Integrated local demographic forecasts constrained by the supply of housing or jobs: practice in the UK

Ludi Simpson
Cathie Marsh Institute for Social Research, University of Manchester.
ludi.simpson@manchester.ac.uk

Abstract. Demographic forecasting models that integrate population, housing and jobs aim to help planning in two ways. First, the models describe the future needs of the population, with a range of scenarios reflecting the continuation of recent experience and uncertainty about which assumptions best reflect that experience. These models apply the standard mathematics of demographic cohorts and their change through births, deaths and migration, and of derived forecasts which apply age-sex specific household headship rates and economic activity rates to the future population. Second, the models are extended to calculate the impact of planned developments that will change the population by attracting or deterring people at a different rate from recent experience. This paper focuses on the need for both types of forecast scenario in the context of local development plans which are required throughout the UK. It provides the mathematics to calculate migration in a forecast which has imposed a constraint or target future number of jobs or housing units. These balancing models, are known as dwelling-led or housing-led forecasts in the UK, and are commonly used in the planning industry though seldom documented. The paper includes an example application and discusses further developments.

Key words

Planning, forecasts, population, housing, workforce, targets, constraints, POPGROUP

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Introduction

This paper describes the use of models that integrate demographic forecasts of local population, household and workforce. The models have become standard in the UK, where planning law requires each elected authority to develop a local development plan based on a review of need including demographic forecasts. The plans attempt to foresee the demand for housing and employment embodied in the current population's growth and ageing, and the impact on that population of alternative plans for supply of housing or employment.

The paper begins by reviewing the contexts of planning and data availability that have determined the particular approach described in the rest of the paper. This approach is embodied in the software POPGROUP, a planning industry standard in the UK, but the mathematics can be applied more widely. Standard cohort component and derived forecasting methods form the framework for the demographic modelling. The technical core of the paper is the derivation of future migration from the imbalance between the supply and demand of either housing or jobs. These are specific instances of a more general methdology to implement constraints within demographic forecasts.

Scenarios have two distinct roles in planning: they exploring factors either outside or within the control of planners. The paper's approach is applied in the example of East Cheshire district's Local Plan. A discussion of future developments and research conclude the paper.

Contexts of planning regulations and data availability

The demographic models used in the UK are standard ones advised by the United Nations and used by the official statistics agencies of most countries for national planning. A projection of the future population is made by applying assumptions about fertility, mortality and migration to each age-sex cohort. To this future population are applied household headship rates and economic activity rates to derive household and labour force projections. In the UK, these same methods are applied at the sub-national scale for most local planning. These are not the only methods available for sub-national demographic projections, and practice can be varied even within one country (see for example Smith, Tayman and Swanson 2013 for the case of the USA, and Wilson and Rees 2005 for a general review).

The sub-national forecasting practice described here has been shaped on the one hand by government planning regulations which insist that the designation of land for development be based on forecast population and households, and on the other hand by data availability including population estimates with age-sex composition for all sub-national areas. While these two contexts have favoured the demographic models described, other strategies exist that may be appropriate at different geographical scales. There is a great deal of room for evaluation of different methods.

The planning context

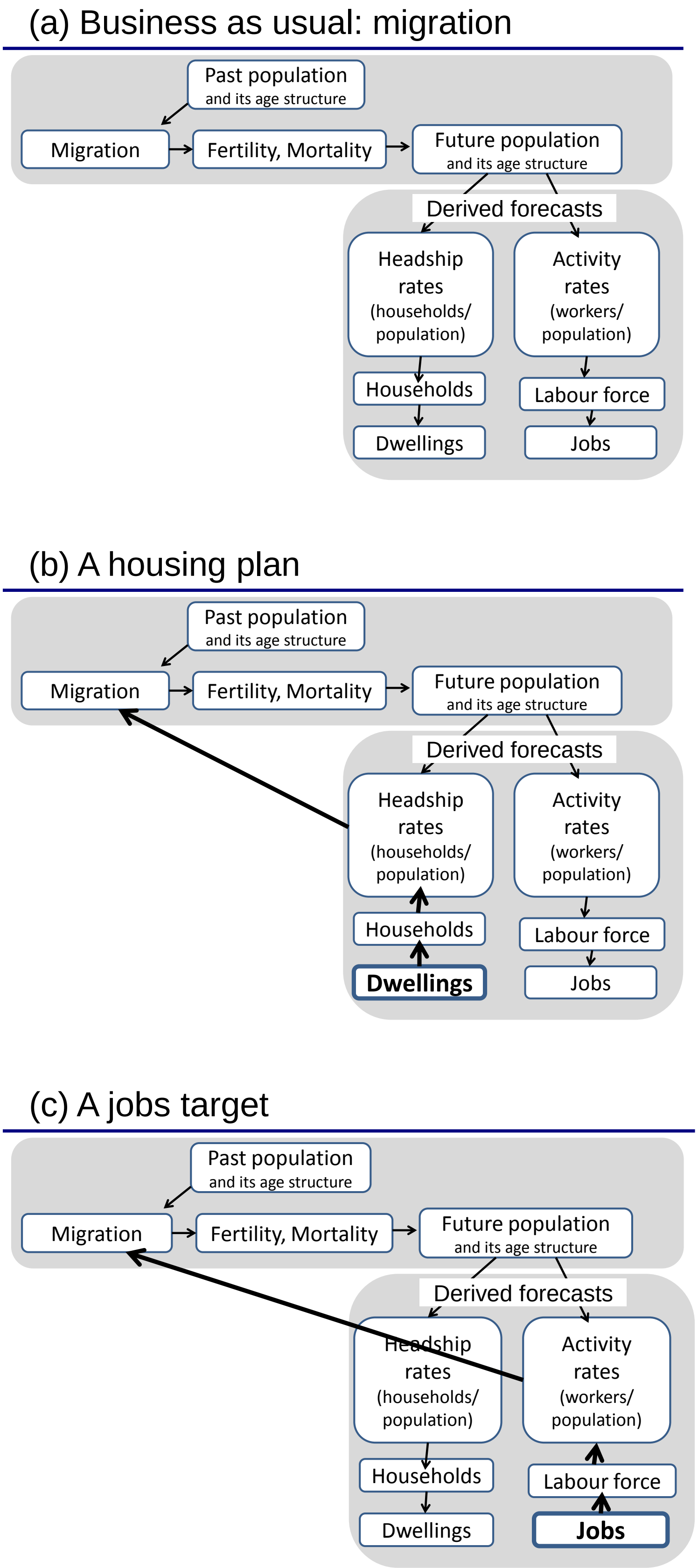
Any country that co-ordinates land use according to social needs must assess the composition of the future population in sub-national areas. Planning is about the future. The future population and its composition represent the social demand for housing and for jobs. Planning regulations in Britain are relatively strongly led by national government (Oxley et al. 2009; Monks et al. 2013; Cullingworth et al. 2015). A forecast of need for housing is required by government guidance in England (DCLG 2015a), and the minimum release of land for development must be calculated on the basis of satisfying that need. The guidance oversees the Local Plan that each district planning authority must make to guide its decisions about proposed housing and commerical developments. Local Plans can be challenged, and usually are, leading to Examinations with legal status where the plan is judged by an Inspector appointed by government. This paper focuses on practice in England, with 55m of the UK's 65m population, where guidance since 2010 has shaped the actions of the 336 district planning authorities, and has prioritised growth through economic targets. The legal planning structure is similar in Wales, Scotland and Northern Ireland, although strategic policies for regions larger than planning authorities have more weight outside England (Inter-Parliamentary Research and Information Network 2013).

