Demographic projection as a tool for analysing trends of community vulnerability

Glavac, Hastings and Childs discuss the potential for using demographic and socioeconomic data projections to study geographical and temporal trends of community vulnerability to hazards.

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This paper discusses the potential for using demographic and socioeconomic data projections to study geographical and temporal trends of community vulnerability to hazards. Several techniques are outlined, and their practical application critically discussed in relation to variables considered to be indicators of hazard vulnerability. Demographic projections for Southeast Queensland Local Government Areas were generated, mapped and discussed as an illustration of possible information outputs.

Introduction

Ferrier (1999) outlined the importance of knowing the characteristics of populations when considering issues of emergency management. He suggested that demographic data were useful in assessing community needs, resource planning, and developing targeted educational campaigns. Socioeconomic and demographic variables have also been incorporated into assessments of community 'vulnerability' to natural hazards[1]. (e.g. Granger et al., 1999; Granger and Hayne, 2001). Ferrier further identified the potential value of population/ demographic projections to emergency-management planning and briefly commented on their possible sources, methods and applications in Australia.

This paper advances the theme of using population/ demographic data projections, particularly in the context of studying temporal and geographical changes in community vulnerability to environmental hazards. The opportunities, constraints and techniques of projecting possible socioeconomic and demographic indicators of vulnerability will be outlined. As an illustration of applying projection techniques in this context, an analysis of demographic and geographical trends was produced for Local Government Areas of Southeast Queensland.

Demographic indicators of community vulnerability

The overall paradigm shifts in Australian disaster/ emergency management described by Salter (1997) include an increasing emphasis on understanding and assessing community vulnerability. Studies, including those of Blaike et al. (1994), Granger (1996), Salter (1997), Granger et al. (1999), Middlemann and Granger (2000), Granger and Hayne (2001), Zameka and Buchanan (1999), King and MacGregor (2000) and Buckle et al. (2000; 2001), identify characteristics that are deemed to reflect aspects of community vulnerability. Among these characteristics, demographic and household measures often feature. Groups commonly identified as being vulnerable include: the very young, the aged, single parent households, lone-person households and new arrivals/migrants (e.g. King and MacGregor, 2000). Levels of language skills, income and mobility are also cited in the literature (e.g. see Buckle et al. 2000, 2001). Quantification of these variables for localities is enabled via Australian Bureau of Statistics Census data, as undertaken by the "Cities Project" research (e.g. Granger et al., 1999; Middlemann and Granger, 2000, Granger and Hayne, 2001).

Measuring vulnerability is, however, not as simple as quantifying demographic information. King (1999) and King and MacGregor (2000) raised several issues involving Census-data usage, including its application to derive demographic vulnerability indicators[2]. Furthermore, King and MacGregor (2000) and Buckle

1. In this paper, the term "vulnerability" will be used as a collective term referring to the interrelated concepts of vulnerability and resilience. According to Buckle et al. (2000; 2001), the former implies a susceptibility to loss, while the latter describes capacities to withstand or recover from loss.
2. Issues included the impacts of data amalgamation/ standardisation on resolution and relevance; the choices and weightings of 'vulnerability' variables; and the impacts of these on data analysis and interpretation.

et al. (2000; 2001) urge an appreciation of the complex and contextual nature of vulnerability and resilience, and promote the importance of many 'less quantifiable' social determinants including attitudes, values, behaviour, perceptions and social/ community networks.

Despite the limitations, socioeconomic and demographic Census data are accessible (in terms of availability & cost), systematically collected and reported, and regularly updated at a range of geographical scales. They will likely continue to provide *at least a basis* for further vulnerability analyses by providing an overview of geographical patterns and facilitating the broad monitoring of socio-demographic change. Though favouring contextual vulnerability assessments based upon needs and services, Buckle et al. (2001) acknowledge that certain socio-demographic characteristics (such as those listed above) are linked to higher *potential* levels of vulnerability. King (1999) ultimately concluded that *total population* was the key independent demographic variable for community vulnerability analyses. Cities Project documentation identifies population as "clearly the most significant element as risk" (e.g. Granger and Hayne, 2001, Appendix C.9).

This paper will continue under the assumption that Census-derived socioeconomic and demographic variables are useful inputs into vulnerability assessments, as broad indicators at least.

Demographic indicators: trends over time

The Cities Project, and most other regional vulnerability studies to date, emphasise static analyses. Community characteristics affecting vulnerability, however, change over time. King (1999) noted appreciable changes in total population, age distribution and other potential demographic vulnerability indicators for coastal Queensland over only a five year period (between the 1991 and 1996 Census).

A new set of questions arises when longitudinal change is considered. Will historical trends continue? Will new trends emerge? Are there particular regions into which 'vulnerable people' may concentrate in the future? Is management adapting to, or planning for, demographically changing communities? In answering such questions, techniques of population/ demographic projection and extrapolation may play important roles.

Ferrier (1999) identified population projections, often developed by government authorities for planning purposes, as a useful data source for emergency management planning. There are obvious strategic benefits of incorporating accurately projected data into forward planning, but projections are also valuable for "updating" Census information. The latter is important where significant regional change occurs during inter-Censal periods, resulting in rapid "decay" of Census information (e.g. King, 1999).

