The Population Dynamics Behind Suburban Sprawl

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Table of Contents

Table of Figures

Abstract

No clear consensus has been reached with regards to the causes of suburban sprawl and those that have ventured ideas mostly settle on some type of behavioral change as the reason. The research presented here seeks to determine if demographic factors have had any role in the uneven dispersal, spatially and temporally, of housing (a major component of suburban sprawl) in Rhode Island. The hypothesis is that sprawl, or urban-rural migration, is not just a result of a behavior change but also more significantly a result of changes in the age structure of the population. Given age-specific migratory patterns driven by residential preference, coupled with age specific behavior patterns and a changing age structure, growth in sprawl indicators will occur seemingly unrelated to the overall growth of the contemporary population. Therefore it is necessary to compare the growth of sprawl indicators not to the growth of the total population at the time in question but to the growth of a subset of the population (a specific age group for instance) most likely to engage in the behavior associated with that indicator. Using age structure deviation analysis and a decomposition of changes in population by age group, it has been concluded that a significant portion of Rhode Island's problems with high levels of development is due to these demographic effects. This study suggests programs designed to stop sprawl should focus on specific age groups in a population to create more tailored programs. It was also determined that suburban sprawl is intimately linked to population growth displaced in time by about 30-40 years. As a result of not accounting for these demographic dynamics, the measure of success or failure of policy decisions currently risks being over or under stated if the policies are designed to decrease certain indicators of sprawl that appear may not be tied directly to sprawl. Also the research suggests that other indicators of sprawl may be susceptible to the age structure effects detailed here.

Part 1: Overview of Sprawl in Rhode Island

Introduction

Sprawl has become the hot land use topic in the past few decades as more and more land is being developed for residential and commercial purposes. Although RI is not experiencing the growth seen in hot spots such as Atlanta, GA there has been a large amount of public outcry at the building occurring throughout the state, especially in the southern region of the state. The primary goal of this research is not to determine the existence of or quantify sprawl in the state of Rhode Island but to inquire into the causes of suburban sprawl. However, knowing if sprawl exists is important to determining what elements of human behavior are part of the cause. Therefore, an overview on sprawl is included as background on the issue in RI. This leads into the methods and data used in elucidating the population dynamics behind sprawl with an analysis of the results following that. Finally a discussion regarding the implications of the study's findings are included at the end.

Definition of Sprawl

One of the most elusive aspects in a discourse regarding sprawl is a definition. Many papers and publications invoke the term without any attempt at defining what it is they are discussing (Harvey and Clark 1965). William Whyte's classic essay, "*Urban Sprawl*" (Whyte 1958), defines in a round about way suburban sprawl as leapfrog development. He then goes on to elucidate its negative effects on the economics and aesthetics of the surrounding area. From there the picture has only gotten worse with variations on the term "urban sprawl" with terms such as "rural fringe", "sprawl", "counter-urbanization" and "suburban sprawl" with expanded definitions encompassing everything from strip malls (Harvey and Clark 1965) to automobiles (Ewing 1994). Within this collection of variants a few common strains are visible upon closer inspection. Within the academic community they are limited but most notable is "the segregation of residential from other land uses, with the greater part of residences locating in peripheral suburbs" (Anderson, Kanaroglou et al. 1996). The definition by Marion Clawson that has served as the basis for much future iteration is simply stated as a "tendency to discontinuity—large closely settled areas intermingled haphazardly with unused areas" (Clawson 1962). Some later variants are "the scattering of new development on isolated tracts, separated from other areas by vacant land" (Ottensmann 1977) and "Sprawl … is composed of areas of essentially urban character located at the urban fringe but which are scattered or strung out, or surrounded by, or adjacent to undeveloped sites or agricultural uses" (Harvey and Clark 1965).

A good portion of definitions for "sprawl" come from the popular press and activist groups concerned with environmental issues. Some of note are from the Sierra Club, Grow Smart Rhode Island (GSRI) and the Vermont Forum on Sprawl. Below is a list of these definitions.

