number of people who are unwilling to work in area i

Q_j is the number of people who are unwilling to work in area j

U_i is the number of people who are not occupied in area i

U_j is the number of people who are not occupied in area j

B_i is the active labor force (age group 15 − 45) in area i

B_j is the active labor force (age group 15 − 45) in area j

W_i is the number of productive workers in area i

W_j is the number of productive workers in area j

H_i is the number of professional / technical workers in area i

H_j is the number of professional / technical workers in area j

E_i is the armed force (age group 20 − 24) in area i

E_j is the armed force (age group 20 − 24) in area j

D_{ij} is the space dimension (travel time or effective distance in km, for example) and α_a, α_2, β_1, β_2, λ_1, λ_2, η_1, η_2 and θ are parameters

It should be noted that productive workers includes workers of all ages occupied in the production of goods, especially for export.

The range of the value (if constant) should be between 1 and 3. For instance, in application studies in Detroit (U.S.A.) the value of θ was 0.5 for urban and 2.3 for rural areas and in Munich (Germany) the value of θ was 1.6 for urban and 2 for rural areas. Also, another study by Carroll and Bevis found that for intrametropolitain travel in the Detroit region the appropriate exponent for total person trips was 1.63. In addition, Ikle found considerable variation in the appropriate exponent of Dij : his values range from 0. 689 to 2.6 (Isard, 19).

It is obvious that if the exponent on distance were set at zero, then Dij would be unity, and distance would have no effect on the movement made. If the exponent were raised to, say, 5 then nearly all movements originating in subzone 1 would terminate in subzone 1. Isard (Isard, W. 21) mentioned that the appropriate exponent on distance seems to be within the range of between one and three.

L_{ij} is the ratio of the levels of development, defined as a function of per capita incomes LN_i and LN_j in area i and j, respectively, where

$$L_{ij}=\frac{\max(LN_i, LN_j)}{\min(LN_i, LN_j)} \qquad [5.10]$$

The equations of social interaction can be presented mathematically as follow :

$$Iij=C\frac{(Pi\ \ Pj)}{D_{ij}^{\theta}} \qquad [5.11]$$

$$Iij=C\frac{(Pi\ \ Pj)^{k}}{D_{ij}^{\theta}} \qquad [5.12]$$

$$Iij=C\frac{(Pi^{k_1}\ \ P_j^{k_2})}{D_{ij}^{\theta}} \qquad [5.13]$$

where

Iij is the social interaction between cities i and j

Pi is the population of city i

Pj is the population of city j

Dij is the space dimension

C is constant, and θ, k_1 and k_2 are parameters

Needless to say, the effective distance can be measured in various ways. For instance, distance in kilometers or miles, travel time, traffic cost, specific transport mode (e.g. railway, waterway, airline, etc.), fuel consumption in transportation, number of stops or gear shifts and other forms of physical distance. The use of any space dimension depends upon the study and problems identified.

With respect to the population growth rate, the coefficient variation can be obtained from the following formula :

$$CV=\sqrt{\frac{1}{n}(x_i-\bar{x})^2/\bar{x}} \qquad [5.14]$$

where

CV is the coefficient of variation of the population growth rate

x_i is the population growth rate of city i

$\bar{x}_i$ is the average of x_i

n is the number of cities

(see Jinichiro Yabuta, 12)

As Isard mentioned (Isard, 21), the value of S (a constant) can be obtained from the following formula :

$$S=\frac{V}{\frac{P_1}{d_{11}}+\frac{P_2}{d_{12}}+\frac{P_3}{d_{13}}+\frac{P_4}{d_{14}}} \qquad [5.15]$$

where V is the average number of people moving to area j per year. P_1,P_2,P_3 and P4 are the population and d denotes the distance.

Walter Isard (Isard, W., 20 and 21) mentioned also that the distance from one place to itself is assumed to be positive. If the distance between one place and itself is zero, the value of the constant S will be zero.