Techniques for demographic projections/extrapolations

This section outlines key projection techniques, and describes the opportunities and limitations of projecting and extrapolating vulnerability-related demographic variables (mostly Census-derived). Issues of variable choice and application of outcomes to community vulnerability assessments are matters for individual practitioners in their own situation.

Population projections are not forecasts that predict the future, but rather are mathematical "what if" exercises, given assumptions about (for example) the future trends in fertility, mortality and migration. The better the assumptions the better the projections. It is important to note that such modeling is beyond simple "extrapolation", which only projects on the basis of past population trends.

There are several methods of projecting population counts, and the components of population (including particular age-groups). Typically a projection method is selected to produce the best estimate for a given point in time, at a given scale. Users of such projections should have a basic understanding of the range of the methods and their assumptions so that they can critically interpret end-products or plan information acquisition. Table 1 outlines the key techniques for generating demographic projections and briefly comments on their application.

There is no single "best" projection method, as evidenced by the lively debate in the literature about alternative methods. For example, Smith and Sincich (1992) argue for the use of simple exponential extrapolation, Long (1995) for full cohort-component projections and Ahlburg (1995) for more complex methods involving economic-demographic models. These debates are inevitably linked to the question of how far into the future projections can be made with "acceptable" accuracy. With all projection methods, however, the shorter the projection period the more reliable the projections—particularly in regions of fast population growth. Generally, projections out to five years are good in most situations. In the end, projections are only as good as the assumptions they are based upon.

Table 1. Major demographic projection techniques.

PROJECTION TECHNIQUE	BRIEF EXPLANATION AND COMMENT
Growth Rate Methods	• a geometric or exponential growth rate is assumed over a period of time • simple; requires relatively little data • does not project changes in population composition • best restricted to one year projections (e.g. see Newell 1988)
Cohort Component Method (& derivatives)	• projects populations by typically one or five-year age cohorts using fertility, mortality and migration data and assumptions • commonly used for state and national projections, but also for Statistical Divisions and sometimes Local Government Areas; most reliable for larger geographic areas • small changes in assumptions concerning input variables can result in greatly differing projections; migration data/ assumptions are key in Australia, but data are not comprehensive—objective approximations or expert systems are required to account for regional dynamics (economics, policies etc.)
(Aggregate) Time Series Analysis	• historical trends of population size, total fertility and life expectancy are approximated by logistic ("S" shaped) curves • due to assumptions concerning "fixing" variable limits and trends, some demographers suggest that these models provide little basis for projecting into the longer-term future (e.g. Marchetti et al., 1996); although others see some potential value (Lee et al., 1995)
Ratio (Share) Method	• a statewide total is used as a control to which the sum of totals from smaller areas (such as Local Government Areas) must add; projections based on multiple correlations relate city/region growth to both state growth and city density during the same period to create a regression equation. • may be problematic for fast growing large areas as it can erroneously force all areas to show growth; but is often used in conjunction with cohort component methods by many State Government Departments in Australia.
Microsimulation	• computer algorithms simulate the behaviour of individuals' life-course events (e.g. marriage, divorce, birth of children etc.) to make projections for the population. • data and computational demands are high; analyses are therefore based on samples, and scaled to the whole population • able to accommodate large numbers of changing life "states" (e.g. 'married with children' is a "state"); cohort component analysis is less able to do this.

Applying projection/extrapolation to demographic and socioeconomic 'vulnerability' indicators

Several of the Census-derived demographic variables that have been related to vulnerability can be projected for a given area and period by directly using demographic projection modeling (as described). These include: total population; total number of households; the proportion/ number of the very young (e.g. number of children under 5 years); and the proportion/ number of the aged (e.g. number of people 65 years & over). For other demographic and related socioeconomic variables, projections must be developed in alternative ways. Extrapolations of historical trends and/or the application of "multipliers" are options, but these introduce further assumptions, and can limit the interpretation of results.

It is important that users of such projection modeling appreciate the complexity of demographic projections and avoid inappropriately using information gained from simply extrapolating past trends into the future. For some variables, projection may be possible, but considerable data are required beyond the Census or similar readily available sources. Household-related projections (e.g. household size, single parent households and lone person households) and socioeconomic variable projections (e.g. low income, number of cars per person, proportion of the population that rent, are non-English speaking) are examples of these.

Household-related projections (e.g. household size and structure) can be calculated through a variety of means including: modeling based on demographic trends and projections, the projection of demographic cohorts which typically head various 'types' of households ("headship rate"—an operational and relatively simple technique), and microsimulation. The most reliable and consistent sources of this type of information are generally specialist government departments[3] and private consultants who engage in advanced regional modeling.

Socioeconomic factors are thought to be harder to predict than the demographic processes themselves (Keyfitz, 1981). Vulnerability-related socioeconomic variables that can be projected include: the proportion of households/ population that rent, and the proportion of the population with cars. These data are collected not only via the Census every five years but also through other agencies such as State Government departments. Possible projection methods involve time-series analysis, or using multipliers. An example of the latter would be to calculate the number of cars per person; make assumptions about how this will change in the future based on past behaviour; and apply this information to population or household projections.