- **Grow Smart Rhode Island**- Sprawl is "an inefficient development pattern." "Sprawl describes land development trends and patterns that are wasteful because they tend to consume an unnecessarily large amount of natural resources, require redundant capital investments (public facilities and infrastructures), and waste considerable

human resources by making people commute unnecessarily long distances. Sprawl is also wasteful because it causes the under-utilization of the sizable investments already made in urban areas." (Grow Smart Rhode Island 2000)

- **Vermont Forum on Sprawl**- "Sprawl is dispersed development outside of compact urban and village centers along highways and in rural countryside." (Sprawl 1999)

- **Sierra Club 1998**- "Sprawl is low-density development beyond the edge of service and employment, which separates where people live from where they shop, work, recreate, and educate - thus requiring cars to move between zones." (Sierra Club 1998)

- **Richard Moe, president of the National Trust for Historic Preservation-** "[Sprawl is] low-density development on the edge of cities and towns - poorly planned, land-consumptive, auto-dependent and designed without respect to its surroundings" (Lockwood 1999)

The above definitions have some similarities and yet there are significant differences between them. Some of the similarities noted by Reid Ewing are, in order of frequency; scattered development, the similar leapfrog development, low-density development and finally the least discussed of the common identities of sprawl is the aesthetically challenged strip mall development (Ewing 1994). The generic definition of the English language term sprawl is "to spread out in a straggling or disordered fashion"[1] giving the term it's negative connotation[2] which is, by many involved, very intentional (Clawson 1962; Grow Smart Rhode Island 2000). While "undesirable" land use patterns generally sum up most definitions, some have equated sprawl to natural expansions of the city and others to "haphazard" or unplanned growth (Ewing 1994). Most other literature refers to sprawl without actually defining it. Tom Daniels starts "*When City and Country Collide*" (Daniels 1999) defining "rural fringe" but soon uses the term sprawl intermittently and in, what appears to be, a synonymous manner with "rural fringe". Because of the diverse nature of the literature, while also leaving the value judgments aside, "suburban sprawl" is far from universally definable. Reid Ewing makes the analogy in his literature review that sprawl could very easily be compared to the term "obscenity" which, as the courts have struggled with, has been popularly summed up as "you know it when you see it" (Ewing 1994). Leaving suburban sprawl undefined and something vague in this respect, which can be best described and discerned by measuring it's effects, is possibly one way of determining if sprawl exists in a particular area (Ewing 1994). However, this can lead to many difficulties as will be discussed below, as well as later on.

Since the course of this research is to understand what is causing sprawl, a working definition of sprawl and confirmation it is occurring in RI was needed. Using the definitions from above as a baseline from which to work from, a definition was created which encompassed the main points for which there was the greatest agreement.

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[1] Source: The American Heritage® Dictionary of the English Language, Third Edition Copyright © 1996, 1992 by Houghton Mifflin Company. Published by Houghton Mifflin Company.

[2] GSRI's actual quote is "The word *sprawl* is clearly used in a negative sense…" pg. 2-1. Clawson says "the descriptive designation of 'Sprawl'… well connotes its hit-or-miss character"

Therefore sprawl is to be defined here after as *low-density, large-lot residential and commercial development that is scattered across a large land area. This land area is separated into distinct zones requiring regular inter-zone travel. Sprawl changes the "rural" landscape of farmlands, parks and other "natural" areas into human-made environments*. This seems to encompass the meaning and spirit of what it is these organizations and individuals are trying to express. Please note that this definition does not try to "fix" what is wrong with the current definitions of sprawl but merely try to determine a clear definition that most can agree reflects what it is they see sprawl to be.

Data on Sprawl

The present research will rely on a study published in the spring of 2000 when data is not readily available from the original source and/or when the data is not relevant to the completion of the original research goals. The report entitled "*The Costs of Suburban Sprawl and Urban Decay in Rhode Island*" was undertaken by Grow Smart Rhode Island and contracted out to H.C. Planning Consultants and Planimetrics, LLP. The cost of the study was approximately $250,000 and took over two years to complete. It was funded by philanthropic organizations and state and federal sources. The detailed study of suburban sprawl included appendices of all the relevant data used and the sources for the included data were well cited.

In order to avoid debate over the study's analysis, only the raw data presented in the appendices will be used. The mistakes in the data that have been found represent such a small fraction of the overall data that, for the purposes of this research, the probabilities of more error are small enough to qualify as an acceptable margin of error. Where issues arise with regards to the analysis of sprawl in the report, discrepancies will be noted in the text but not be thoroughly dealt with.

Another aspect of the report that will be paralleled here concerns the use of certain definitions and classifications. Unless otherwise noted, these will match GSRI's, classifications and definitions. For example the classification of a municipality as urban, suburban, etc… Please note that these are not related to, nor are compatible with, US Census Bureau definitions regarding urban and non-urban classifications. Under those classifications most of the state would be classified as urban. The implications of this distinction will be dealt with later on. A map of these classifications illustrating the location of these municipalities within the state is shown in Figure 1.