The guidance for Local Plans in England (DCLG 2015a) stipulates that the starting point to calculate an 'objective assessment of need for housing' must be the official government household projections, in which recent local demographic levels of fertility, mortality, migration and household formation are assumed to continue or to change in line with national forecasts of each of these factors. The Local Plan (which has in past years come under varied names of strategic, structure, spatial or development plan) must identify the land that will be available to developers to satisfy the forecast number of households. This predict-and-provide approach may be tempered by physical constraints, legal constraints on development in Green Belt areas around cities and National Parks, and policies to shift provision between neighbouring districts.

Figure 1 describes the three common questions which demographic forecasts seek to answer in the analyses that support Local Plans. First, what is the demand for housing and jobs if migration continues as recent trends suggest? This is the 'business as usual' forecast that the official projections provide an answer to. Forecasters may attempt to improve it by using more recent data or more sensitive analyses of migration trends. It is not 'policy off' or 'policy free' as sometimes claimed; rather it assumes that any impact of past policies will continue unchanged. In the second part of Figure 1, a plan or target number of dwellings determines the future trajectory of households, which in turn determines the level of migration required to meet that target. The revised population forecast is then used to estimate the future need for jobs. Finally, if the plan is for jobs growth, it is this that affects future migration, which in turn determines housing need.

The Cameron government since 2010 has changed the guidance for Local Plans in England in a number of ways to encourage more land to be released than the forecast of housing need from demographic trends. The guidance has been translated into practical steps for implementation by the Planning Advisory Service (2014). When draft plans are contested, alternative figures for future land need are proposed, not least by developers whose incentives include maximising the area identified as available for development, to reduce the price of housing land and to increase their choice of the most profitable sites. The new guidance allows no reductions from the demographic forecast unless balanced in other areas. On the other hand, the Local Plan must cater for more than the demographic demand to make up for any previous undersupply, and to meet local policies that must consider targets for future growth in the number of jobs (DCLG, 2015a: paras 14-20).

Figure 1. Migration determines a population forecast, or is determined by constraints



Thus an aspirational target of jobs has become the 'new normal' and has created a focus on the future of economic activity. All other things being equal, a growth in jobs beyond that expected from demographic change would require more land for housing to accommodate the extra workers and their families. However, if economic activity were to continue to increase in the UK as in the 2000s, including the impact of a rising state pension age, then those extra jobs could be taken by the existing population without any requirement for extra housing. Thus aspirational jobs growth and future economic activity have become much more central to the examination of local plans than hitherto (for examples of the debate, see Peter Brett Associates 2014, especially Appendix D, Shropshire County Council 2014, and Simpson 2015). In the past, 'jobs-led scenarios' as illustrated by Figure 1c, were only encountered where a demonstrable major jobs expansion or contraction was expected, such as North Sea oil expansion off Scotland, or de-industrialisation elsewhere, both in the 1970s and 1980s.

Housing-led scenarios have regularly been used to assess how a plan for future land release, expressed as numbers of housing units per annum, might impact on local population. Outside the preparation and debate of Local Plans, housing-led scenarios are common when assessing the impact of developer's proposals to use specific major land sites. The regulations covering permission to build allow *Planning Contributions* and a *Community Infrastructure Levy* from developers where a development impacts on school, transport or other services, stimulating the quantification of those impacts through the modelling implied by Figure 1b (DCLG 2015b; North Devon Council 2015).

The data context

The UK system of official statistics has been fortunate that universal health services record the date of birth of every registered patient, which has led to the annual measurement of internal migration by age and sex since the 1970s (Scott and Kilbey 1999; ONS 2015a). Since 2001, registers from the health service have also been used to provide population estimates by single year of age for small areas within each country of the UK (NISRA 2011).

The decennial Census provides data for the household composition of sub-national areas. The Census also supplies three other key areas of information used in local planning: a sub-national series for economic activity; the local links between demographic demand for housing and its supply: vacant housing, shared housing, and second homes; and the local links between demographic demand for jobs and its supply: unemployment and commuting.

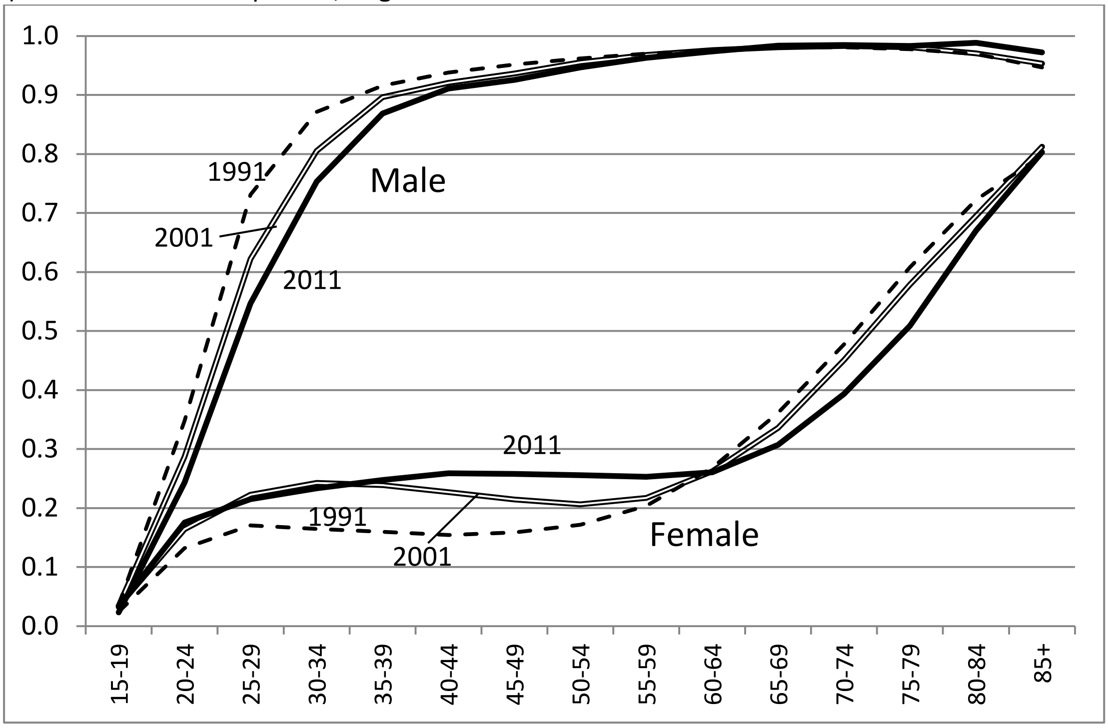
Tax and benefit systems also supply information on housing and unemployment. Together, vital statistics, universal health services, the Census, tax and benefit systems have been central in the development of the cohort component demographic forecasts and derived forecasts that are now essential ingredients of sub-national planning in the UK.