Although many variables can simply be extrapolated forward, there may be limited theoretical bases behind such extrapolations. In this context, socioeconomic variables that cannot be easily projected include religion, proportion of the population that is disabled, proportion of the population that is non-English speaking, and proportion of the population that is low income. In these cases, changes rely too heavily on other factors (e.g. economic and policy factors), and/or data are not available at an appropriate resolution, and/or variables such as income and religion are reported unreliably on the Census. The Australian Bureau of Statistics' composite SEIFA indices (Social and Economic Indicators for Areas, ABS, 1998, Cat 2039.0) are similarly problematic. Though linked to vulnerability by Granger et al. (1999), Middlemann, M. and Granger (2000) and Granger and Hayne (2001), they can be difficult to interpret, are based on the relatively volatile Census counts (rather than Estimated Resident Population) and because of the way in which they are constructed, their use in some quantitative projection techniques is open to question.

Some simple rules of thumb

As described, there is a range of projection/extrapolation techniques. Each affords particular opportunities and limitations. There are, however, some simple rules of thumb that generally relate to the accuracy of projections and should be considered when deciding which projections to use.

1. The shorter the projection period the more reliable or accurate the projection. This is particularly the case for rapidly changing localities.
2. The larger the geographic area the more accurate the projection. Some regional vulnerability analyses, including those of Granger (1999) and Granger and Hayne (2001), used data at suburb and Census Collection District (CD) resolution. This is appropriate for analyses based on one point in time, but projections for small areas such as these have a very high likelihood of inaccuracy. This is because there is little data available at the CD level that has not been randomised to protect the identities of individuals. A large error component is therefore introduced that adds to the error inherently associated with small-area projections.
3. The lower the current fertility rates and the higher the life expectancies, the more accurate the projections.
4. Temporal methods that typically underlie projections are often volatile. A method that only uses a single point in time, such as only using the year 2001 to make projections for the year 2006 is likely to produce inaccurate forecasts. It is unlikely that future trends will hold the same as at that one point in time, no matter what is being forecast.

Practical considerations

Demographers routinely use a series of projections for an area to better reflect the "what if" nature of projections. The most common approach is to present scenarios, such as *high, medium* and *low*. Most governments receive such scenarios, from sources such as Australian Bureau of Statistics, internal government groups and/or consultants. Again, users of scenarios should understand the assumptions behind all projections so that they can critically evaluate their appropriateness for individual purposes. Where finances allow, it may be beneficial to include demographers on an interdisciplinary research team who can produce projections that are custom-designed for the question at hand, such as in emergency management. While this is not always feasible, it would have the potential to greatly improve the rigour of the analyses.

3. For example, the Planning Information and Forecasting Unit in the Queensland Department of Local Government and Planning.

Illustration: Southeast Queensland (SEQ) projections and geographical Trends

As a brief illustration, this section presents the output from projections of demographic variables that have been linked to vulnerability. Selected variables were projected to the years 2006 and 2011 for Local Government Areas (LGAs) of Southeast Queensland and mapped using MapInfo Professional v7.0 software (MapInfo Corporation, NY). These maps depict the geography of the projected demographic changes across the region (from the 2001 Census base), which potentially could be interpreted to reflect trends in vulnerability. Note that these results are merely a guide, intended to present a simple, regional illustration of technique application and outcomes for the purposes of this paper only. They do not represent a comprehensive series of projection scenarios tailored to specific user needs, as would normally be calculated (see the preceding section). The results may vary from those of other sources due to differences in the data used, techniques and assumptions. Projections are estimates that inherently contain uncertainty.

The techniques used in generating the projections, and some comments about them, are presented in Table 2. In essence, this case study represents a practical application of demographic projection modeling, where choices between techniques have been made on the basis of factors including: the geographical resolution, data availability and limitations, and individual expertise. Census data used as bases for the projections were derived from CDATA 2001 and CDATA 96 (Australian Bureau of Statistics, 2002, 1997–1999).

The *absolute changes* in numerical totals between 2001 and the 2006 projections for the selected variables are presented in maps 2, 3, 4, 6 and 8. Maps 5 and 7 (pages 16–17) show similar data reflecting the 2001 to 2011 projection period results for the 0 to 4 years and 65 years and over age cohorts. Map 1 (page 15) is the map key. In further analyses, these data could be considered in conjunction with *rates* of change. Prominent aspects of maps 1–8 (unless otherwise stated) are briefly outlined on pages16–17 from a geographical perspective.

Western LGAs (Kilcoy, Esk, Gatton, Laidley, Boonah)

For the period 2001 to 2006, absolute totals of: estimated resident population, number of households and number of lone person households are projected to increase in the western LGAs. These increases, however, are significantly less in absolute terms than for coastal areas. A relatively moderate increase in the number of residents 65 years and over, with the exception of Laidley, is also projected. This region further marks an area of forecast decline in the 0 to 4 years age group.

