GEOGRAPHICAL ASSOCIATION of ZIMBABWE

PROCEEDINGS OF 1982/1983

Number 14 September, 1983

Distributed free to all members.
Price $6.00

Back issues of Proceedings are available on request from the Editor.

CONTENTS

Notes on Contributors:

Prof. G. Kay is Head of the Geography and Sociology Department at North Staffordshire Polytechnic, England.

Mr C.M. Rogerson is a Lecturer in Geography at the University of Witwatersrand, South Africa.

Miss S.D. Harvey is a Lecturer in Geography at the University of Zimbabwe.

Mr J. Beaumont is a Lecturer in Geography at Keele University, England.

Dr N.M.D. Mutizwa-Mangiza is a lecturer in the Regional and Urban Planning Centre, University of Zimbabwe.

Mr D. Mazambani is a Research Fellow at the University of Zimbabwe.

Mr J.R. Whitlow is a Lecturer in Geography at the University of Zimbabwe.

The authors alone are responsible for the opinions expressed in these articles. Articles intended for publication and all correspondence regarding Proceedings should be addressed to the Hon. Editor, c/o Department of Geography, University of Zimbabwe, P O Box MP 167, Mount Pleasant, Harare, Zimbabwe. (Tel. 303211-265).

A SIMULATION MODEL FOR RESIDENTIAL LOCATION

IN HARARE, ZIMBABWE

by

S D HARVEY and J R BEAUMONT

INTRODUCTION

The post-independent period in Zimbabwe has been characterised by a number of alterations to the previous organisation and structure of society. The spatial manifestation of these alterations is of particular interest to the geographer and provides many avenues for useful research which have much to contribute to the planning of the country's future. The development of a resident black population within those city suburbs formerly reserved exclusively for the white population is one example of these structural changes.

Prior to independence in Zimbabwe, the Land Tenure Act of 1969 divided the country into European, African and National Land. All urban areas fell within the European Land and thus blacks were not permitted to own or lease land within the cities where the interests of whites were paramount. Provision was made for black workers in the city in the form of domestic quarters and African Townships. The availability of such housing was however, conditional on employment in the city, and could not be purchased by these workers.

Thus the spatial arrangement of the city in Zimbabwe has been strongly influenced by enforced segregation of black and white residential areas during the colonial period. The repeal of the Land Tenure Act in 1979 removed the legislative restrictions with the result that noticeable changes to the patterns of residential occupation have occurred.

This study seeks to describe these changes within Harare, the capital city. A computer based simulation model is developed to aid this description and to enable predictions to be made concerning the future trends.

and destination respectively. (Fig 1). Interaction between the origins (i) and destinations (j) is then represented by the notation T_{ij}.

In relation to mass terms, it is necessary to include the number of households who leave the origin i which can be represented by O_i. In the case of residential interaction flows, some measure must also be made of the attraction of the possible destinations j. The most practical measure in Zimbabwe is the number of vacancies, V_j.

The final function to be incorporated is the distance between the origin and the destination which is measured in a straight line and is represented by d_{ij}. This can be described as having an inverse effect on flows because generally the propensity to move decreases with increasing distance from the origin. However, while the effect of distance is important close to the origin, it becomes less important as distance increases. Figure 2 illustrates this initial sharp decrease in the number of movers as distance from the origin increases and then the levelling off of the curve until distance no longer has any effect. This relationship can be represented by the notation $e^{-\beta d_{ij}}$ where e is the Naperian logarithm and β is a parameter derived from the data to approximate the best fit relationship (using a specified criterion such as the minimisation of the sum of least squares between differences in the observed and predicted flows). It is noted that an alternative distance function, such as the negative power, can also be used.

To summarise the rationale of the model; the volume of flows between i and j (T_{ij}) is a function of the number of households moving, the number of vacancies at the destination and the distance between the zones.

$$T_{ij} \propto O_i \tag{2}$$

$$T_{ij} \propto V_j \tag{3}$$

$$T_{ij} \propto e^{-\beta d_{ij}} \tag{4}$$

By combining these variables the following equation is derived.

$$T_{ij} = K\, O_i V_j\, e^{-\beta d_{ij}} \tag{5}$$

Where K is a proportionality constant.