The demographic models

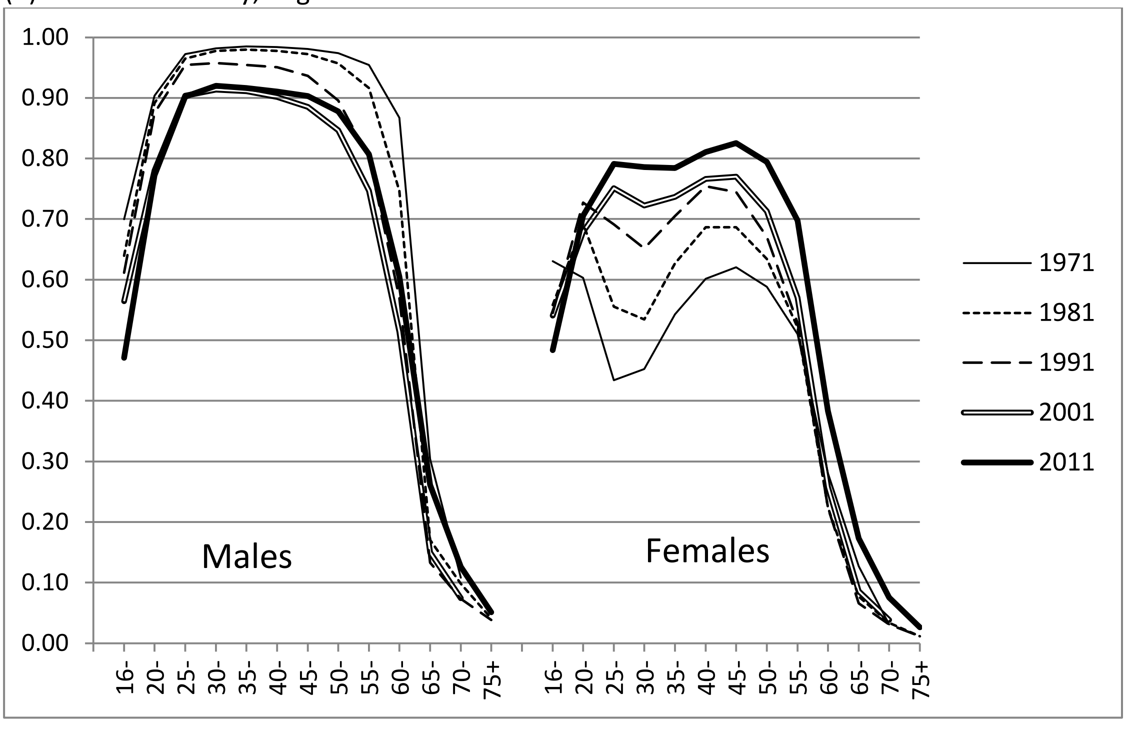
Official statistics agencies in the UK provide population forecasts by single year of age using cohort component methods for each local authority district (ONS 2015b). These districts are singly or sometimes in their aggregate the same as the planning authorities referred to above, with a range of about 50 thousand to one million population. The same cohort-component approach is favoured for many other planning purposes whether for districts or for smaller areas, taking advantage of the

Figure 2. Age-specific headship rates and economic activity rates

(a) Household headship rates, England



(b) Economic activity, England and Wales



Sources: (a) DCLG (2015c). In this source, the 'head' is a statistical representative, calculated in a way which favours the male in a couple. (b) Population Censuses 1971-2011. '70-74' refers to 70 and older in 1971; 75+ was not recorded in 2001; school leaving age was raised from 15 to 16 in 1972.

existence of data with detailed age-composition already referred to. The approach provides the future composition of the population which is directly useful to many services that address the needs of infants, young people, those of working age, elderly or other specific sections of the population. Detail of age and sex is also exploited for the derived household and labour force projections, since household composition and economic activity vary with age and sex in predictable patterns (Figure 2).

In the official population projections, the future trajectory of each of fertility, mortality, international migration, and household rates is established by national analysis. The local characteristics of each of these components of change are established by an average of the recent past, usually five years, and its future trajectory assumed to be parallel to the national projection.

Official household projections in the UK use headship rates in a variety of ways (Welsh Government 2011). England and Scotland favour age-specific proportions of the household population (those not in communal establishments) that *represent* their household, classified into household types. Wales and Northern Ireland use age-specific proportions of the household population that are *members* of households of a particular type, then dividing the projected number of people in each type of household by its average household size. The latter approach avoids an algorithm to identify one person as the head or representative of a household while losing some rationale for being a stable indicator. Both approaches forecast the future household headship or membership rates by extrapolation from past census values, with some influence of recent national surveys.

There are no official projections by UK government departments of economic activity or the labour force, and those provided by the European Commission and the Office for Budget Responsibility are unsatisfactory in their treatment of young adults and the elderly, leading local planners to provide their own assumptions (Simpson 2015).

These forecasts of future population, households and the labour force are projections under the assumption of 'business as usual' (Figure 1(a)). However they do not give the demand for housing and jobs, which requires further adjustments which will now be described and have been part of the toolbox of strategic planning for many years (Breheny and Roberts 1980; Field and MacGregor 1987: chapter 8).

Some households share the same dwelling unit, reducing demand, while dwellings that are vacant or used as second homes or holiday homes increase the number of dwellings needed to house a forecast number of households. These relationships are used to compute the demand for dwellings from the forecast number of households by the following identity:

Dwellings = Households * (1 – sharing rate) / (1 – vacancy rate – second homes rate – holiday homes rate)

Similarly the number of jobs demanded by a resident labour force is dependent on the future unemployment rate and the impact of commuting. Commuting is represented by the ratio of those residents in the area who are employed divided by the number of occupied jobs in the area. For example the commuting ratio is more than one when there is net out-commuting, because this decreases the number of jobs demanded by a projected resident labour force. The identity linking jobs to the labour force is:

Jobs = Labour force * (1 – unemployment rate) / (commuting ratio)

= Labour force * (1 – [unemployed living in area]/[employed + unemployed living in area]) / ([employed residents living in area] / [jobs in area])

Software

Within the planning industry – spanning the public sector, agencies representing developers, and community groups – a variety of technical implementations are used to replicate the official demographic projections and to extend them with planning scenarios. POPGROUP is the only available software documented in the public domain and has become an industry standard in the UK (University of Manchester 2014; Edge Analytics Ltd 2013). It was developed by a consortium of local authorities in the late 1990s, and specified and developed by the author of this paper. It is now owned by the Local Government Association and leased to Edge Analytics Ltd.

The POPGROUP software is a projection model-maker using the Microsoft Excel platform and VBA programs, free from data and appropriate for use with any geographical scale, so long as the user is prepared to locate and enter appropriate data. Up to 40 regions are forecast independently in the same model. POPGROUP implements the single year cohort component projection with gross flows of migration between each region and one or two external areas, chosen when setting up the model. These external areas are usually the rest of the UK and international, but may be specified as short-distance and long-distance depending on the data available and the concerns of the forecaster. Each component of change may be represented by counts or rates, which in turn may be age-specific or general. Options allow controls to data for the aggregate of regions, which together with the use of a national population forecast for internal in-migration rates, introduces strong elements of bi-regional models. The minimum data entry comprises a base population and single-year demographic rates for fertility and mortality. Counts of events and population allow the model to be used to estimate past local demographic trends. Targets of housing or jobs form constraints which are discussed in the next section.