Coastal LGAs (Noosa, Maroochy, Caloundra, Caboolture, Redcliffe, Pine Rivers, Brisbane, Redlands, Logan, Gold Coast)

For the period 2001 to 2006, all coastal LGAs are projected to have marked increases in resident population, with the exception of Redcliffe City, which shows only a relatively small absolute increase. Brisbane and the Gold Coast are particular "hot spots" for growth in population, household number, and the number of lone person households. For the latter two variables,

Table 2. Demographic projection techniques used for Southeast Queensland.

PROJECTED VARIABLE	METHOD USED	COMMENT/ JUSTIFICATION/ SOURCE
Total population Population aged 65 years and over, Population aged 0–4 years	Combination of methods; but featuring ratio-share and cohort component methods for LGAs.	State and Statistical Divisions were first projected in project control totals as well as age/sex structure by cohort component method. Ratio-share method was then applied to LGAs, still producing age/sex breakdowns. This methodology is best for smaller geographic areas such as LGAs but can be problematic for fast growing areas. It is however, a relatively complicated approach. 2001 figures are based on June ERP produced by the Australian Bureau of Statistics.*
Number of households, Number of lone person households	Average household size projections were produced, where assumptions were based on changing household size.	This is a good approach where good quality population projections are available, requiring least specialist knowledge and data. 2001 figures were produced for this paper from ERP derived from the the 2001 Census of Population and Housing (Australian Bureau of Statistics)*

(*Population for 2001 was available from the Australian Bureau of Statistics, so it was used, but all other estimates are based on 2001 ABS Census of Population and Housing data converted to Estimated Resident Population, ERP. The data source was CDATA 2001, Australian Bureau of Statistics, Canberra) these LGAs have greater projected increases than their neighbouring areas.

Increases in the 0 to 4 years cohort are projected for all LGAs to 2006, with the exception of Redcliffe City. The Gold Coast is again prominent, with a greater absolute rise than Brisbane. The 2011 projection, however, reveals a subsequent reversal in this overall trend (map 5, see pages 16–17). Forecasts of absolute *declines* in this age cohort, though not substantial, are revealed for Brisbane, Ipswich and Redcliffe. Projected increases are maintained on the Brisbane metropolitan fringes to the north and south, including the Gold Coast to 2011. This pattern could be related to general trends in population ageing, fertility decline and mortgage-belt developments characteristic of Australian capital cities (e.g. O'Connor et al. 2001). This requires further clarification and analysis.

The greatest absolute increases in the 65 years and over age cohort are projected for Brisbane, Logan and Redlands over the period 2001–2006. On the other hand, the projections show an absolute *decline* in this age group in some coastal areas including the Gold Coast and Maroochy—although the numerical decline at the Gold Coast is very small (inspection of original data). Projected further to 2011 a clear increase in this cohort for both of these LGAs is evident, in concert with the overall pattern for coastal LGAs (map 7, see pages 16–17). The need to consider the length of the projection period is thus underlined.

Transitional LGAs (Ipswich and Beaudesert)

These LGAs show mixed patterns, with some variables reflecting "coastal" trends, and others reflecting "western" trends across the projection periods.

