WORKING PAPER 534

POPULATION PROJECTIONS FOR DEVELOPMENT PLANNING

PHILIP REES

School of Geography
University of Leeds
LEEDS LS2 9JT

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ABSTRACT

The paper considers the ingredients needed to carry out population projections in the context of development planning. Not only must the demographic model for projection be appropriately specified but it must be connected to the variables under the control of or of key interest to the development plan via the design of the migration sub-model.

POPULATION PROJECTIONS FOR DEVELOPMENT PLANNING

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Philip H. Rees
School of Geography, University of Leeds, Leeds LS2 9JT, United Kingdom

"O that a man might know
The end of this day's business ere it come!"
William Shakespeare (1599-1600) *Julius Caesar*. 5.1.122.

"Truth is the main thing. Lenin said:
More light! Let the Party know everything."
Mikhail Gorbachev (1987) *Perestroika*. English Translation, William Collins, Fontana Paperbacks, 1988.

1. *POPULATION: CAUSE OR CONSEQUENCE?*

Humankind has been concerned with the planning for the future ever since the Neolithic Revolution gave us agriculture and some measure of control over future food supplies. Where we have differed and continue to differ is over who should make the plans and for how long a period. The Scots economist Adam Smith proposed that planning be left to the self interest of the indivdual; the German economist Karl Marx argued that it should the business of the collective-interest of the people. The dichotomy of views also makes itself evident in the preparation of population projections in the context of development planning. Should the projections be regarded as simply the aggregate result of a myriad individual decisions or the planned results of deliberate policies under the direction of planning organizations?

Development planning can broadly be defined as the specification of future actions to improve the economic and social well being of particular, spatially defined communities. It usually involves investment in one or more of the following: infrastructure, production, consumption and social facilities. Sometimes the facilities are new; sometimes they replace what was there before. The scale of development planning can range from a small area in a city (such as the "ex-Docklands" in London) to that of a huge nation (such as the Soviet Union).

How far does "population" fit in with development planning? People may be viewed as the stimulation for development planning or they may be regarded as the result of development planning. Most often both views must be catered for simultaneously. The projected future numbers of people may be looked upon as variables entirely exogeneous to development planning (i.e. largely unaffected by it) or as the intimate product of developmental activities.

For example, the development of state pension plans normally regards the national population forecast (the projection among many alternatives considered most likely) as being unaffected by the policy changes being debated such as raising the age of pension entitlement, or making the pension ages of men and women the same. This is an instance of the view that the future population is an exogeneous variable. However, were there to be a drastic cut in pension benefits, this would feed back through higher mortality (because mortality is intimately related to povrty/affluence) to a lower forecast of pensioner numbers. Governments which depend on the consent of a growing pensioner population are likely to avoid such policy scenarios.

On the other hand, the development of a new production complex, such as the new financial centre at Canary Wharf in London's ex-Docklands or such as the Kuzbass mining-industrial complex in the Soviet Union, will involve the creation of new jobs which must, of necessity, be filled by either in-commuting workers (the Canary Wharf development) or by in-migrating workers (the Kuzbass example) or by a mixture of the two. The future population of the area will be the consequence of the development plan, whether this is prepared by a private organization as at Canary Wharf or by a state organization as in the Kuzbass.

These observations are not, of course, new. Regional science has long been concerned with the interactions between jobs and homes and with the consequences for the regional economy of new inputs of capital and jobs. However, much of the work has tended to be fixed at one point or interval in time (e.g. the regional input-output model, the Lowry urban development model, the traffic planning model) and viewed the population as undifferentiated by the demographic attributes of age, sex, marital status and so on. Demographic science has long been concerned with the evolution over time of populations differentiated by such characteristics but has largely ignored the influence of non-demographic developments on the time path of population.

It is very difficult to construct a general model of both population and economic development that gives due weight and disaggregation to both sectors, and is at the same time usable by planners in operational situations. The temptation is avoided in this paper of making yet another try at building a general demo-economic model. Rather a careful review is carried out of the choices that must be made in constructing a population projection in a development context that recognizes the importance of links between demographic and socioeconomic sectors.

2. *CHOICES IN POPULATION PROJECTION*

The planner who wishes to integrate population projections into the development plan faces a number of difficult choices concerning the system to be modelled and the methods to be used, particularly if there is a need to treat population as an endogeneous variable. These choices concern (i) the definition of the geographic units, (ii) the definition of the population units, (iii) the attributes of the population units, (iv) the components of population change to be incorporated, (v) the accounting concept to be adopted, (vi) the age-time plane to be used, (vii) the estimation methods needed, (viii) the methods of forecasting component rates, (ix) the role of exogeneous variables and (x) the type of software to be used to implement the projection model. Each choice is considered in turn.