POPGROUP's sub-module Derived Forecasts (Edge Analytics Ltd 2010) applies rates to a forecast of the population. It is also a model-maker in that (a) the rates may be defined for the user's specified age-sex groups, aggregated from individual years of age, (b) the rates may refer to several categories such as household types, (c) adjustments before the application of rates cope with day-time, household or other population bases, (d) subsequent adjustments allow for household size or monetary or other factors applied to an initial forecast, and (e) the number of areas and their naming along with the naming of derived variables are under the control of the user when setting up the model. The flexibility has allowed users of Derived Forecasts to implement a great variety of models, including each of the UK official household projections, labour force forecasts and forecasts of the disabled population.

The integration of population and derived forecasts is key to successful modelling in the planning context. The Derived Forecasts software may take its population from POPGROUP outputs. One or two derived forecasts may be run in the background from POPGROUP, providing for example the consequences of a population forecast for the future number of households, housing units, the labour force, and jobs. When a plan of housing or jobs is used as a constraint on the population forecast, POPGROUP and Derived Forecasts are used together to determine the level of migration required so that the population will be consistent with the plan, as discussed in the next section.

Migration determined by a mismatch of households and housing, or a mismatch of labour supply and jobs

For a given supply of housing, how will the population adjust and what will be the consequent demand for jobs? Alternatively, for a given supply of jobs that may be an aspirational target, how will the population adjust if the target is achieved, and what will be the consequent demand for housing? To answer these questions, extensions are required to the 'business as usual' projection forward of recent experience, as described in Figure 1(a) and the previous section. The extensions integrate estimates of future housing or jobs as described in Figures 1(b) and 1(c). This section briefly reviews approaches to making these extensions and specifies the common solution in UK modelling.

In the USA context, Smith, Tayman and Swanson (2013: 222-227) describe econometric models linking population, jobs and migration, and balancing models in which migration is adjusted to match future population to the supply of jobs. In the UK, econometric modelling is represented by the work of commercial companies such as Oxford Economics and Cambridge Econometrics, and academic modellers Jeff Meen (2011) and Glen Bramley (Bramley et al. 2010). Econometric models can create a target of jobs within the context of past relationships between jobs and wage levels, house prices, migration and other aspects of the economy. In debates at Local Plan Examinations, target jobs growth is often set by econometric models embodying assumptions about demographic and economic trends. However, there is some circularity in the modelling if these targets based on assumptions about demographic change are then used to determine demographic indicators of housing need (Planning Advisory Service 2014: sections 6.10-6.13).

In contrast to econometric models, balancing models assume an exact equation between housing, jobs and population, as described above. With assumptions for future headship rates, economic activity, sharing households, unoccupied housing, unemployment and commuting already set by past experience in the 'business as usual' projection, or adjusted by policy, a new level of migration is calculated to balance the population with the target of housing or jobs.

Since the planning question asks for the demographic consequences of fixing the housing or jobs target, the balancing model has been accepted as an appropriate tool, if not the only analysis considered. Smith, Tayman and Swanson also observe its simplicity:

> "Unlike an econometric forecasting model, a balancing model does not require formal statistical equations or time series data to project future levels of migration. In addition, it does not require implementing a large-scale model of the economy. Consequently, balancing models are less costly to implement and easier to use than econometric models, and are more accessible to a wider range of practitioners" (Smith et al., 2013: 225).

If labour demand exceeds labour supply, it is projected that workers will move into the area. If labour supply exceeds labour demand, it is projected that workers will move out, and equivalently with the balance of housing demand and supply. The constraint on the population forecast is either an estimate of future house-building, which may vary each year, or an annual growth rate in the number of jobs, also variable over time. A scenario that fixes the future level of both is not considered relevant unless operating at different geographical scales: for example a target of jobs growth for a region whose consequences for housing is satisfied with a plan for each neighbourhood.

The balancing model is technically described in the remainder of this section as implemented in the POPGROUP software. Its simplicity does not avoid making multiple assumptions and somewhat complex calculations, in order to respect what is known about the age-composition of migrants and the way in which household are formed. In what follows, a housing target is assumed and its impact on a population forecast is calculated; note is made where the operation of a jobs-led forecast would be different.

The impact of achieving a target level of house-building of say 10,000 dwellings (housing units) per annum may be varied. Vacancy levels, sharing households, numbers of second residences or holiday homes, may each change. Households may spread over a larger number of dwellings with higher headship rates. All those factors are 'levers' that the projectionist must consider and may change within the forecasting model, by making alternative assumptions about the future. It is possible that the provision of housing also affects fertility or mortality of the population. However, in this Paper's treatment the challenge is to calculate how the population may change due to extra housing being filled by migrants into the local area.

When more housing is available, it is unreasonable to assume that it will be occupied directly by migrants from outside the area. In general, the extra housing allows movement from within the area by residents whose own housing then becomes available to others. Thus the *type* of new housing is not usually taken into account when calculating the migration attracted by extra housing stock. Instead new migrants will arrive in the general housing stock, or fewer migrants will leave the area. The specific flows of migrants that are affected – in- or out-flows, national or international, short-distance or long-distance, may be specified by the projectionist.

Calculations

In general, the derived forecast at time t is a linear function of the age-sex composition of forecast population. For households, the function involves deducting those in communal establishments, and then multiplying by a headship rate:

$D_t = f(\underline{P}_t)$, where $\underline{P}_t$ represents the age-sex set of population results projected for time t.

As mentioned, it is possible to alter the function f in order to meet a target population derivative, for example taking the target as evidence of a change in the assumed headship rates. The headship rates would then be scaled to meet the estimated housing without any change to the population projection. On the other hand, if the estimated future housing is considered as a cause of change in future population, then it is the population that should be adjusted to achieve the target. This latter option is considered here. The discussion assumes a housing target, household headship rates and a relationship between housing and households for simplicity of explanation. The same calculations are correct for a jobs target, economic activity rates and a relationship between jobs and workforce.

Let $D^1_{t+1} = f(\underline{P}^1_{t+1})$ be the derived forecast at future time *t+1* according to all the assumptions without a constraining target. The aim is to compute the population consistent with a target derived forecast number of houses, D^2_{t+1}. This target forecast is usually the plan for house-building or release of housing land expressed as a number of housing units. It is assumed that births and deaths are accurate, so the aim is to compute new flows of migration at each age and sex that are consistent with the housing target. The distance between the target and the unconstrained forecast of housing units is the difference between the linear function of the two population projections, and so it can be expressed as the same linear function applied to the difference in populations at each age and sex. With births and deaths fixed over a single time period, the difference is the same linear function of the difference in migration:

$$D^2_{t+1} - D^1_{t+1} = f(\underline{P}^2_{t+1}) - f(\underline{P}^1_{t+1}) = f(\underline{P}^2_{t+1} - \underline{P}^1_{t+1}) = f(\sum_{i=1}^{M}(\underline{m}^{2i}_t - \underline{m}^{1i}_t)) \qquad (1)$$

where $\underline{m}_t$ represents a collection of age-sex-specific migration from time t to t+1, and i=1,…,M are the flows of migration to or from the area (out-flows being negative). A projection has been made without the constraint, so the left hand side and the initial unconstrained migration $\underline{m}^{1i}_t$ is known, as is the function that involves headship rates and the ratio of households to housing units. The aim is to find the adjustment to migration so that new migration flows $\underline{m}^{2i}_t$ may be substituted which will be consistent with the constraining target.