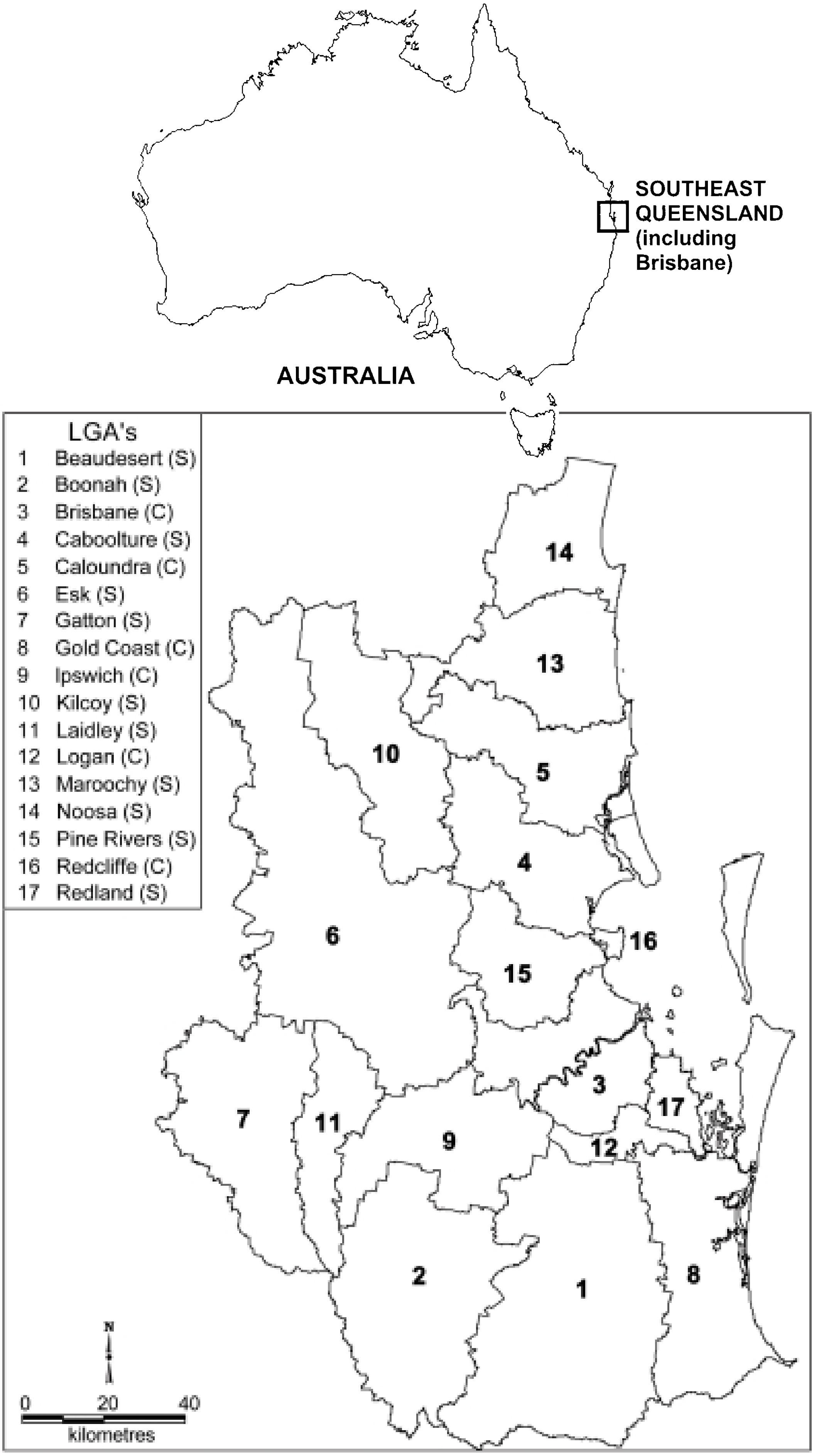
The above offers only broad observations of the spatial variability of absolute change in selected demographic variables. Further interpretations of geographical and temporal patterns, and their relationships to vulnerability, will be prompted by individual perceptions and needs. Vulnerability assessors should consider patterns of absolute change in conjunction with rates of change in order to identify when and where hazard vulnerability "hot-spots" could emerge. These potentially mark localities commanding attention from emergency service planners and managers. This theme will be further discussed in the following section. The assessor should also be ever-mindful of the opportunities, assumptions and limitations of demographic projection methodologies and the use of demographic variables as indicators of vulnerability.

Demographic projection and vulnerability assessment

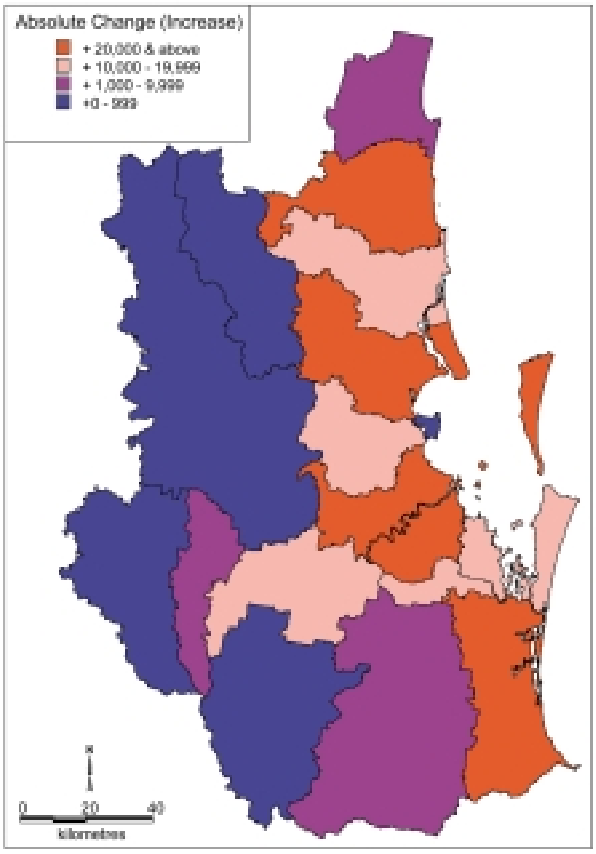
This paper recognises that community vulnerability is dynamic; changing over time as social, cultural, physical and economic landscapes evolve. As a tool, demographic projection potentially offers opportunities for planners and managers to gain valuable planning lead-time by assisting them to anticipate the location, character and pace of demographic changes that can transform levels of community vulnerability. Balancing the "tradeoffs" of accuracy, spatial resolution, projection period, data requirements and analysis complexity, however, will be required and is best addressed in specific problem contexts. Similarly, decision-makers need to deal with the uncertainty of projected data and considering multiple scenarios. The projections of the type and scale illustrated here for Southeast Queensland can be incorporated at the strategic-planning level at regional (e.g. Southeast Queensland) or local government resolutions. In Queensland, this scale of application is now highly relevant, given the adoption of the State Planning Policy 1/03: Mitigating the Adverse Impacts of Flood, Bushfire and Landslide. This policy places significant responsibilities on local governments to identify, evaluate and manage the risks from these hazards. Their appraisals of hazard mitigation requirements and their determinations of future emergency-management resource needs and strategies could be significantly aided by knowledge of future populations, and populations of vulnerable people, within their jurisdictions.