2.1 *The geographic units*

2.1.1 General argument

Development planning is normally concerned with a single subnational unit or a regional set of such units. However, the units of interest should not be studied in isolation from the rest of the nation nor from the rest of the world. Migrants arrive from these areas in the units of interest, and residents of the areas depart for other parts of the nation or the world. Migration between units of interest should also be included. Migration is the process by which development trends and projects are translated into population change. The response of natural increase to development is much slower.

2.1.2 Illustration

For example, to carry out population projections for Greater London (as in Rees 1988) it was essential to include the Rest of the United Kingdom as an equivalent region in the system of interest, and to incorporate migration flows to and from the Rest of the World. Table 1 shows how internal and external flows have counterbalanced each other: internal net losses are compensated for by external net gains. However, this has varied by broad age grouping: all ages bar the 15-19 to 20-24 period-cohort lose through internal migration, whereas only the elderly ages show net external losses.

2.2 *The population units*

2.2.1 General argument

Most demographic projection methods employ the individual as the fundamental unit which is subjected to vital migrational processes, but households (groups of individuals living together) form the key units of labour production and consumption in economic processes. However, household dynamics are virtually impossible to handle except as the outcome of individual transitions, unless special surveys of household transitions have been carried out. Projected individual numbers can be converted into household numbers and sizes by the cross-sectional application of headship rates as in most macro-demographic projections or via the simultaneous list processing of both individuals and households in micro-demographic models (Rees 1989). In both cases care must be taken to project institutional populations and the homeless living outside the normal private household environment.

2.2.2 Illustration

Most population projection models adopt groups of individuals (classified by age and gender) as the units of analysis to which demographic rates are applied. The importance of tracking households as well is illustrated in the calculations of Table 2 which show that the number of households living in an area can increase at the same time its population is decreasing.

TABLE 1. *Migration flows to and from Greater London, 1981-86*

Migration flow	Period-cohort age groups					Totals
	15-19 to 20-24	20-24 to 25-29	B-14 & 25-54 to 0-19 29-59	55-69 to 60-74	70+ to 75+	
Internal flows						
In-migration	144.8	168.6	427.5	33.7	12.5	787.2
Out-migration	128.3	175.3	563.5	86.9	23.0	977.1
Net migration	16.5	-6.7	-136.0	-53.2	-10.5	-189.9
External flows						
Immigration	59.6	70.2	177.0	6.1	1.6	314.9
Emigration	28.4	49.5	144.9	7.6	2.2	232.6
Net migration	31.2	20.7	32.4	-1.5	-0.6	82.3
Total flows						
In-flows	204.4	238.8	604.8	39.8	14.1	1102.1
Out-flows	156.7	224.8	708.4	94.5	25.2	1209.7
Net flows	47.7	14.0	-103.6	-64.7	-11.1	-107.6

Source: projections reported in Rees (1988).

TABLE 2. *Illustrative estimations of the number of households in Greater London, 1961-91*

Year	Greater London population (thousands)	Great Britain population per household	Estimated households (thousands)
1961	7,977	3.2	2,493
1971	7,529	2.9	2,596
1981	6,806	2.8	2,431
1991	6,790	2.7	2,515

Sources: 1. GL population 1961-81: Champion and Congdon (1988), Table 1. 1991 - projections reported in Rees (1988).
2. GB population per household: OPCS and CSO (1986), Table 1. 1991 figure - extrapolated.

2.3 *The attributes of the population units*

2.3.1 General argument

At a minimum, the population of each subnational unit of interest must be classified by age and gender because the forces of all demographic processes vary dramatically with age. It is also illuminating to introduce a socioeconomic classification of the population as well, for all sorts of reasons, but this is rarely done because of the scarcity of transition data (e.g. on the rate of movement between occupations). Household units should be classified by size and adult/child composition because of the importance of linking these attributes to the available housing stock to identify mismatches.