If O_i is known then a limiting condition must be incorporated such that the total number of flows must not exceed the number of movers from the origin.

EMPIRICAL STUDY

The movement of black households into former white residential areas is being studied with data collected over the period 1978 to 1980. This data includes variables such as property size, house type, income group, family size and place of work. More importantly, however, it includes the volume of movement within the city by race and it is this information which is used to initiate the simulation of future movements.

A SIMULATION MODEL

Spatial interaction models are a relatively simple method of describing the volume and nature of flows between spatially separate locations. Whilst spatial interaction modelling has been applied widely in urban and regional planning (Wilson, 1974), and also in residential location models (Clark and Avery, 1978), it is necessary for the model to fit the problem rather than vice-versa. Consequently, in the context of Harare, some minor extensions are proposed in this paper.

The spatial interaction model is based on the gravity model which simply states that two places interact with each other in direct proportion to the product of their masses, and in inverse proportion to the distance between them.

$$\text{Interaction} = f\left(\frac{\text{mass x mass}}{\text{distance}}\right) \qquad (1)$$

where the two measures of mass refer to the conditions at the origin and destination respectively. In the present case, the interaction relates to the movements of households from one location to another. In order to formulate a mathematical model, it is necessary to consider the type of spatial representation, the variables of interest, and the parameters to be calibrated from empirical work. In this study, a discrete spatial representation or zoning system is applied. The study area must be divided into a number of zones because the use of individual addresses would be cumbersome and impractical. It is necessary to be aware that different zoning would produce a different calibrated value for the model's parameter even if the same data set is used. A direct effect, for instance, is zone size which changes intra- and inter-zonal flows by definition (Beaumont, 1982).

For simplicity, the zones are numbered sequentially and then for the purposes of the model, the subscripts i and j are used to denote the zones of origin

Fig.1

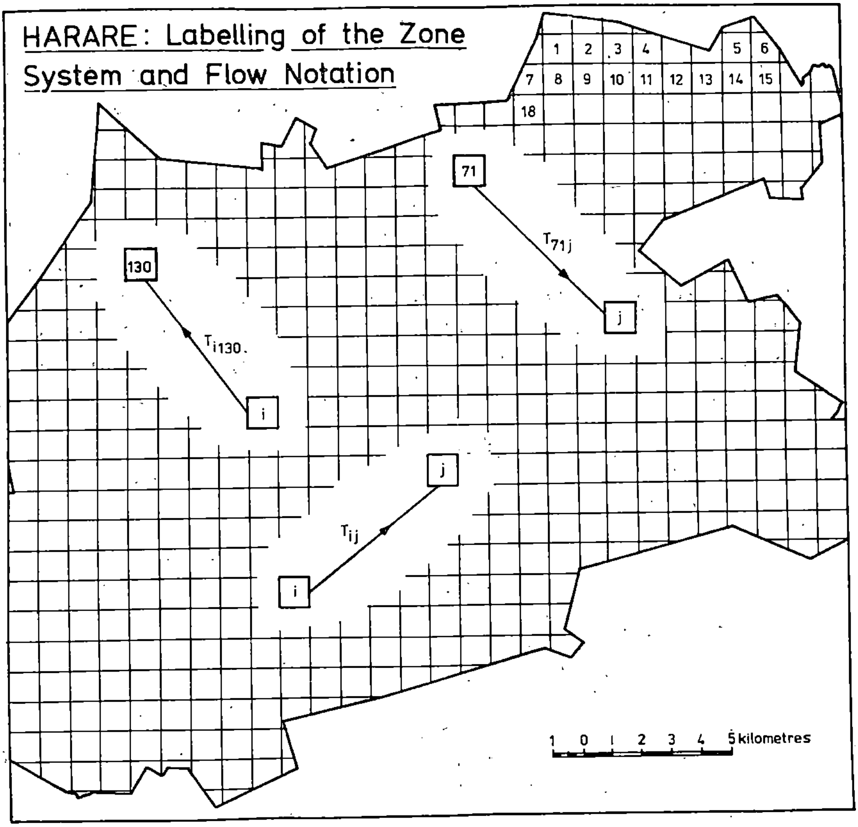
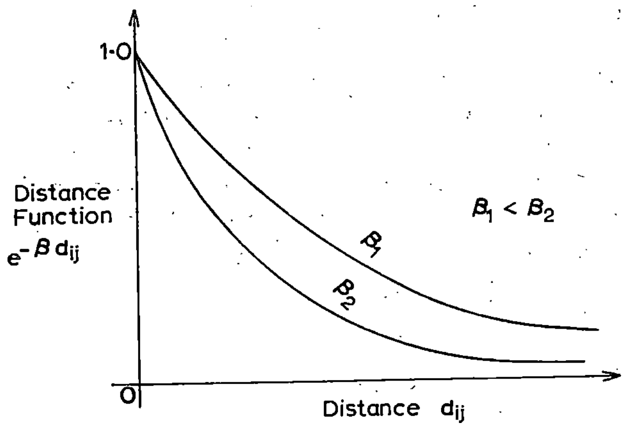