At the scale illustrated here, demographic projections cannot, however, greatly contribute to forward planning that involves locating facilities or resources within Local Government Areas. To achieve this, projections for smaller areas such as Statistical Local Areas and Census Collection Districts are needed. As described, this is problematical given that increasing spatial resolution will compromise accuracy and methodological simplicity. Nevertheless, where a wider regional perspective is taken (e.g. Southeast Queensland as a region, or some Queensland Disaster Districts), geographical patterns across the collection of Local Government Areas comprising the region may broadly reveal regional "hot spots" of growth or decline in vulnerability indicators, and hence where forward planning may be prudent. The Southeast Queensland case study presented in this paper illustrated the point. Such regional strategic planning is possible, for example, under the framework of Southeast Queensland's SEQ 2021 (formerly SEQ 2001) planning initiative. The Regional Framework for Growth Management therein (SEQ RFGM 2000) does not yet, unfortunately, emphasise the inclusion of natural hazard or hazard vulnerability analyses into the planning mix (with the exception of environmental pollution, and in broadly identifying environmental constraints).

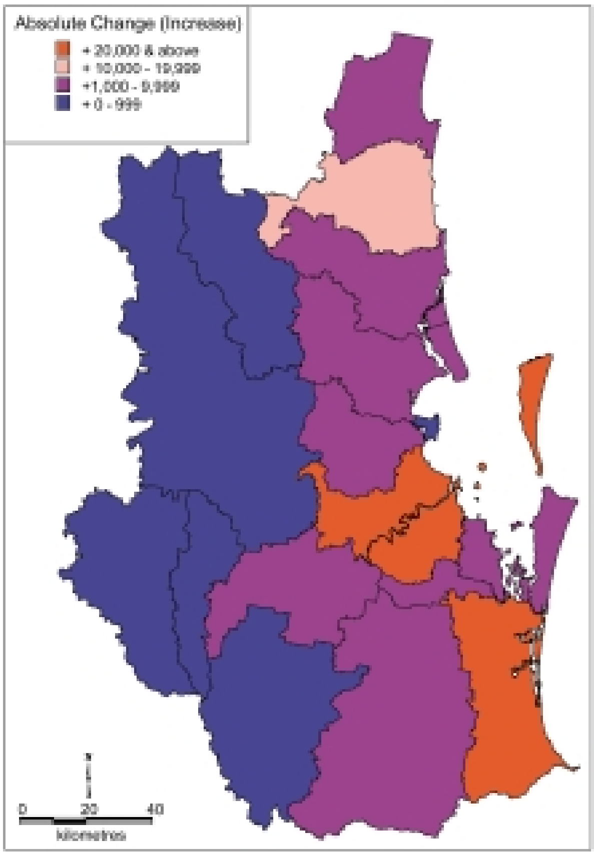
Hazard/ disaster managers themselves now strongly promote community vulnerability assessment as a key step in risk management and ultimately local and regional planning. From the viewpoint of this paper, the question is how to systematically include projected data



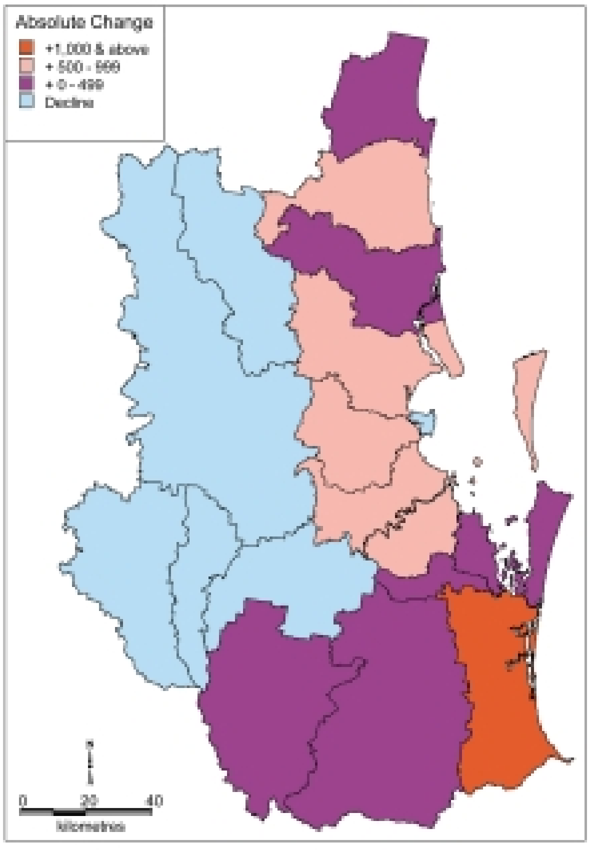
Map 1 Key to Southeast Queensland Local Government Areas.