The solution is a proportional fitting procedure that respects the age-composition of migrants, which is strongly skewed towards young adults and whose local characteristics have already been estimated for the initial forecast. As there is more than one migration flow that may be adjusted, the solution requires a choice between them, which is kept flexible by allowing a weight w_i for each migrant flow *i*, adding to 1.

In practice there are four flows of migration in a POPGROUP model (M=4) involving short-distance and long-distance in- and out-flows with the area's population. The weights are set by the forecaster, using knowledge of the housing and labour markets. A housing target has usually been considered as an attraction or deterrent to migration within the UK. It has been usual to set the weights for in- and out-flows equal to suggest that the impact may be equally via an attraction of in-migrants or a deterrence of out-migrants.

To solve equation (1), the impact of a single migrant on the derivative (housing) is first considered. The single migrant is expressed as a vector of all the age-sex population categories *a* and the M migrant flows, scaled to sum to 1. The age-sex 'composition' of this single migrant is based on the projected flows without the constraint, by dividing each m^{1i}_{at} by the total number of migrants in the flow across all age-sex categories, $m^{1i}_{\bullet t}$, and using the weights of each flow:

$$\sum_{i=1}^{M} w_i \underline{m}^{1i}_t / m^{1i}_{\bullet t} = \sum_{i=1}^{M}\sum_{a} w_i m^{1i}_{at} / m^{1i}_{\bullet t} = 1 \qquad (2)$$

Equation (2) is simply an identity, adding the elements of the vector of migration flows $\underline{m}_t^{1i}$ after weighting and scaling. The sum of each flow's migrants by age and sex, divided by the flow total, is one. Since the weights w_i add to 1, the weighted total of all migrant flows expressed in this proportional way is also 1.

The impact on the population derivative of this single representative migrant, is $f(\sum_{i=1}^{M} w_i \underline{m}_t^{1i} / m_{\bullet t}^{1i})$. It may indicate that the single representative migrant only fills half a dwelling, since many migrants are not household heads. In the case of jobs, not all migrants are workers, since workers have families. This impact of the representative migrant is then scaled up to calculate the adjustment to the total number of migrants required to meet the target population derivative:

$$\sum_{i=1}^{M} (m_{\bullet t}^{2i} - m_{\bullet t}^{1i}) = (D_{t+1}^{2} - D_{t+1}^{1}) / f(\sum_{i=1}^{M} w_i \underline{m}_t^{1i} / m_{\bullet t}^{1i}) \qquad (3)$$

For example, if the representative migrant fills half a house, an extra 50 houses will require 100 extra migrants. Equation (3) provides the *total* adjustment to migrants required to meet the target population derivative. It is a single value and its division into flows and age-sex groups is not yet known. So far we have assumed that it is positive value, but the target D^{2}_{t+1} may be less than the demand implied without the constraint, D^{1}_{t+1}. For example an adjustment to migrants of –1000 would indicate that a *deduction* of 1000 migrants with the composition of the weighted initial flows will produce the target population derivative.

The separation of this total adjustment into the M flows and each age-sex category is achieved using the representative migrant vector again:

$$\underline{m}_t^{2i} - \underline{m}_t^{1i} = (\sum_{i=1}^{M} (m_{\bullet t}^{2i} - m_{\bullet t}^{1i})) * (w_i \underline{m}_t^{1i} / m_{\bullet t}^{1i}) \qquad (4)$$

The first term of the right hand side of equation (4) is the single value calculated from equation (3). For each flow *i*, this value multiplies the vector of age-sex-flow proportions that is the representative migrant.

Finally, the adjustments from equation 4 are made to each of the M initial flows, adding to in-flows and deducting from outflows, in order to meet the population constraint. Negative gross flows can result from an adjustment greater than the existing flow. These are avoided by adding the negative result to the opposite flow. Thus for example, an inflow of –100 is set to zero while 100 is added to the outflow from the same age-sex category.

To summarise: housing or employment constraints are achieved by scaling each age-sex- group migrant flow by the single factor that will reproduce the constraint, but allow for different weights for each flow of migration. The approach described above is a development of the 'plus-minus method' of Judson and Popoff (2004: 708-711) for adjusting gross flows to implement a constraint of a single net migration total. Alternatives could relax the requirement that the constraint be met exactly, or allow the migrants generated by a housing plan to have a different age-sex composition from that used in the initial projection.

This approach to constraints is extended in the POPGROUP software to allow constraints on each component of population change and on the population itself (Simpson 2006 provides the calculations and examples). The extensions are used to estimate missing demographic rates and migration age-sex profiles for small areas when a time series of vital events and population estimates are available (Simpson and Snowling 2011).

Scenarios for uncertainty and scenarios for plans

Planners have to deal with uncertainty about the future. RJS Baker provided a framework for considering the relationship between forecasts and planning which remains useful today though seldom developed. He suggested four phases:

- "Research and intelligence – inquiry into past and present events and situations…
- Forecasting future events and situations outside one's own immediate control.
- Planning action to be taken by oneself or under one's own control.
- Forecasting the effect of such action". (Baker, 1972: 121-2)

In the current context of land use planning, the events and situations outside the planner's immediate control might include future fertility, mortality and the relationship between population and housing. The planner demands that the demographer forecasts these future events, and provides advice about the reliability of these forecasts. The demographer should provide a trend-based projection of population, with alternatives that are also indicated as equally likely due to past fluctuations in fertility, mortality and migration. Although difficult to make precisely, the likelihood of a range of scenarios should be provided to the planner. This completes the first two parts of Baker's framework.

Once the planner has determined possible actions to be taken, the demographer is then asked to forecast the effect of such action. This is achieved through further modelling such as the scenarios described in the previous section that test the impact on population of housing or job targets. The demographer should once again be clear about the assumptions made, and also describe the uncertainty in the estimates of the effect of the planner's proposed actions.

There are other approaches to scenarios which instead might intend to force planners' attention away from the past trends by imagining plausible different futures (Ramirez and Selin 2014).