Classifications:

- **Urban Core:** Contains Central Falls, Providence, Pawtucket, Woonsocket, Newport. These municipalities are also called "old urban municipalities".
- **Urban Ring:** Contains N. Providence, E. Providence, W. Warwick, Cranston, Warwick. These municipalities are considered "new urban municipalities" and have only become urbanized after WWII.
- **Suburban:** Contains Bristol, Warren, Barrington, Middletown, Narragansett, Johnston, Cumberland, Lincoln, Westerly, E. Greenwich, Portsmouth, Smithfield, N. Kingstown, Jamestown.
- **Rural/Emerging Suburban:** Contains Tiverton, Coventry, S. Kingstown, N. Smithfield, Burrillville, Charlestown, Scituate, Little Compton, Glocester, Hopkington, Richmond, Exeter, Foster, New Shoreham (Block Island), West Greenwich

- **Urban:** Contains both urban core and urban ring groups combined.
- **Non-urban:** Contains both suburban and rural/emerging suburban groups combined.

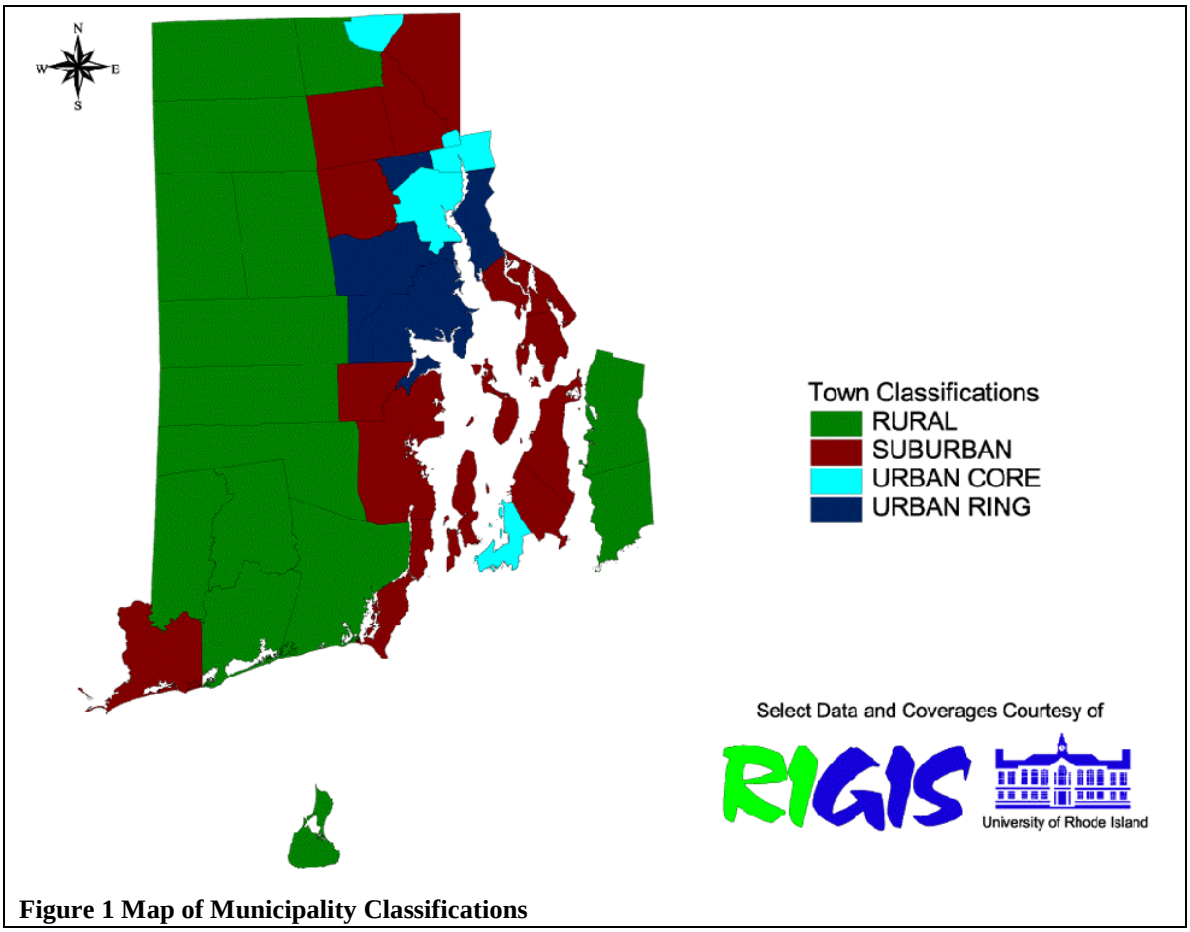


Figure 1 Map of Municipality Classifications

Effects/Indicators of Sprawl

The pool of possible effects that could potentially be measured follows in Figure 2:

- Loss of open space
- Increased cost of infrastructure
- Loss of rural character
- Loss of farms and forestland
- Loss of community character
- Air pollution
- Water pollution
- Increased time in traffic/increased vehicle miles traveled (VMT)
- Increased energy consumption
- Loss of urban population to non-urban areas
- Urban decay
- Increases in housing starts and building permits
- Housing location trends in once rural areas

Figure 2 Effects of Sprawl, Taken from various sources.