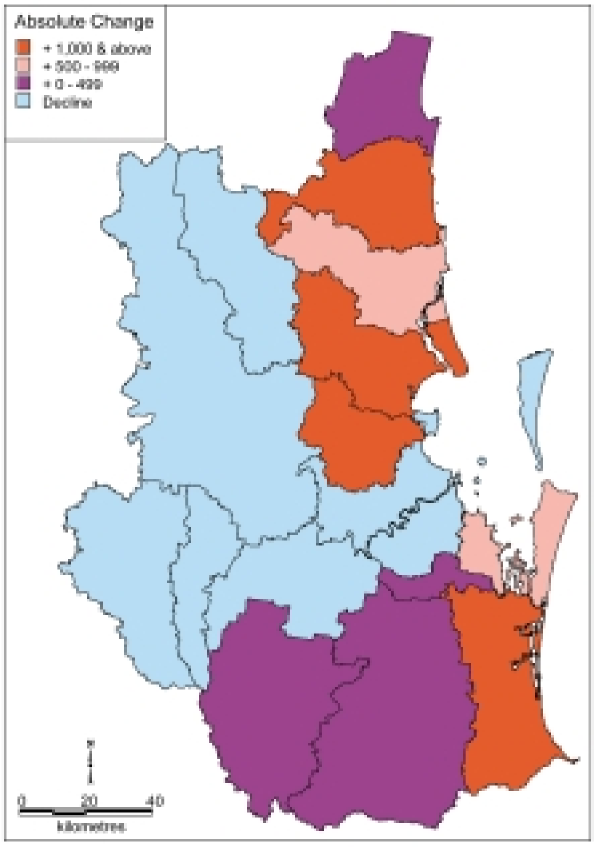
Map 2 Projected Absolute Change in Estimated Resident Population, 2001 to 2006.



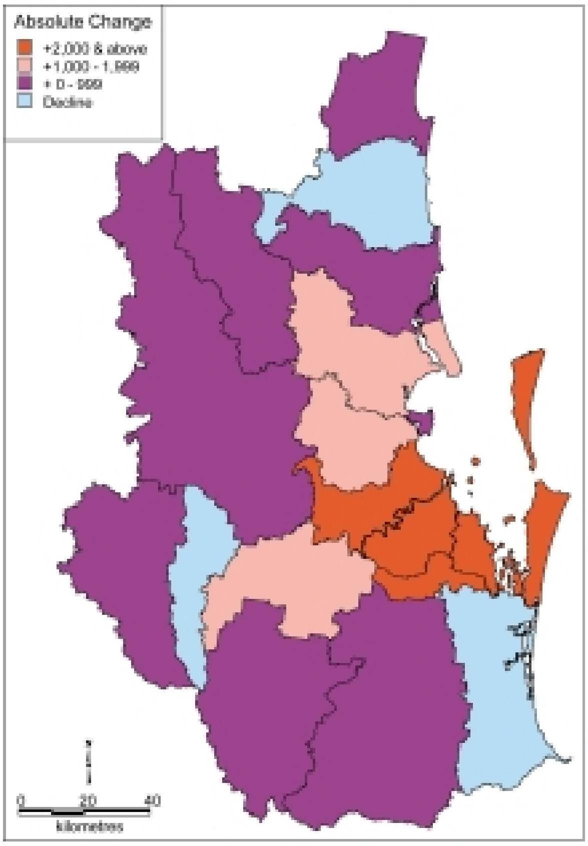
Map 3 Projected Absolute Change in the Number of Households, 2001 to 2006.



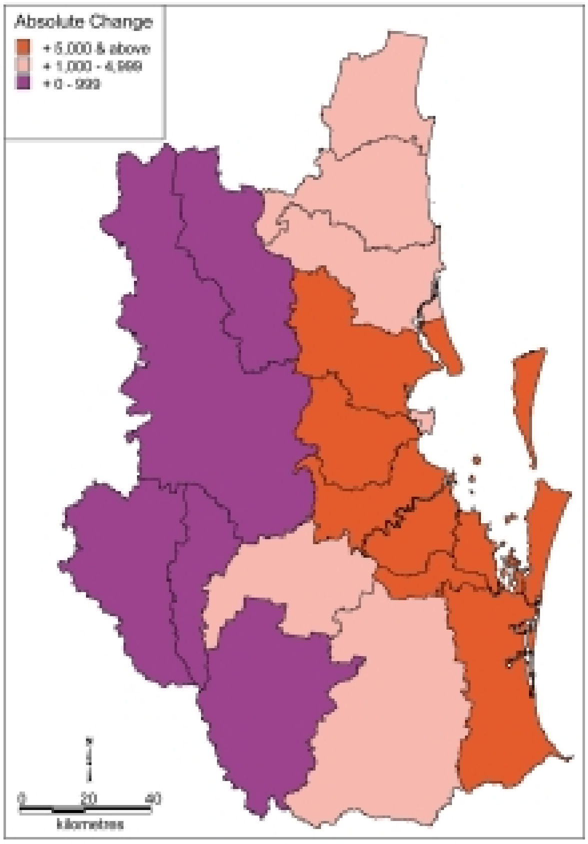
Map 4 Projected Absolute Change in the Number of People Aged 0–4 Years, 2001 to 2006.