Fig.2: The Effect of Changing the Parameter of the Distance Function



$$\sum_{j=1}^{n} T_{ij} = O_i \qquad (6)$$

If V_j is known a similar condition must be incorporated whereby the total number of flows must not exceed the number of vacancies at the destination.

$$\sum_{j=1}^{n} T_{ij} = V_j \qquad (7)$$

If both these conditions apply, as they do in the case of Harare, then the model is said to be doubly constrained or production-attraction constrained model (Wilson, 1974), because both the number of movers and the number of vacancies are known. To satisfy both the above conditions, the proportionality constant, K, is replaced by two zone specific balancing terms, A_i and B_j.

$$T_{ij} = A_i B_j O_i V_j \, e^{-\beta d_{ij}} \qquad (8)$$

Where

$$A_i = 1 / \sum_j B_j V_j \, e^{-\beta d_{ij}} \qquad (9)$$

and

$$B_j = 1 / \sum_i A_i O_i \, e^{-\beta d_{ij}} \qquad (10)$$

A_i is the proportionality constant to ensure that the condition in equation (6) is satisfied while B_j is the proportionality constant to ensure that equation (7) is satisfied.

This general spatial interaction and activity model can now be used as a basis for the simulation of residential location in Harare. However, within the Zimbabwean context it is necessary to make certain modifications in order to incorporate the effects of the racial composition of the population. This can be achieved by disaggregating equation (8) so as to consider blacks and whites separately.

$$T_{ij} = A_i^k B_j^k O_i^k V_j \, e^{-\beta^k d_{ij}} \qquad (11)$$

Where

$$A_i^k = 1 \Big/ \sum_j B_j^k V_j \, e^{-\beta^k d_{ij}} \tag{12}$$

and

$$B_j^k = 1 \Big/ \sum_i A_i^k O_i^k \, e^{-\beta^k d_{ij}} \tag{13}$$

Where superscript k = b or w to represent functions relating to black or white households respectively.