- Loss of open space
- Housing construction trends in once rural areas
- Increases in single family housing starts and building permits[3]
- Loss of farms, forestland
- Increased time in traffic/increased vehicle miles traveled (VMT)[4]
- Greater increase of population in non-urban areas as opposed to urban areas
- Generalized urban decay

Figure 3 Rhode Island Specific Indicators of Sprawl Chosen for this Research

Taken from the list in Figure 2, the effects of sprawl that will be of concern to Rhode Island are listed in Figure 3. What will not be considered as a measurable effect in this research are the many subjective characteristics of sprawl such as loss of rural character and loss of community character. Some quantifiable aspects such as air pollution, water pollution and increased energy consumption, although measurable, will remain un-contested.

As most research on sprawl uses the effects of sprawl as indicators, the current work will do the same. In the following list, the effects relevant to RI are being employed as indicators. For some indicators the timeframe is outside the timeframe being employed for the demographic analysis (1970-1990). This is due to data availability and so this data should only be used as a trend indicator and not be used to draw exact comparisons.

Loss of open space

One indicator of sprawl is the level and location of land that is developed in an area. In Rhode Island, from 1960-1995 the amount of developed land increased from ~ 6,000 ft^2/person to ~ 9,000 ft^2/person for an increase of 50% (Crawley and Nelson 2000). As well, between 1961 and 1995 the urban core saw a 54% increase in developed land while the rural and suburban areas experienced a 205% increase in the amount of developed land. (Grow Smart Rhode Island 2000)

[3] Apparently this is both in the aggregate and/or in rural areas. The literature has both.
[4] Apparently measured in per capita terms.

With regards to residential housing and its effect on land use and the environment, 71% of all housing in Rhode Island was located in urban areas in 1960 while in 1995 only 59% of all housing was located in these same urban areas. (Grow Smart Rhode Island 2000) This shows that there is a decentralization of housing in the study time period of 1970-1990. That has also led to issues regarding the level of land dedicated per housing unit. Between 1961 and 1995 the acreage per housing unit in the urban core rose from .09 to .14 acres. In contrast the rural areas saw an increase from .64 to .85 acres per housing unit. (Grow Smart Rhode Island 2000) An example of this growth can be seen in Figure 4 where the housing is being placed in the center of large lots.

Housing location trends in once rural areas

Currently there is a strong push in Rhode Island's rural communities to enact growth caps or other anti-growth measures to curb sprawl. Municipalities such as Hopkinton, Charlestown and others have enacted growth caps while Coventry had banned construction altogether for six months to study the effects of what construction had already taken place (Sabar 1999). For reference, a map of construction for 1988 through 1995 is shown in Figure 5 and illustrates where development has been concentrated. Only land that was re-classified is shown. On the left is the classification the land was in 1988 while the right shows what the land was reclassified as by 1995. Notice that most of the land that was re-classified was land in the non-urban portion of the state.

Images Courtesy of:
Matthew Amengual

Select Data and Coverages Courtesy of
RIGIS
University of Rhode Island

Figure 4 Sub-Division in Charlestown, RI.

The housing construction was incomplete at time of photo.