Then, if the weights of adjusting masses are included, the MIM (equation 5.9) will appear as follows :

$$MM(ij)=S\left[L_{ij}\left(\frac{Q_j}{Q_i},\frac{U_i}{U_j}\right)\left(\frac{w_i(B_i)^{\alpha_1}w_j(B_j)^{\alpha_2}w_i(W_i)^{\beta_1}w_j(W_j)^{\beta_2}w_i(H_i)^{\lambda_1}w_j(H_j)^{\lambda_2}w_i(E_i)^{\eta_1}w_j(E_j)^{\eta_2}}{D_{ij}^{\theta}}\right)\right] \qquad [5.16]$$

where

w_i and w_j are the weighting factors.

Isard mentioned that (Isard, W., 19) the validity of any specific weight derived for a given city is questionable.

In short, the equations for weighting factors are as follows :

$$w_i=\sum_{g=1}^{g} cg\ wg_i \qquad [5.17]$$

and

$$w_j=\sum_{g=1}^{g} cg\ wg_j \qquad [5.18]$$

where

cg is the weight of the g th weighting factor.

wgi and *wgj* are sub − weighting factor of *wi* and *wj*, respectively.

The following factors were considered in deriving *wgi* and *wgj* for use in calculating the weighting factors *wi* and *wj* in equations [5.16], [5.17] and [5.18].

(1) Employment status (self − employed, for example).

For the case of Egypt, self − employed are defined as those who work on their own property, do not represent a cost to the government, and produce something that contributes to the GNP (this can be ideas resulting from research, for example).

(2) Level of technology.

(3) Level of education (university first degree, for example).

(4) Skill level (based on training centers and services available).

It should be noted that the MIM can be applied to each area. For instance each urban governorate can receive people from all other urban governorates. Thus the number of spatial interactions will be

$$[N(N-1)] \qquad [5.19]$$

where N is the number of urban governorates

5.3. IDENTIFICATION OF SUBURBAN AREAS

It is possible to determine the assistant urban boundary. This is the boundary which determine the distance from the place of origin to the place of destination. In other words, this boundary lies between the origin and destination. However, this can be done by using the Converse model which is known as the "Breaking Point Concept". The Breaking Point is that location that marks the division of two streams of movement, each directed to a different focal point (P.Converse, 6).

The Converse model was modified from the Reilly model (Ray M. Northman, 26).

Reilly's model takes the following form :

$$\frac{R_1}{R_2} = \left(\frac{P_1}{P_2}\right)\left(\frac{d_2}{d_1}\right)^2 \qquad [5.20]$$

where

R_1 and R_2 are the relative shares of sales in each of two cities, made to residents of an intermediate city. P_1 and P_2 are the populations of competing trade centers deriving customers from the intermediate city. and d_1 and d_2 are the distances respectively from each of two cities (P_1 and P_2) to an intermediate city.

The Converse formula is expressed symbolically as

$$B = \frac{d}{1+\sqrt{\frac{P_1}{P_2}}} \qquad [5.21]$$

where B is the breaking point (in km) from the smaller of two adjacent trade centers and d is the distance (in km) and P_1 and P_2 are the populations as in equation [5.20].

If the Converse formula (equation 5.21) is raised to a power (as factor of development), it would be much more effective.

Then, the new formula will appear as follows :

$$B = \frac{d}{\left(1+\sqrt{\frac{P_1}{P_2}}\right)^h} \qquad [5.22]$$

where h is a parameter.

However, the exponential function equation is used to identify the suburban area from the best density patterns point of view. This equation is expressed mathematically as follows

$$R(z) + a_0\ e^{-bz} \qquad [5.23]$$

where

$R(z)$ is the density (residents per square kilometer)

z is the kilometer distance from the center of the urban area

a_0 is the estimated density from the data at the center of urban area

e is the base of the Naperian Logarithm System (2.71828)

b is a parameter

The value of b describes the rate at which density falls with distance. In other words, it is the percentage decrease in density from the center. Specifically, if the average density decreased 10 per cent per kilometer of distance from the center, the value of b would be 0.10 (Edwin & Byung, 11).

Thus, the larger b is, the faster density falls with distance from the center of the urban area. As a result, the value of b provides a natural measurement of identifying the suburban area which could help the decision maker.

6. SIMULATIONS AND EMPIRICAL RESULTS

6.1. MODEL SIMULATION

In this section, we will focus briefly on the simulation of the MIM and the manner in which it works practically. The MIM was given variables associated with the real situation in Egyptian urban governorates in relation to the CMA. These represent the core variables when dealing with the development issue of developing countries.