By definition

$$\sum_i T_{ij}^b + \sum_j T_{ij}^w = V_j \tag{14}$$

It should be noted that two of the variables in equation (11) are not racially determined. Firstly: physical distance while unaffected by race, is influenced by the parameter β which measures the effect of distance and is thus race specific. Secondly: vacancies are clearly neither black nor white, but the type of households attracted to a particular vacancy will be closely related to the racial composition of the destination zone at the time of the move. The individual is more likely to move if a large proportion of the population in the destination zone belong to his racial group. This phenomenon can be expressed by the following equation.

$$V_j = \left(\frac{P_j^b}{P_j^b + P_j^w} \right) V_j + \left(\frac{P_j^w}{P_j^b + P_j^w} \right) V_j \tag{15}$$

Where V_j = the total number of vacancies in zone j

k = black or white

P_j^w = the total number of white households in zone j

P_j^b = the total number of black households in zone j

Equation (11) can now be adjusted to incorporate the relationship given in (15).

$$T_{ij}^{k} = A_i^{k} B_j^{k} O_i^{k} \left[\left(\frac{P_j^{k}}{P_j^{b} + P_j^{w}} \right) V_j \right] e^{-\beta^{k} d_{ij}} \qquad (16)$$

Where

$$A_i^{k} = 1 \Big/ \sum_j B_j^{k} \left[\left(\frac{P_j^{k}}{P_j^{b} + P_j^{w}} \right) V_j \right] e^{-\beta^{k} d_{ij}} \qquad (17)$$

and

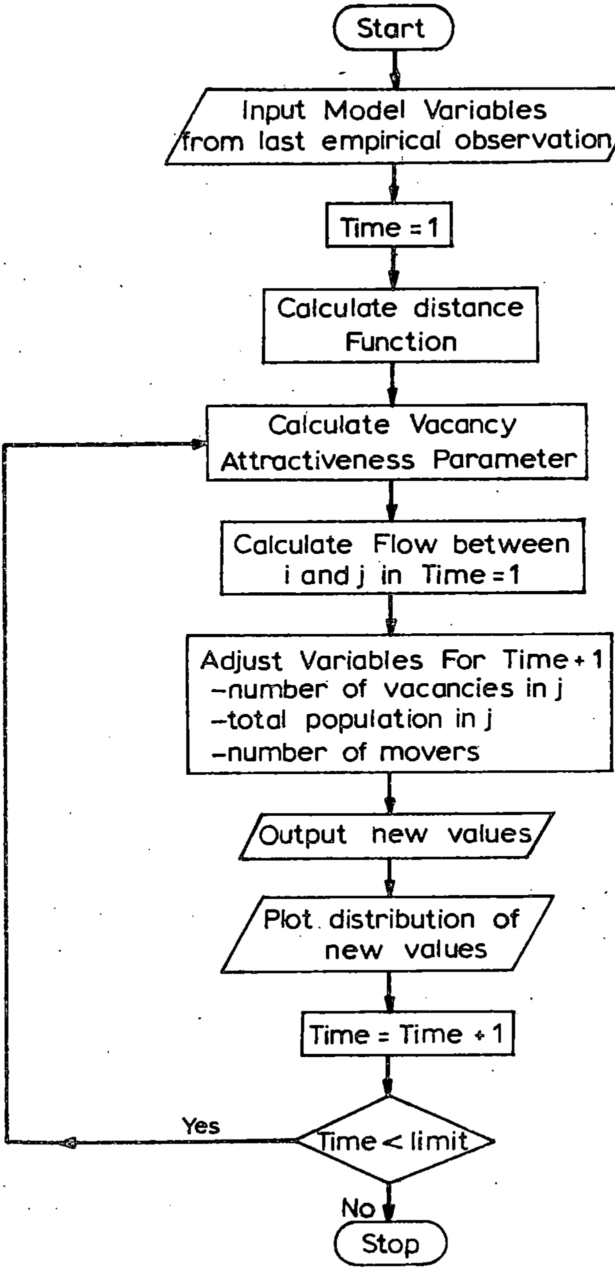
$$B_j^{k} = 1 \Big/ \sum_i A_i^{k} O_i^{k} e^{-\beta^{k} d_{ij}} \qquad (18)$$

Although the weighting thus introduced into the model is still very simple, a more realistic simulation related to the racial composition of the population can be obtained with equation (16) than would be possible with equation (11).