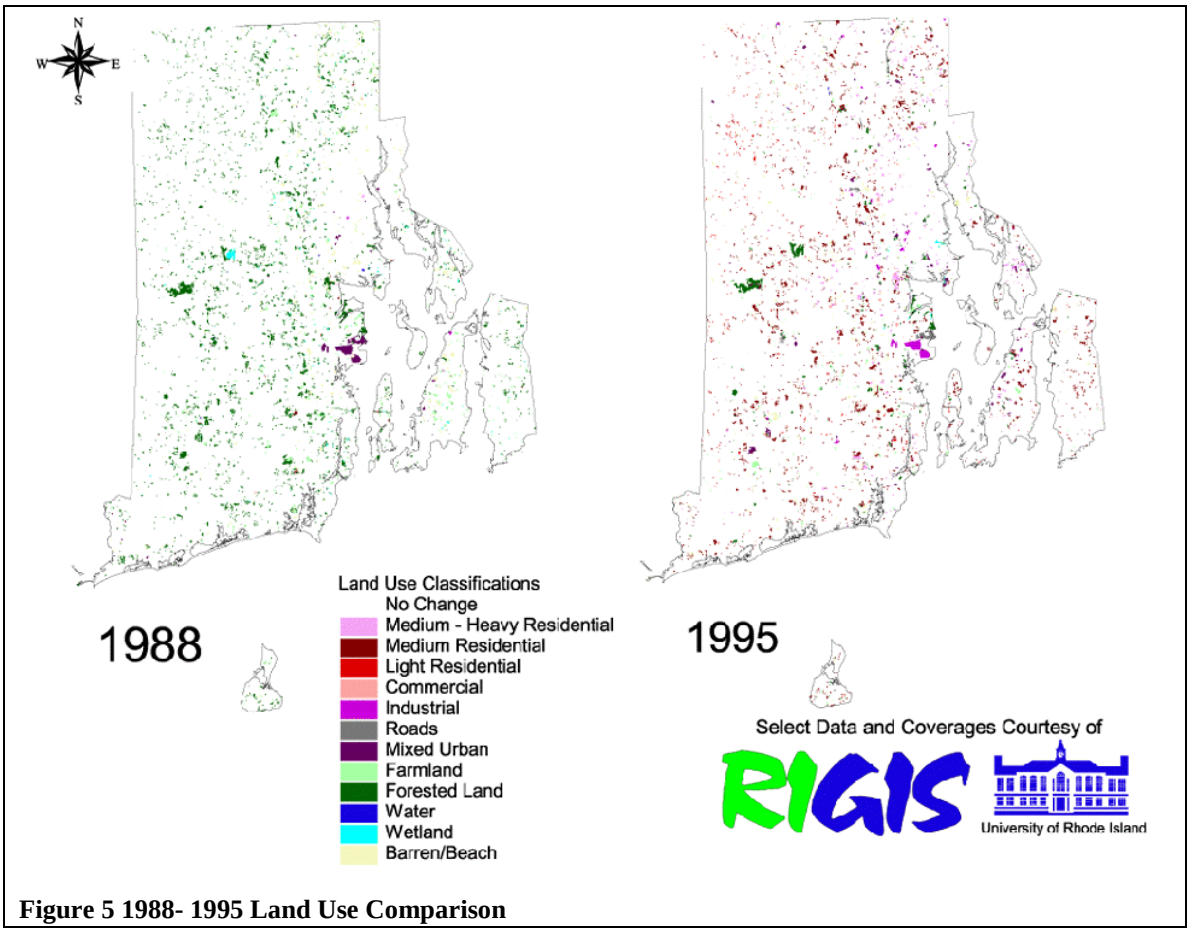


Figure 5 1988- 1995 Land Use Comparison

Increases in single family housing starts and building permits

One of the major marks of sprawl is the increase in the housing construction outside of the urban areas. Figure 6 shows peaks in construction during '86 and '87, which was the height of the building boom and the similar pattern over a longer period starting in 1954. Although the data is for the state as a whole, most of this construction took place in the non-urban areas. These peaks also correlate with known economic "boom" times in both Rhode Island and the US as a whole. In general, increases in single-family units are considered less desirable since multi-family units are economically more cost effective (Sussman 1977) and conceivably utilize less space per person for housing.