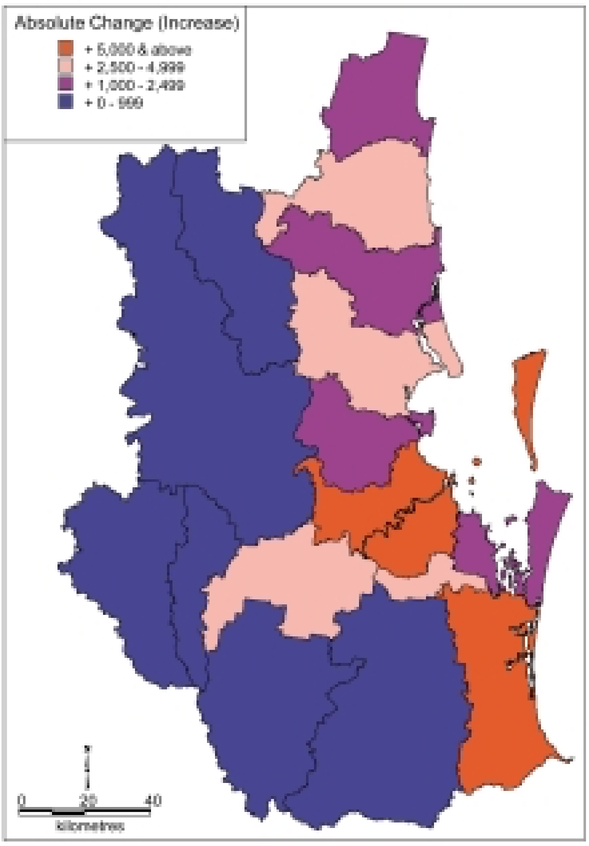
Map 5 Projected Absolute Change in the Number of People Aged 0–4 Years, 2001 to 2011.



Map 6 Projected Absolute Change in the Number of People Aged 65 Years and Over, 2001 to 2006.



Map 7 Projected Absolute Change (Increase) in the Number of People Aged 65 Years and Over, 2001 to 2011.



Map 8 Projected Absolute Change in the Number of Lone Person Households, 2001 to 2006.

Community vulnerability can be measured through demographic and socio-economic data projections

into such assessments, if appropriate. In Queensland, Zameka and Buchanan (1999) set out a risk management framework wherein indicators of community vulnerability are documented and holistically assessed at the local government level. The demographic characteristics of the community is presently an input, but the framework itself is mostly based around analysing the "present" landscape, and hence the inclusion of projected data is not particularly highlighted. Nevertheless, the integration of projections with periods aligned to key strategic-planning horizons appears to be feasible within the structure. In the context of that structure, risk evaluation, which includes rating the likelihoods and consequences of hazards affecting landscape elements, could include analyses of "projected" demographic landscapes. This may help to identify emerging risks, and those likely to rapidly change in the near future, and hence affect the nature and prioritisation of treatment options.

In documenting the geography of vulnerability in Cairns, Mackay and Southeast Queensland, Granger et al. (1999, 2000, 2001) (Cities Project) developed vulnerability indices using a ranking, then compositing, methodology based on social and demographic vulnerability indicators for suburbs and Census Collection Districts. Again, "present" data were used to gain a current snapshot. The same techniques could, however, be broadly applied to projected demographic data at least, and appropriate comparisons made with the current landscape to resolve pathways of future change. Although again, the issue of poorer projection accuracy (perhaps unacceptably so) at the spatial resolutions used by the above-cited studies is raised—amalgamation to LGA resolution would be preferable, but reduces the number of cases to consider. Rates of demographic change based upon projections could also be included as ranking variables in the construction of the vulnerability indices to introduce a forward-looking temporal dimension.

The incorporation of demographic projections into adapted frameworks of vulnerability and risk assessment, then into strategic hazard/disaster planning at appropriate spatial and temporal scales is clearly a subject for further research.

Conclusion

This paper sought to comment on the potential use of demographic projections to forecast spatial patterns of community hazard vulnerability. It was assumed that particular demographic variables can contribute to assessments of vulnerability, at least on a regional basis. There is a range of projection methodologies available, each having advantages and disadvantages involving data requirements, assumptions and levels of complexity. In practical application, shorter projection periods (e.g. 5 to 10 years) for regions not smaller than Local Government Areas are the most reliable for demographic variables (e.g. total population and population age cohorts). Other socioeconomic indicators and indices are, if not impossible to project, difficult to project with credibility. Users must carefully consider the their information or requests in the contexts of the assumptions and limitations of projection techniques, and the decay of data reliability with decreasing spatial resolution and increasing projection period. Current challenges involve developing hazard/ disaster management, vulnerability assessment and planning frameworks that can embrace a temporal dimension, and hence systematically incorporate projected data at appropriate periods and spatial scales.

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