Quite obviously this sort of simulation would be undertaken on a computer due to the large number of zones and the many repetitive computations involved. The flow chart for such a computer program is given in Figure 3. The values for β^{w} and β^{b} are calculated first by inserting calibrated values obtained from the empirical observations. The base line for the simulation is taken as the last period of empirical observations. The first run calculates the flows between all zones based on the number of vacancies and movers in the last time period. The values obtained for the flows are then used to adjust the variables for the next time period.

The number of vacancies is obtained from the following equation.

Fig. 3: *Flow Chart of the Simulation Model*



$$V_{j(t+1)} = V_{jt} - \sum_i T_{ij(t+1)}{}^b - \sum_i T_{ij(t+1)}{}^w + \sum_i T_{ji(t+1)}{}^b + \sum_i T_{ji(t+1)}{}^w \tag{19}$$

Where $V_{j(t+1)}$ = vacancies in zone j in the next time period

$T_{ij(t+1)}{}^k$ = flow of black or white households between i and j in the next time period

$T_{ji(t+1)}{}^k$ = flow of black or white households from zone j to zone i in the next time period

V_{jt} = vacancies in zone j in the previous time period.

Simply stated the vacancies for the next time period are obtained by subtracting the flows of black and white households into the zone from the previous number of vacancies and then adding the flow of black and white households out of the zone.

The changes to the total number of black or white households in each zone is represented by the following equation.

$$P_{j(t+1)}{}^k = P_{jt}{}^k + \sum_i T_{ij(t+1)}{}^k - \sum_i T_{ji(t+1)}{}^k \tag{20}$$

Where k = black or white

$P_{j(t+1)}{}^k$ = total number of black or white households in the next time period

$P_{jt}{}^k$ = total number of black or white households in zone j in the previous time period.

Thus the new population of the zone is found by adding the inward flows to the previous population total and then subtracting the outward flows.

The number of movers from each zone is the final variable to be adjusted. This figure is a function of the total population in the zone, but the exact proportion thereof is calibrated from the empirical data and is represented by the parameter ψ . This parameter is not fixed, but varies for each zone and is also race specific.

$$O_{j(t+1)}^{k} = \psi_i^{k} P_{j(t+1)}^{k} \qquad (21)$$

Where k = black or white

$O_{j(t+1)}^{k}$ = number of black or white movers from zone j in the time period

ψ_i^{k} = empirically derived parameter to indicate the proportion of the total population in any zone likely to move.

These adjusted values can now be used in a re-run of the model in order to simulate the flows for a specified number of time periods to give an indication of the future trends to be expected in residential location patterns in the city.

CONCLUSION

One of the fundamental characteristics of the simulation model outlined above is that it is operational. It therefore permits an investigation of a significant feature of change in Zimbabwe's capital city. It allows a relatively simple prediction to be made concerning future trends in residential occupation. The separation of functions relating to blacks and whites is very necessary because of different responses made by the two major racial groups to the present situation. The race specific attractiveness parameter related to vacancies is a further modification of the general model to suit local circumstances without introducing undue complexity.

Further factors such as mortgage availability, property size, property values and accessibility should be incorporated as weightings in the model at both the origins and the destinations, but this data will clearly be more difficult to obtain than that for the more general model. Of course, the use of the computer lessens this problem of processing, but does not avoid the problem of programming increased complexity.

It seems more urgent in the country's present circumstances to predict the future trends in general terms as soon as possible, than to produce a very complex and refined model. The more complex simulations can be performed at a later date when a detailed scenario is required.

REFERENCES

ABLER, R., ADAMS, J.S. and GOULD, P. (1972)
'Spatial Organisation: The Geographer's View of the World', Prentice Hall, London.

AYENI, 'BOLA. (1979)
Concepts and Techniques in Urban Analysis', Croom Helm, London.

Land Tenure Act 1969, Rhodesian Government.

REILLY, W.J. (1931)
The Law of Retail Gravitation, Pillsbury Publishers, Inc, New York.

WILSON, A.G. (1974)
Urban and Regional Models in Geography and Planning, Wiley and Sons, London.