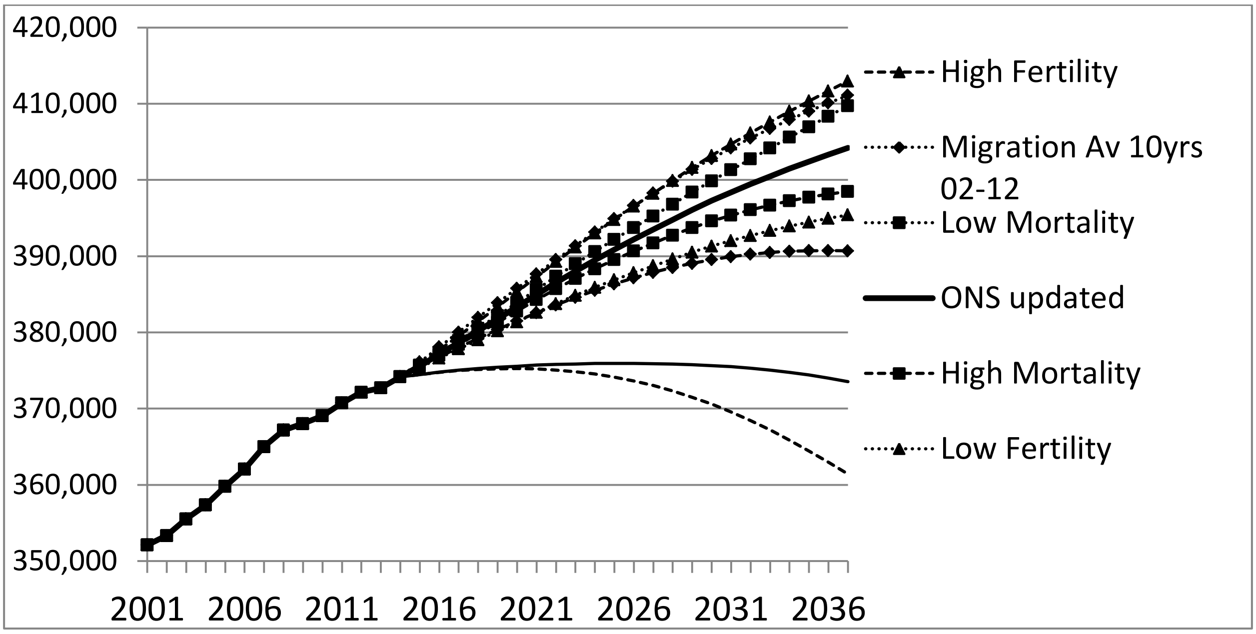
Examples for East Cheshire

East Cheshire is one of the 336 planning authorities of England, including the towns of Nantwich, Crewe, Congleton and Macclesfield. It has no major institution of higher education, serves as a commuting belt for the conurbations of Manchester and Liverpool to its north, and receives older migrants from those cities. As such it is attractive to developers wishing to provide housing at the more expensive end of the range.

Figure 3 shows the growing population of East Cheshire 2001-2014. The thick continuous line shows the continued growth expected in the official projection by the Office for National Statistics (ONS), updated with the most recent population estimates. Two low scenarios showing steady or decreasing population from zero migration are not realistic but indicate the nature of migration to the area. Migration accounts for all of the district's expected population change – the 'Natural change' scenario shows a steady population. The 'Net Zero UK migration' scenario assumes a balance of gross flows of migration in total, but maintains the age structure of the district's recent flows to and from the rest of the UK. This scenario leads to a clearly decreasing population, showing that in net terms Cheshire East gains mostly older people who have already had children and are more likely to subsequently die than to give birth.

The other scenarios are intended to realistically show the impact of alternative population scenarios that are quite feasible without any intervention. They are alternative representations of 'business as usual'. The bounds of fertility labelled by ONS in their national projections as high and low are applied as proportional changes to East Cheshire's projected fertility. This range of fertility adds rather more uncertainty than the ONS national range of mortality. Two alternative assumptions about migration provide slightly more uncertainty. They are based on continuing flows of migration averaged from the five years prior to 2012 (mostly in a period of economic recession), or averaged from ten years prior to 2012. The official projection was based on migration from the five years prior to 2012, but applied in a rates-based multi-regional model rather than constant flows at each age and sex.

Figure 3. Demographic scenarios testing the official population projection for East Cheshire



Notes: The scenarios are labelled in order of their projection at 2037 from highest to lowest. The scenario 'ONS updated' is the government 2012-based projection updated with 2013 and 2014 Mid-Year Estimates of population. Each other scenario applies alternative assumptions from mid-2014. Scenarios are as defined in the text.

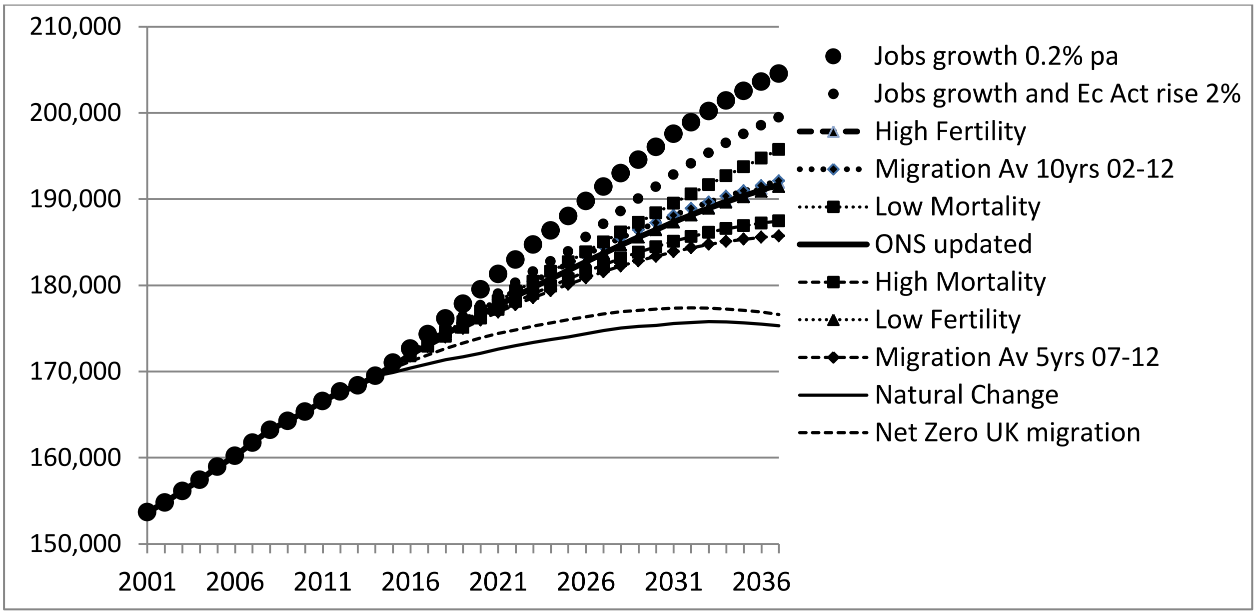
Figure 3 shows that East Cheshire's future demographic growth cannot be easily disputed, but that by 2036 that growth may be between 20 and 40 thousand when compared to the population of 374 thousand in 2014. This range represents slight variations of the recent past. It shows uncertainty about the future even if the recent demographic experience continues.