2.3.2 A problem

Can we go on adding as many attributes to the population as are thought of use in development planning? The answer is certainly no, if we stick with the multistate macro-demographic model used in most population projection work. The number of transition variables that have to be estimated becomes impossibly large to handle. It is argued in Duley, Rees and Clarke (1988) and Rees (1989, section 7) that the "dimensionality" problem can only be solved by adopting a compromise model somewhere between one that uses the full transition probabilities

$$Pr(a_2,b_2,c_2,\ldots,z_2|a_1,b_1,c_1,\ldots,z_1)$$

where Pr stands for probability, a to z are desirable population attributes and the subscripts 1 and 2 refer to successive points in time and the model that simply assumes independence of the desired attributes

$$Pr(a_2|a_1)\ Pr(b_2|b_1)\ Pr(c_2|c_1)\ \ldots\ Pr(z_2|z_1)$$

The compromise model would have to contain conditional probabilities of the form

$$Pr(a_2|a_1,b_1,c_1)\ Pr(b_2|b_1,c_1)\ \ldots\ Pr(z_2|y_1,z_1).$$

Such a strategy can be implemented using either a macro-model (e.g. Greater London's population projection model) or a micro-model that employs Monte Carlo sampling methods.

2.4 *The components of population change*

All subnational population projections should incorporate mortality, fertility and migration components. Choices, however, have to be made about how to handle the migration component. The net migration approach must be rejected because net migrants cannot be directly connected to job gains or losses, or housing additions or demolitions whereas gross migrants can. It is also important to separate intra-national from inter-national migrants: the latter are subject to close state control, while the former are not in most countries (although both the Soviet Union's internal passport and residence permit system and Britain's judicial orders excluding suspected IRA terrorists from the mainland are exceptions).

2.5 *The accounting concept*

2.5.1 Theory

All projection models are founded on one of two conceptualizations of population change. These are the movement and the transition concepts, respectively. In the *movement* case, knowledge of inter-unit border crossings only is available and the migration flows cannot be linked directly to location at the start of the benchmark time interval nor to the location at the end. In the *transition* case, the planner only has knowledge of the transfers between initial and final locations in the benchmark period: intervening comings and goings are not recorded. These two concepts lead to different specifications of the projection model; both versions are consistent and correct, yielding the same projections when fed equivalent assumptions. Migration data from population registers are normally supplied in the form of counts of moves between subnational units. Migration data from population censuses are usually tabulated as counts of migrants (transitions) between subnational units. The key point is that the projection model adopted should match the concept used in the source of the migration data used.

2.5.2 Practice

Careful comparison of migration data from Census and Register sources has revealed that the conceptual difference between the two methods of measuring migration is not the only source of discrepancy between the two sources. Table 3 reveals that undercounting in the Census and the Register, and different treatment of particular subpopulations - students and the Armed Forces - result in differences as big as those due to concept differences. Great care must be taken in handling these definitional problems in population projection, as in any other piece of demographic analysis.

2.6 *The age-time plan*

Population projection models use the period-cohort age-time plan. Many of the demographic components input to the projection in the benchmark period are measured using the period-age time plan. Either the data should be converted from the period-age to the period-cohort plan prior to input to the projection model (the author's preference) or the projection model should incorporate such a conversion (the conventional approach but one that often leads to sloppy errors).

2.7 *The estimation methods*

2.7.1 General principles

There is frequently a mismatch between the detail of data required in the projection model and the data available from published sources. This is particularly true of the age detail of component inputs. The United Nation's *Manual X on Indirect techniques for Demographic Estimation* provides extensive guidance on how to treat fertility and mortality components. Chapter IV of the *Manual on Subnational Population Projections* (in preparation) outlines the techniques for making the necessary estimates from less than ideal migration data. In both fields increasing use is being made of models of the age profiles of component

TABLE 3. *An estimated decomposition of 1980-81 migration flows between FPC areas from the NHSCR and the Census*

NHSCR component	NHSCR migration flows	Census migration flows	Census component
First moves of non-student survivors who are 1 year of age and whose sex and age are stated	1,301.3	1,131.1	Civilian, non-institutional surviving migrants aged 1 or more
		172.0	Migrants missed in Census
Common component	1,301.3	1,303.1	
Migrants who die	4.7	-	
Infant migrants	17.6	-	
	-	78.6	Armed forces' migrants
Moves by students	100.1	-	
		7.4	Prisoners and psychiatric patients
Sampling error	+ or -7.3	-	
Moves with sex n.s.	25.5	-	
Moves with age n.s.	3.3	-	
Second and further moves	101.7	-	
Total re-registrations	1,554.2	1,216.6	Total (less missed)

Source: compiled from a variety of estimates in Devis and Mills (1986).

rates, particularly when single year age detail is required. Also important in making estimates of inter-unit migration are spatial interaction models (consistent re-formulations of Newton's gravity law in a social context).