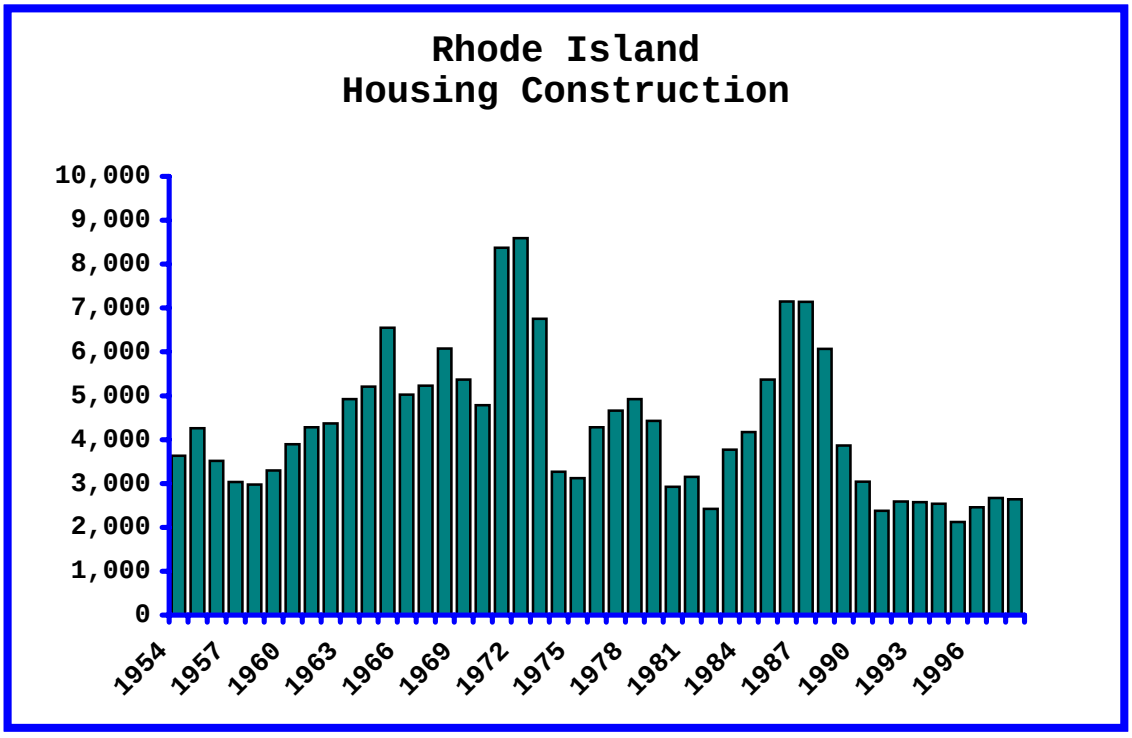
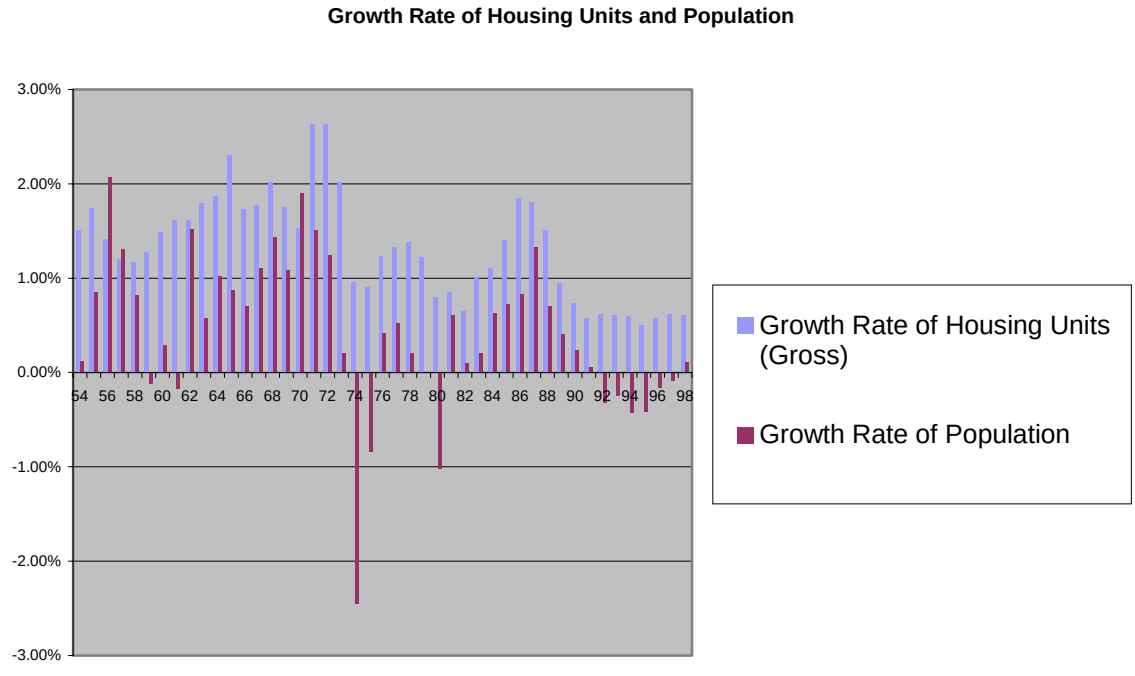


Figure 6 Single and Multi Family Housing Construction 1954-1998. Data and Graph from RI–EDC



US Census and Rhode Island Economic Development Corporation

Figure 7 Comparisons between Population Growth and Housing Growth

Figure 7 illustrates that the level of construction has far outpaced the population growth for the period from 1954 through 1998. Some of this phenomenon has been attributed to declining household size, which will be dealt with later on. Taking census numbers as well as data on housing stock/construction from the US Census Bureau and Rhode Island Economic Development Corporation Figure 7 was created. The sharp spikes in the Census numbers reflect known out migrations of people in the time periods shown. It is not known whether this was based on a complete count or on sampled data from surveys but the latter is assumed, as it is not a census year. It is likely that the negative spikes in the mid 70's are military base closings/cut backs along with a change in the handling, by the Census Bureau, of military in census enumerations. This will be detailed below in Part 2 in the section regarding data on page 19.