Figure 4 translates these projections into need for housing by applying the officially projected age- and sex-specific headship rates for Cheshire East (DCLG 2015c) and household/dwelling ratios from the 2011 Census. The Figure includes two further scenarios based on modelling as follows:

- Housing required by a job growth of 0.2% per annum, as proposed locally in 2014 (Cheshire East Council 2014), assuming that economic activity, commuting and unemployment remain the same as at the 2011 census.
- The same job growth of 0.2% per annum but also a gradual increase of economic activity by 2 percentage points over the decade 2015-2025.

The two extra scenarios are examples of the implementation of Figure 1(c). In these scenarios, the jobs target is implemented as described earlier. Jobs are a derived forecast which acts as a constraint on migration, causing a change in population and its age structure. Figure 4 shows the impact on the second derived forecast, of housing.

Figure 4. Demographic scenarios and jobs-led scenarios: the impact on housing need: projections for East Cheshire



Note: Scenarios are as defined in the text

A comparison of Figures 3 and 4 is instructive about the demographic processes modelled. While the range of fertility was a significant influence on the size of the population it has practically no impact on housing need in the 23 year period of the projection, as newly born take nearly a generation before they significantly contribute to the number of householders. On the other hand, the impact of Cheshire East's relatively older population among in-migrants is very significant on housing need. Although the population tends to reduce as older migrants die rather than produce children, the older population tends to live in households that are smaller than the average. Thus the impact of migration's age structure is to reduce population but to add to household need. This is seen by comparing the 'Net Zero UK migration' and the 'Natural Change' scenarios.

The population of Cheshire East is ageing as are all English Districts, mainly due to the growing old of the large cohorts born in the 1950s and 1960s and the continued lower fertility since then. As we have seen, in Cheshire East internal migration exacerbates ageing. Thus the demographic need for jobs in Cheshire East peaked in 2012 and is now reducing in spite of a growing population and growing need for housing (these figures are not in the graphs but are part of the output of the modelling). The Local Plan target of 0.2% per annum growth in the number of jobs may therefore be rather optimistic, though developers have argued that it is insufficient. If achieved, Figure 4 shows that the jobs target suggests a higher need for housing in the District than any of the 'business as usual' scenarios.

Some of that need to house new workers and their families would be eliminated if the economic activity of the residents of East Cheshire were to rise. Figure 4 shows one crude scenario in which all age groups' activity is increased by 2 percentage points over the ten years 2015-2025. The housing need reduces by about 2%, from 204.5 thousand to 199.4 thousand. The *extra* housing needed during the period 2014-2037 is reduced by 15%, from 35.1 thousand to 30.0 thousand.

The modelling for Figure 4 assumed that the migrants required to fill extra jobs will have the same age structure as those generally moving between Cheshire East and the rest of the UK, half of shortfall coming from deterred out-migration and half from increased in-migration. One might think that the jobs will result in younger population and this should be specified. In fact, meeting the constraint wholly by deterred out-migration which we know is younger than in-migration, makes little difference to the result, reducing housing need by less than 300 over the whole period. This is because both in and out-migration are largely composed of young adults. It is only when balanced in large gross flows that the net difference of older in-migration is revealed in the Net Zero Migration scenario that was mentioned above.

The planning legislation in the UK demands a single Plan releasing land to a single schedule allied to a single forecast. Which forecast should be chosen? This should depend on evidence about likely change due to trends expected to continue, and the feasibility of aspirational targets. The uncertainty in future development that the range of forecasts shows, even within a continuation of recent experience, suggests that planners should release land cautiously and review frequently. The cost of defending contested plans tends to mitigate against frequent reviews.

Discussion

Planning is about the future, and as such requires forecasts. In some countries including the UK there is a legal requirement that developments conform to a local plan conforming to an agreed set of demographic forecasts that may include planned target levels of development. This paper has described how projections and targets are integrated to the benefit of strategic planning. Integrated population, housing and jobs forecasts involve describing not a single future but a variety of scenarios, which reflect on the one hand the uncertainty about the direction of recent trends, and on the other the impact of planners' and politicians' intention to change trends.

The first set of scenarios test alternative assumptions about fertility, mortality and migration, and lead to an understanding of the robustness of the 'trend-based' or 'business as usual' forecast, along with its implications for the demographic demand for housing and jobs. The second set of scenarios include alternative assumptions about the future supply of either housing or jobs, leading to a balancing adjustment of migration, a revised population forecast and a revised assessment of the need for other derived demands. The example explored a target growth of jobs, and its implications for population and the demand for housing. The modelling described in this paper allows the exploration and comparison of both these types of scenarios. There is room for more clarity over the nature of scenarios, their calculation and their use in planning, ranging from the ways in which future migration is specified to the role of imaginative scenarios that address the way we live.

The main technical contribution of the paper has been to describe how constraints of housing or jobs can be used to adjust population projections. A brief comment on two aspects indicates where technical development is in order. First, there may be multiple constraints available for the same projection year, which are not independent, and this commonly occurs when geographical sub areas or social divisions such as ethnic group are projected. Typically a prior population or economic projection for a larger area acts as a constraint for smaller areas that have observed or planned housing constraints. To achieve consistency the headship rates for each smaller area must also be adjusted.

Second, constraints have been accommodated above for a single time period. Constraints are often presented as estimates available at the end of longer intervals of say 2 or 5 years, or as a target 10-20 years ahead. In this case the question may be: which adjustment applied over n time periods, will produce a projected population consistent with the constraint? One practical solution is to impose a constraint for each time period by interpolation between the current population and the given constraint, to which the single period solutions that have been described here can be applied. While this solution will ensure neither exactly constant numbers of migrants nor constant migration rates, the aggregate migration over the longer period is of practical interpretation and use. A solution with a constant migration is only possible within an iterative framework, where the solution is amended after each interim projection with successive solutions providing closer consistency with the constraint. The iterations would continue until a pre-determined small convergence criterion is attained. The interaction of migration, births and deaths that occurs within one time period has been ignored in this paper, as is usual within projection models (Keilman, 1985).

This paper has focussed on planning authorities in England, but the principles and modelling is applied to larger and to smaller areas. For smaller areas the availability of data is a constraining factor, but since 2001 the UK has been covered by annual small area population estimates which with vital statistics and socio-economic characteristics from the decennial census are sufficient to allow the cohort component and associated demographic forecasts to be estimated for many purposes (Simpson and Snowling 2011; Hampshire County Council 2015).

More generally, forecasters must warn planners that not only must demographers provide them with multiple scenarios to reflect uncertainty in the system and in its impact of their decisions, but also that our methods require improvement. There will be great value to be gained from evaluation of local demographic projections, including the assumed link between housing and population. There is a wealth of experience available from the analysis preceding local plans but precious little evaluation at a later date. By the time projections ten or twenty years ahead can be compared with an outcome, those involved have long since gone to other projects and the previous data rarely remains in detail.

Long-term academic evaluations are in order, and would promise to guide improved practice and improved allocation of public and private investments. Post-hoc examination of demographic forecasts can established confidence intervals to better judge future forecasts and to better choose the most appropriate methods to each context, as has been achieved in general terms by Smith at al. (2013) for the USA. While probabilistic forecasts should be considered, they are at present unusual in sub-national demography and may be more technically demanding than helpful in practice.