Age profile models and spatial profile models can be used as well inside population projection models as a means of reducing the large number of variables involved in multi-unit models.

2.7.2 Illustration: a unified family of age profile models

Rogers (1986) and Rogers and Gard (1989) have recently generalized earlier work on designing age profile models to describe the variation with age of component demographic rates. Table 4 and Figure 1 gather together the different specifications that have been proposed based on single or double exponential functions and present them as one family (see Rees 1989 for a detailed discussion).

How have such age profile models been used in a projection context? The model parameters have been calibrated on observed rate schedules standardized to particular summary rate norms. To obtain the estimated rates the model rates are multiplied by the ration of the summary rate norm to the observed summary rate. So, for example, the model migration schedule parameters are for a schedule whose rates sum to a gross migraproduction rate (GMR) of unity. If the particular regional population being projected has a total out-migration GMR of 0.25 and we predict a 10% increase in this in the next time interval, the projected migration rates are estimated by multiplying the model migration rate of 0.4, say, by these factors:

projected migration rate = 0.4 x 0.25 x 110/100

Changes in the "rules" governing migration can be catered for by altering specific parameters: mu_2, for example, would be reduced if a decision were taken to reduce the length of degree courses in higher education.

2.8 *Methods of forecasting component rates*

Population projection requires forecasts of the component inputs. Experience has shown that statistical time series modelling of input rates is rarely effective, except perhaps for mortality. Even for that component new surprises such as the HIV/AIDS pandemic can arise which require very different projection techniques.

Fertility rates have proved forecastable in situations where populations are undergoing the demographic transition led by family planning programmes. But in both pre- and post-transition situations fertility rates have proved difficult to predict. Underlying generational completed family sizes appear to change rather slowly but period influences (economic conditions in particular) and variations in timing can lead to pronounced swings in period fertility rates in post-transition societies.

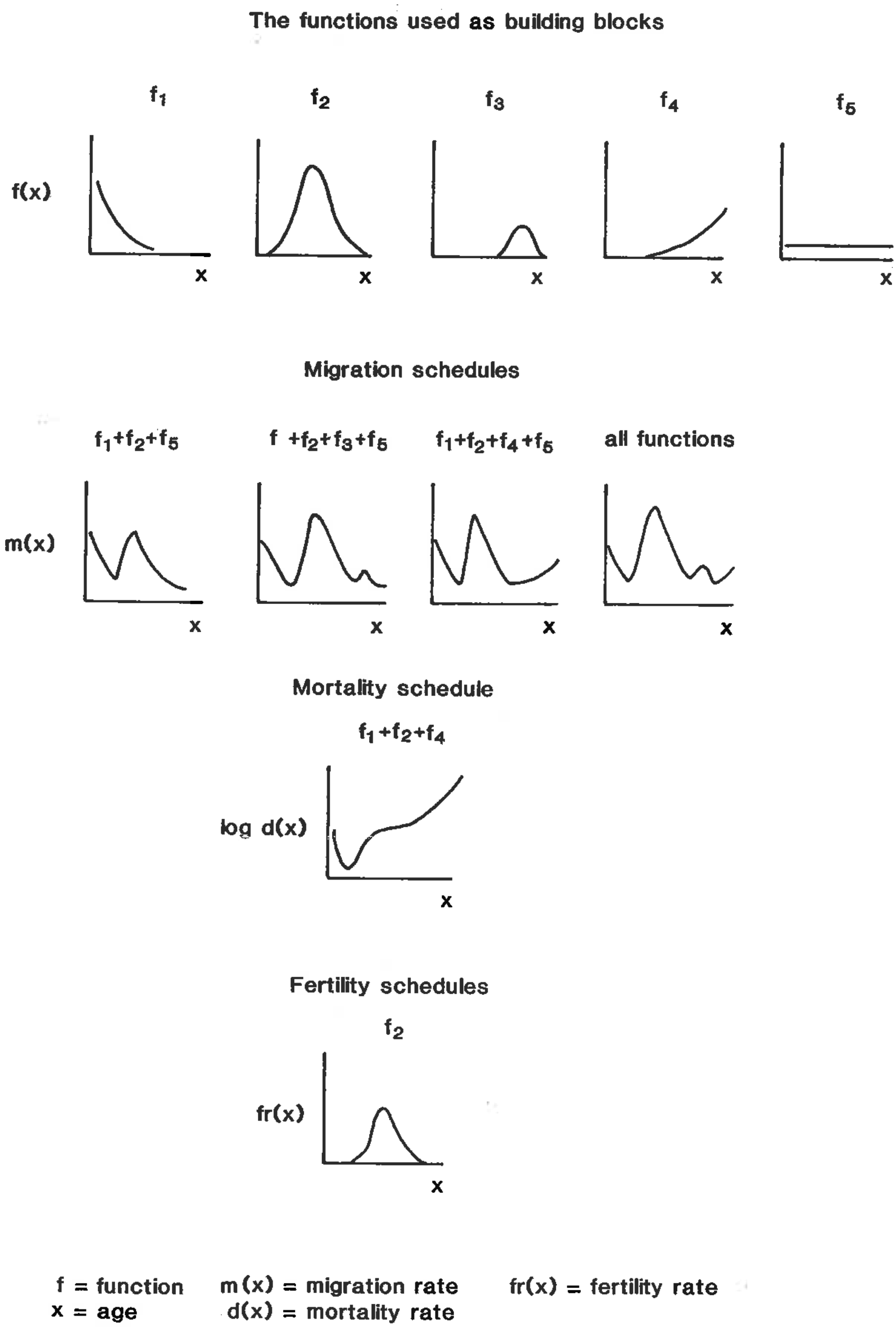
Little experience has been gained with forecasting internal or external migration rates. In the past, current rates have been assumed to continue indefinitely. Yet swings in migration rates have been just as fierce as