Loss of farms and forestland

A loss of farms and forestland is also considered an effect of sprawl. In Rhode Island, between 1970 and 1995 the acreage of forestland decreased from 410,640 to 300,861 acres and the acreage of farmland decreased from 62,120 to 49,091 acres. (Grow Smart Rhode Island 2000) The change in these two indicators total about 123,000 acres. Total increase of developed land for the state over the same time period was 60,000 acres. This leaves a discrepancy of approximately 60,000 acres that went from farm/forestland but were not developed. No obvious answer to this mystery was readily available. However, one possible idea is that reclassifications in the GIS coverages that these values were calculated from had occurred. An example is where forestland was reclassified as something such as wetland, which is not considered developed or forested, even if it has tree cover. This is a limitation of the current GIS classification system that allows only one land use classification to any given parcel of land. It is also important to note that it does overestimate the damage sprawl has had on farming and forestland. All told however, there has been significant degradation and removal of those things that are characteristic of rural areas.

Increased time in traffic/increased vehicle miles traveled (VMT)

Every area has its particular quirks and oddities that separates and distinguishes it from the world around. For Rhode Island measuring an increase of commute times is rather futile due to the fact commute times have only increased an average of one minute per every ten years between 1970 and 1990 when it was calculated at around 20 minutes as per the US Bureau of the Census General Characteristics for 1990.

Rhode Island does not have the gripping traffic congestion characteristic of many other metropolitan areas. However, vehicle miles traveled has increased markedly. Between 1992 and 1998 the VMT/person went from 7,600 to approximately 8,000 in 1998 according to the RI DOT as cited in (Sabar 1999). There was also a large increase from 1987 and 1992 but the data used to determine that has been called into question (Mc.Enanly 1999). Additionally, motor vehicles per person increased 81% from 1960-1997 in Rhode Island (Grow Smart Rhode Island 2000) and between 1979 and 1988 the number of registered motor vehicles in urban areas increased 35% while in the non-urban areas the increase was 65%. (Grow Smart Rhode Island 2000)

Loss of Urban Population to Non-Urban Areas

Notice in Table 1 that growth in population, housing and motor vehicles has all increased over the last twenty years in the suburban and rural areas above the state average while the urban areas have increased below the state average with the Urban

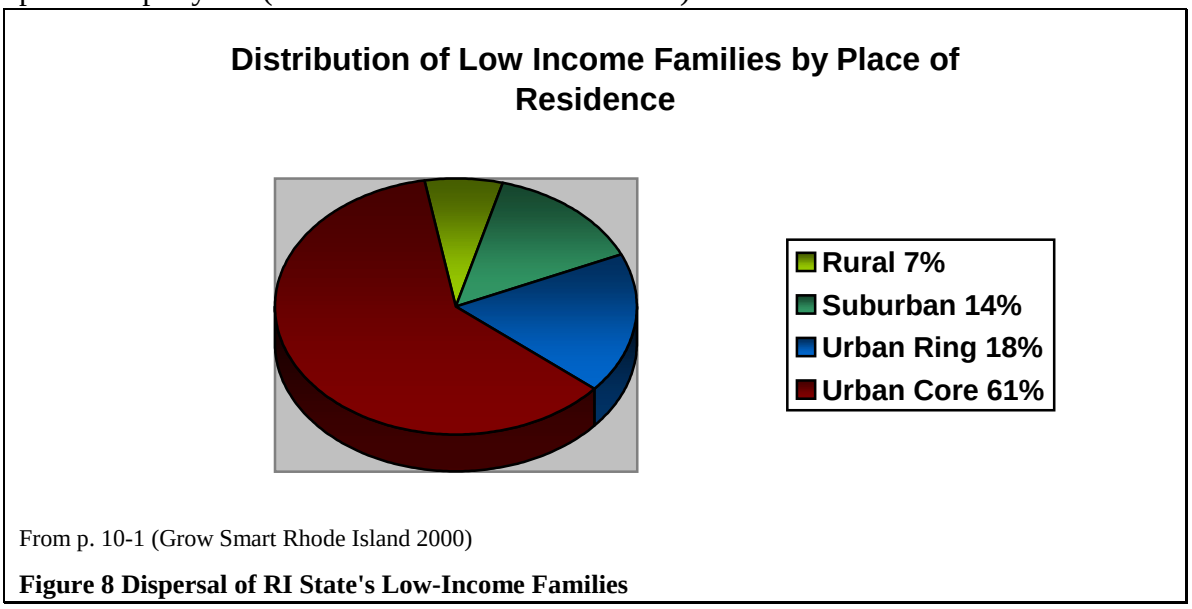
Core actually experiencing decreasing growth. At the very least this shows that the vast majority of people are not moving into the urban areas but instead moving into the non-urban areas. Despite being almost fully developed, the urban areas have land that is capable of housing more people than current numbers. For example, in 1998, within the urban areas, there were 8,723 vacant residential lots and 2,065 vacant commercial/industrial lots. (Grow Smart Rhode Island 2000) At a rate of 4 people per home that would house over 34,000 more people in the cities and lessened demand for new construction in the outlying areas.