First, in this study some assumptions are made. These assumptions are — The travel time among urban governorates is assumed to decrease year by year. There are two reasons behind this assumption. The first one is related to the policy adopted by the Egyptian government which aims to improve the entire traffic system. The other reason is due to the lack of available detailed data. The travel time can clearly reflect the degree of development of transportation means (highways, for example).

— The space dimension when measured in distance, takes the form of a straight line.

— The movement of people does not involve airplanes or waterways (i.e. via the Nile River).

However, the model is estimated in a log — linear form, using the method of least squares.

Also, in equations [5.11], [5.12] and [5.13] the populations of the origin and destination have been used as explanatory variables.

In equation [5.11] the population elasticity is assumed to be unity, which implies that if the population increases by one unit, the movement of people will increase by one unit.

Let us turn now to show some results (due to space consideration) of the working of the model.

The estimations from equation [5.12] are presented in table 4. However, with respect to regression method, interest is often focused upon the significance of specific variance of dependent variables (e.g. F—test, t—value, R—Square, etc.).

In the simulation, the distance was measured in kilometers instead of travel time in order to show the degree of relationship between population and movement.

It requires no great imagination to see (from the statistical values pointed out in table 4) the significance of changes in Alexandria, Port Said and Suez on the situation of the CMA.

Tables 5 and 6 illustrate estimations of the parameters according to different forms. Here, the travel time was used to measure distance.

In table 5, the value of the parameter θ was $-$ 8.0665 for Alexandria, $-$ 10.7650 for Port Said and $-$ 6.6907 for Suez. These results show that a one per cent increase of the

Table 4 Stepwise regression of population variables

	Constant	K	R-Square	ADJ R-SQ
Alexandia / Cairo	2.25	0.0434 (0.0641)	0.9863	0.9726
Port Said / Cairo	0.82	0.6675 (0.2751)	0.9356	0.8712
Suez / Cairo	0.71	0.6768 (0.2411)	0.8873	0.7747

Note : standard error is in parentheses.

Summary statistics of the interaction between Alexandria and Cairo :

F-test	= 71.885
t-value	= 8.478
PROB>F (Significance probability)	= 0.0747
C.V. (Coefficient of variation)	= 0.0854
(Mean of the dependent variabke)	= 9.3994

Summary statistics of the interaction between Port Said and Cairo :

F-test	= 14.530
t-value	= 3.812
PROB>F (Significance probability)	= 0.1633
C.V. (Coefficient of variation)	= 0.3633
(Mean of the dependent variabke)	= 8.9973

Summary statistics of the interaction between Suez and Cairo :

F-test	= 7.877
t-value	= 2.807
PROB>F (Significance probability)	= 0.2179
C.V. (Coefficient of variation)	= 0.6015
(Mean of the dependent variabke)	= 8.9134

Table 5 The empirical results of applying equation [5.11]

	Constant	θ	Standard Error
Alexandria / Cairo	5.54	− 8.0665	0.0465
Port Said / Cairo	6.78	−10.7650	0.1355
Suez / Cairo	4.75	− 6.6907	0.1733

Table 6 The empirical results of applying equation [5.13]

	Constant	K1	K2	θ
Alexandia / Cairo	11.18	−1.2234 (1.9349)	0.3880 (2.3231)	−8.8989 (0.3736)
Port Said / Cairo	45.05	−11.2628 (2.2512)	6.5563 (1.4113)	−8.2586 (1.5237)
Suez / Cairo	−6.61	−1.9031 (2.0104)	4.1345 (0.3201)	−1.4888 (1.2307)

Note : standard error is shown in parentheses.

Table 7 The empirical results of mobility interaction between Alexandria and Cairo

Parameters	Values of Parameter estimated	Standard Error
α_1	−1.1354	5.5934
α_2	2.0877	7.1724
β_1	−1.1841	5.6902
β_2	2.1503	7.2970
λ_1	−1.4018	5.9591
λ_2	2.4289	7.6399
η_1	−1.2107	5.6825
η_2	2.1844	7.2874

Also, a summary of outputs of statistical analysis are as follows:

Intercept = 2.32
R-Square = 0.8195
F-test = 80.63
t-value = 0.524
PROB>F (Significance probability) = 0.0221
C.V. (Coefficient of variation) = 0.5431

travel time will lead to 8.0665, 10.7650 and 6.6907 decline of the people moving from Alexandria, Port Said and Suez towards Cairo, respectively.