In parallel with a better understanding and practice of demographic forecasts, a dialogue between forecasters and planners is always fruitful. To what extent can different types of planners deal with uncertainty? How useful is the distinction between uncertainty in what is not under the planner's control, and the impact of the planner's intentions on demographic change?

These are some of the avenues for methodological research. It is however an equally pressing priority to document and preserve the current methods and practice of demography as applied in local public planning. The 40% reduction of funding from national to local government in the UK since 2010 (Gainsbury and Neville 2015) will continue and has already seriously affected research and planning with the loss of skills and experience (Radical Statistics 2012). Support for strategic planning waxes and wanes in the UK, and is currently stronger in Wales and Scotland than in England.

References

Baker, R.J.S. (1972) Administrative theory and public administration, London: Hutchinson University Library

Bramley G, Pawson H, White M, et al. (2010) *Estimating housing need*. London: Department of Communities and Local Government.

Breheny MJ and Roberts AJ. (1980) Forecasting methodologies in strategic planning: a review, *Papers in Regional Science* 44(1): 75-89.

Cheshire East Council. (2014) *Local Plan strategy background paper population projections and forecasts*, Document SD019. Crewe: Cheshire East Council.

Cullingworth, B., Nadin, V., Hart, T., Davoudi, S., Pendlebury, J., Vigar, G., Webb, D., Townshend, T. (2015) *Town and Country Planning in the UK*, 15th Edn, Abingdon: Routlege.

DCLG. (2015a). *Planning Practice Guidance: Housing and economic development needs assessments,* http://planningguidance.planningportal.gov.uk, 26 March 2015. London: Department of Communities and Local Government.

DCLG (2015b) *Planning Policy Guidance: planning obligations*. London: Department of Communities and Local Government. http://planningguidance.planningportal.gov.uk/blog/guidance/planning-obligations/planning-obligations-guidance/

DCLG (2015c) *2012-based household projections: detailed data for modelling and analytical purposes*. 10 March 2015. https://www.gov.uk/government/collections/household-projections#2012-based-projections.

Edge Analytics Ltd. (2010). *Derived Forecast (DF) Model Reference manual Version 1.0*. London: Local Government Association. http://www.cmist.manchester.ac.uk/research/projects/past-projects/popgroup/

Edge Analytics Ltd. (2013). *POPGROUP v.4 population estimation and forecasting system reference manual*. London: Local Government Association. http://www.cmist.manchester.ac.uk/research/projects/past-projects/popgroup/

Field B and MacGregor B. (1987) *Forecasting Techniques for Urban and Regional Planning*, London: Hutchinson.

Gainsbury S. and Neville S. (2015) Austerity's 18bn impact on local services. Financial Times, July 19th 2015, http://www.ft.com/cms/s/2/5fcbd0c4-2948-11e5-8db8-c033edba8a6e.html#axzz3qRwnoLmk

Hampshire County Council. (2015) *Small Area Population Forecasts (SAPF) 2014-based*. Online: http://www3.hants.gov.uk/factsandfigures/population-statistics/pop-estimates/small-area-pop-stats.htm.

Inter-Parliamentary Research and Information Network. (2013) Comparison of the planning systems in the four UK countries SPICe Briefing 13/35. Online: http://www.scottish.parliament.uk/ResearchBriefingsAndFactsheets/S4/SB_13-35.pdf.

Judson DH and Popoff CL. (2004) Selected general methods. In: Siegel JS and Swanson DA (eds) *The methods and materials of demography*. San Diego: Elsevier Academic Press, 677-732.

Keilman N. 1985. Internal and external consistency in multidimensional population projection models. *Environment and Planning series A*, 17: 1473-1498.

Meen, G. (2011) A long-run model of housing affordability. *Housing Studies*, 26 (7-8). pp. 1081-1103

Monks, Sarah, Christine Whitehead, Gemma Burgess and Connie Tang (2013) International review of land supply and planning systems. York: Joseph Rowntree Foundation.

NISRA. (2011) Small Area Population Estimates across the UK. Belfast: Northern Ireland Statistics and Research Agency. http://www.nisra.gov.uk/archive/demography/population/small_area/UK_SAPE_Dec_2011.pdf

North Devon Council (2015) *Section 106, Community Infrastructure Levy (CIL) and other planning obligations*. Barnstaple: North Devon Council *http://www.northdevon.gov.uk/planning-and-building-control/section-106-community-infrastructure-levy-and-other-planning-obligations/*

ONS (2015a) *Statistical bulletin: Internal migration, England and Wales, year ending June 2014*. Tictchfield: Office for National Statistics. http://www.ons.gov.uk/ons/dcp171778_407692.pdf

ONS. (2015b) *Subnational population projections across the UK: a comparison of data sources and methods*. Titchfield: Office for National Statistics.

Oxley M, Brown T, Nadin V, et al. (2009) *Review of European planning systems*. Leicester: De Montford Unviversity.

Peter Brett Associates. (2014) *Note outlining approach taken to job forecasts*, West Dorset, Weymouth and Portland Local Plan examination WDWP/Ex13, 12 December 2014. London: Peter Brett Associates.

Planning Advisory Service. (2014) *Objectively Assessed Needs and housing targets*. London: Local Government Association.

Ramirez R and Selin C. (2014) Plausibility and probability in scenario planning. *Foresight* 16 (1): 54-74.

Radical Statistics. (2012) The effect of the cuts on government statistics and their use, report of the Reduced Statistics working group. London: Radical Statistics. http://www.statsusernet.org.uk/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=4122199d-65df-4f2f-a90a-17240e458008&forceDialog=0

Scott A and Kilbey T. (1999) Can patient registers give an improved measure of internal migration in England and Wales? *Population Trends* (96): 44-56.

Shropshire County Council (2014) Labour force projections based on 2012-based sub-national population projections, in EV3c SHMA update addendum July 2014. Shrewsbury: Shropshire County Council. http://shropshire.gov.uk/planning-policy/samdev-examination/evidence-base/

Simpson L. (2006) *Integrating estimates and targets within a population projection*. Manchester: Research Methods Programme Working Paper 18, 89-104. http://www.ccsr.ac.uk/methods/publications/documents/WP18.pdf

Simpson, L (2015) *National and local labour force projections for the UK*. CMIST Working Paper. Manchester: Cathie Marsh Institute for Social Research. http://www.cmist.manchester.ac.uk/research/publications/working-papers

Simpson L and Snowling H. (2011) Estimation of local demographic variation in a flexible framework for population projections,. Journal of Population Research 28(2): 109-127.

Smith SK, Tayman J and Swanson DA. (2013) *A practitioner's guide to state and local population projections*, New York: Springer.

University of Manchester. (2014). *Impact of demographic projections on sub-national planning* (Research Excellence Framework impact study). Manchester: University of Manchester. http://results.ref.ac.uk/DownloadFile/ImpactCaseStudy/pdf?caseStudyId=28160

Welsh Government. (2011) *Household projections across the United Kingdom, Technical Report*. Cardiff: Welsh Government.

Wilson T and Rees P. (2005) Recent developments in population projections methodology: a review. *Population, Space and Place* 11(5): 337-360.