TABLE 4. *A family of multiexponential models of the variation of component rates with age*

Component / Age range	Function of age
Migration	$m(x) = f_1(x) + f_2(x) + f_3(x) + f_4(x) + f_5(x)$
Early-life	$f_1(x) = a_1 \exp(-alpha_1 x)$
Middle-life	$f_2(x) = a_2 \exp(-alpha_2(x-mu_2)-\exp(-lambda_2(x-mu_2)))$
Retirement	$f_3(x) = a_3 \exp(-alpha_3(x-mu_3)-\exp(-lambda_3(x-mu_3)))$
Post-retirement	$f_4(x) = a_4 \exp(alpha_4 x)$
Constant	$f_5(x) = c$
Mortality	$d(x) = f_1(x) + f_2(x) + f_4(x)$
Infant	$f_0(x) = a_0 = d(0)$ observed for age 0 only
Early-life	$f_1(x) = a_1 \exp(-alpha_1 x)$
Middle-life	$f_2(x) = a_2 \exp(-alpha_2(x-mu_2)-\exp(-lambda_2(x-mu_2)))$
Late-life	$f_4(x) = a_4 \exp(alpha_4 x)$
Fertility	$f(x) = f_2(x)$
Middle-life	$f_2(x) = a_2 \exp(-alpha_2(x-mu_2)-\exp(-lambda_2(x-mu_2)))$

Source: adapted from Rogers (1986) and Rogers and Gard (1989).
Notes: the fertility model applies also to marriage and divorce.

FIGURE 1. *A schema for modelling component rate schedules by age*



in fertility in post-war societies.

Recent population projection software attempts to reduce the labour involved in projecting component rates by treating these as a product of a level element which is trended or guestimated, and a distribution across the age or space spectrum which is assumed fixed (as in section 2.7). This may be convenient but doesn't reflect what we know about the historical evolution of any component, i.e. that shifts in the age distribution of demographic transitions have occurred and continue to occur.

Policy clearly impacts particular components directly and assumptions about such matters as abortion laws, health care, and entry and exit visas need to be considered explicitly when a projection is prepared.

2.9 *The role of exogeneous variables*

The part played by non-demographic factors must be carefully considered, as was argued in section 1 of the paper, over and above the type of policy dependency mentioned above. Particular attention should be devoted to migration in this respect. Migration is in part a response to the differences in opportunities between origin areas and destinations. Simplfying somewhat we can say that migrants move either to take up housing opportunities alone or to capitalize on life career opportunities which are combined with residential opportunities.

Housing motivated migration tends to be local or short distance in scale. Migration related to life career opportunities involves longer distance displacement. The opportunities taken up depend on life career position of the individuals which is closely related to their age (the demand for opportunities) and on the availability of job vacancies, places in higher educational establishments or on the needs of the military (the supply of opportunities). After retirement from work, migrants are freer to choose opportunities offering a better environment, proximity to relatives or health care.