Table 6 shows the empirical results of applying equation [5.13]. The standard errors of the parameter are different for the three equations. For instance, equation [5.11] represents the best value for Alexandria (−0.0465) in terms of the parameter of the travel time.

Therefore, the results show that an increase in population growth strongly influences on the movements of people to another area. In this respect, more attention should be paid to the efforts of birth control programs and decreasing the population growth rates. Moreover, in order to overcome the difficulties of population pressure, a policy of reconstruction and development of the desert lands should be implemented effectively and practically (e.g. 94% of the total area of the nation is underutilized — in comparison, one German farmer produced enough food for 60 people in the year 1987).

To identify the factors affecting the spatial interaction between urban governorates and the CMA, the values of parameters α_1, α_2, β_1, β_2, λ_1, λ_2, η_1, η_2 and θ are estimated. In this analysis a multiple regression model is used to estimate the $MM(ij)$ variations in the origin and destination.

Tables 7, 8 and 9 represent the results of applying the model where the distance takes the form of straight line. Also, the parameter of Dij is assumed to be constant. In these tables the estimated values for the areas of origin are negative. This shows that any decrease in the variables of the areas of origin will lead to increase in those of the destination. In Egypt, comprehensive urban development should be taken into consideration, because it is apparent that several lines of action oriented towards the urban governorates could contribute effectively towards relieving the critical situation of the CMA.

On the other hand, when travel time is used as distance variable, Port Said show a great influence on the CMA compared with Alexandria and Suez (Tables 10, 11 and 12). The value of the parameter Dij was −0.5708, −1.9515 and −0.7078 for Alexandria, Port Said and Suez, respectively, but the standard error was the lowest in Suez (0.2544). In short, as mentioned before, the values of statistical analysis included in those tables can give an in — depth view of the interaction patterns between the origin and destination.

Also, the simulation shows that when the level of technology in the area of origin decreases, the movement to the big cities increases. This output is largely observed in the case of interaction between Port Said and the CMA.

Additionally, the analysis shows that an increase in income in the area of origin does

Table 8 The empirical results of mobility interaction between Port Said and Cairo

Parameters	Values of Parameter estimated	Standard Error
α_1	−1.4341	0.5074
α_2	1.4743	0.2112
β_1	−1.4334	0.5079
β_2	1.4740	0.2114
λ_1	−1.4516	0.5159
λ_2	1.4811	0.2147
η_1	−1.4362	0.5086
η_2	1.4750	0.2117

Also, a summary of outputs of statistical analysis are as follows:

Intercept	= 10.52
R-Square	= 0.9995
F-test	= 7365
t-value	= 3.2733
PROB>F (Significance probability)	= 0.0001
C.V. (Coefficient of variation)	= 0.0462

Table 9 The empirical results of mobility interaction between Suze and Cairo

Parameters	Values of Parameter estimated	Standard Error
α_1	−1.2071	0.3147
α_2	1.2442	0.1059
β_1	−1.2063	0.3156
β_2	1.2443	0.1062
λ_1	−0.9182	0.1387
λ_2	1.1525	0.0469
η_1	−1.2107	0.3159
η_2	1.2454	0.1062

Also, a summary of outputs of statistical analysis are as follows:

Intercept = 10.17
R-Square = 0.9997
F-test = 24387
t-value = 9.4367
PROB>F (Significance probability) = 0.0001
C.V. (Coefficient of variation) = 0.0113

Table 10 The empirical results of mobility interaction between Alexandria and Cairo with respect to travel time

Parameters	Values of Parameter estimated	Standard Error
θ	−0.5708	0.7712
α_1	8.2519	13.6851
α_2	−9.1473	16.5911
β_1	8.8728	14.3481
β_2	−9.9073	17.4066
λ_1	8.2112	15.0401
λ_2	−9.1289	18.2894
η_1	8.1796	14.0115
η_2	−9.0693	17.0029