It follows from this thumbnail sketch of the factors influencing developed country migration that the projection of subnational populations should be linked via a set of migration sub-models applicable to (i) the principal ages of entry to higher education, military and penal institutions, (ii) the principal ages of exit from higher education and military institutions, (iii) the principal ages of working and family raising, (iv) the ages around retirement and (v) the elderly ages. In the United kingdom research (Boden 1989) suggests that the following age spans (built up from quinquennial age groups) are applicable and give rise to distinct patterns of inter-region migration: (i) 15-19, (ii) 20-24, (iii) 25-54, together with chidren aged 0-14, (iv) 55-69 and (v) 70+. The exogeneous variables that would enter into the migration sub-models would vary across these five groups: (i) places in educational and military establishments; (ii) job vacancies and turnovers suitable for young labour; job vacancies and turnover for estblished labour; (iv) amenity indicators (e.g. climate, resort status, place of birth) and (v) health facilities and links to relatives. These exogeneous variables apply principally to non-local migration. If the system of interest spans one labour/housing market, then housing opportunities would be the principal exogeneous variables that would need inclusion in the migration sub-models for intra-system migration, although the longer distance factors would influence migration between the system of interest and the rest of the nation.

This framework for linking demographic changes to socioeconomic changes needs additional ingredients involving opportunity-migrant multipliers and forecasts of opportunities. Critical multipliers must be incorporated in the projection that relate the number of opportunities taken up to the number of migrants moving per opportunity. This will vary with life career stage. For a more by an 18 year old to take up a University place, the multiplier will be close to 1, as 18 year olds have few dependants. For the move of a 40 year old middle manager to a new post, the multiplier will be higher (over 2) reflecting the number of dependants of the principal migrant. If the migration sub-model is a global one covering migration by all persons, then the multiplier can be established empirically by analysis of a historical data set. If the migration sub-model is merely a means of assessing the impact of a particular subnational project, then the multipliers must be introduced exogeneously.

Another kind of multiplier that is needed for housing-related migration is the average size of the migrant household. This will depend on the characteristics of the dwelling and the life career stage of the migration.

This linkage of demographic variables to socioeconomic changes presupposes that it is possible to project the latter. In a tightly controlled system (such as British Universities in the 1980s to 1988) it may be possible to make accurate forecasts of opportunities based on agreed plans. But this is rather rare, even in economies with centralized planning. So the nature of the population projections produced will change from being "most likely guesses" to being "what happens if so and so happens". That is, they become strictly conditional forecasts.

2.10 *The type of software*

To carry out the extensive numerical computations involved in population projection and to display selectively and intelligently the extremely voluminous results produced requires use of computers and the development of suitable software. Two general varieties of software can be used in the projection task: packaged software or specific software.

Package software is a program or suite of programs produced by a software house or research organization which has been well documented as to functionality, inputs required and outputs produced, and which is offered for sale to other organizations. The most successful examples of such software are the major statistical packages (such as SPSS, SAS or Minitab) or the database packages (such as Database III or Ingres).

Specific software, on the other hand, is written either within the research or planning body or is commissioned from a software house or consultancy, to meet the particular needs of the planning agency. It requires the employment of skilled professionals within the agency or an expensive contract with an outside firm. Hence the popularity of packaged software in which the costs are spread over very many customers.

What choice of software should an organization wishing to carry out population projections for development planning make? It is very clear that currently there exists no suitable general package that offers any more than a single route through the list of choices in population projection discussed in this section of the paper. That route is unlikely to be the one that fits the aims of the development plan or matches the type of data available. The available programs fail, for example, to provide a choice between projection methods for handling movement and projection methods for handling transition data. No available program incorporates in a general way the ability to link in submodels for projecting key components. No available program incorporates general methods for using age profile models across all components. All these techniques are offered in separate, one-off programs, and it is up to the user to link them together.

So, the development planner probably needs to commission bespoke, tailored software (either in-house or from an outside organization) that will fit the needs of the project. Off the peg, mass produced software just does not fit the job.

3. *CONCLUSIONS*

This paper has speculated about the ingredients that are needed to carry out population projections in the context of development planning. The considerations that need to be borne in mind have been reviewed. Fuller details of many of the issues raised here are covered in United Nations (1989). Successful resolution of these issues needs something more than further academic research and further planning practice: it need well resourced, collaborative projects that will fuse together the analytical skills of the former with the practical experience of the latter.

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