Also, a summary of outputs of statistical analysis are as follows:

Intercept = 12.58
R-Square = 0.9367
F-test = 50.33
t-value = 0.0497
PROB>F (Significance probability) = 0.0001
C.V. (Coefficient of variation) = 0.0997

Table 11 The empirical results of mobility interaction between Port Said and Cairo with respect to travel time

Parameters	Values of Parameter estimated	Standard Error
θ	-1.915	0.9380
α_1	-0.9461	2.1597
α_2	2.6867	0.9786
β_1	-0.9446	2.1601
β_2	2.6865	0.9789
λ_1	-1.0057	2.1656
λ_2	2.7107	0.9815
η_1	-0.9565	2.1626
η_2	2.6902	0.9799

Also, a summary of outputs of statistical analysis are as follows:

Intercept	=	-3.49
R-Square	≒	0.9879
F-test	=	274.13
t-value	=	2.3017
PROB>F (Significance probability)	=	0.0001
C.V. (Coefficient of variation)	=	0.1210

Table 12 The empirical results of mobility interaction between Suez and Cairo with respect to travel time

Parameters	Values of Parameter estimated	Standard Error
θ	-0.7078	0.2544
α_1	0.5727	0.6708
α_2	1.1886	0.0798
β_1	0.5778	0.6703
β_2	1.886	0.0799
λ_1	-0.0583	· .3582
λ_2	1.1201	0.0385
η_1	0.5742	0.6719
η_2	1.1896	0.0800

Also, a summary of outputs of statistical analysis are as follows:

Intercept	=	-3.10
R-Square	=	0.9996
F-test	=	22809.53
t-value	=	19.0165
PROB>F (Significance probability)	=	0.0001
C.V. (Coefficient of variation)	=	0.0156

not affect the mobility interaction to as great an extent as to other factors, such as improvement of skill level and improvement of education status.

The suburban area is identified in figure 8. The distance indicating the appropriate boundary and in turn location for the next suburban area as calculated by the MIM simulation is shown as follows :

	First Suggested Boundary	Second Suggested Boundary
Distance from Alexandria	120 km	128 km
Distance from Port Said	137 km	142 km
Distance from Suez	85 km	89 km

The MIM can be applied to any kind of urban and regional problem that is associated with social and economic development and relevant analyses. Also, the planner can easily measure and weight factors according to influence and power in order to find out the best solution for development. By applying the MIM we can draw up various alternatives which would help the policy maker when dealing with urban and regional issues (especially, the big cities of developing countries).

6.2. CONCLUDING REMARKS

In this paper we present the Mobility Interaction Model (MIM), which is based on the concept of gravity model, in order to be able to describe accurately the spatial structure of the urban areas in general and especially the Egyptian urban governorates with relation to the Cairo Metropolitan Area (CMA).

However, from the foregoing discussion and analysis the authors wish to emphasize the following points :

(1) The concentration of attractiveness factors {e.g. the monopoly of facilities (training centers, for example), services, institutions, etc.} in the CMA should not continue (a decentralization policy must be adopted) in order to achieve the balance of urban systems hierarchy.

(2) A formulation of concrete population policy (i.e. family planning and economic reform) and oversight its implementation, especially in Port Said and Alexandria must be strongly adopted by the government.

(3) The skill of labor force (which means more training centers and training programs are required) and unemployment rate in especially in the origin areas should be considered as a matter of great concern. For instance, improving the skill level of people (especially those who are jobless or not occupied) has more influence in decreasing the number of people moving towards The CMA.

(4) The simulation of the MIM has shown that an appropriate distance for developing the next suburban area which could relieve the movement of people towards the CMA is as follows :

* Alexandria − CAiro = 120 km.
* Port Said − Cairo = 137 km
* Suez − Cairo = 85 km.

Finally, needless to say the MIM is suitable for analyzing and measuring the phenomenon of social interaction from the view point of urban spatial patterns. By applying the MIM , the weight and influence of the most important factors in the origin and destination areas can be identified, which could stem from the pressure of the people movements especially towards the metropolis.

Also, it is hoped that the discussion presented in this paper will provide a useful stimulus for further progress towards more satisfactory studies (i.e. the metropolis area of the developing countries) in the field of urban and regional context.

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