Community Type	Population	Housing	Motor Vehicles
Urban Core	0.90%	2.30%	-5.20%
Urban Ring	2.70%	16.20%	12.00%
Suburb	13.50%	29.00%	27.10%
Rural	22.80%	38.70%	47.80%
State	6.80%	17.10%	16.40%
	From p. 3-3 (Grow Smart Rhode Island 2000)		

Table 1 Growth Rates of Population, Housing and Motor Vehicles from 1980 - 2000

Urban Decay

Another effect of sprawl on the cities commonly cited, and a rather controversial one at that, is the concentration of low-income families in urban centers. In urban areas, 51.3% of school children qualify for free/reduced-price meals while only 13.9% of all Non-Urban school children qualify for the same. (Grow Smart Rhode Island 2000) Figure 8 shows that the five urban core cities have more than half of the low-income families in Rhode Island. In Rhode Island, the percentage of the overall employment attributed to urban areas decreased from 85% in 1960 to 71% in 1997. (Grow Smart Rhode Island 2000) Urban areas lost private sector employment between 1980 and 1997 at a rate of 273 jobs per year. In contrast Non-Urban areas gained jobs at a rate of more than 2,800 positions per year. (Grow Smart Rhode Island 2000)



From p. 10-1 (Grow Smart Rhode Island 2000)

Figure 8 Dispersal of RI State's Low-Income Families

Causes Cited for Sprawl

One of the first qualifiers used from the press (Sabar 1999) to GSRI (Grow Smart Rhode Island 2000) is that overall concurrent population growth in the state was not peaking (had peaked earlier) yet housing construction has reached all-time highs over the same period of time. In other words, the demographic profiles that are most commonly drawn reflect the low levels of population increase within the research period and the overwhelming growth of housing, automobile use and other effects/indicators of sprawl outpacing population growth during this same period. One example of this comes from Christopher B. Leinberger "In the 1970s and 1980s, for every one percent of population growth in a metropolitan area, there was a six percent to 12 percent increase in land consumption." (Lockwood 1999) Mr. Leinberger is the managing director of Robert Charles Lesser & Co., a Los Angeles-based national real estate consulting firm. Another quote comes from the Federal Highway Administration; “From 1969 to 1989, the population of the United States increased by 22.5 percent -- and the number of miles driven by that population (‘vehicles miles traveled’ or ‘VMT’) increased by 98.4 percent.” (Federal Highway Administration 1991) Academic articles also reflect these comparisons as both Ottensmann (Ottensmann 1977) and Boyce (Boyce 1963) compare growth of housing and developed land area to overall population growth. In a bulletin published by the Population Reference Bureau (PRB) dealing with environmental concerns, the authors note “although population grew 34%, waste increased 80%”(Magder and Merrick 1990).

Table 2 List of Sprawl Causes Commonly Cited

Cause	Reason	Objection
Affluence	Periods of rapid land development coincide with prosperity. Sprawl is an inevitable sign of good times.	Developers and homebuyers do not shoulder the entire cost of sprawl.
Government Subsidy	Sprawl is encouraged by government spending…	Over the years, public subsidies have been scaled back. Yet sprawl has not diminished.
White Flight	…Masses of white Americans left cities to live in the suburbs.	Postwar white flight is well documented, but nowadays, race is less of a factor than quality of life issues such as traffic and schools.
Population Growth	Birth and immigration rates drive sprawl	Sprawl has occurred in every metropolitan area whose population has stagnated or shrunk.
Technological Change	Sprawl is a consequence of the popularization of the car… and innovations in assembly style-line-style construction.	Other countries, even with abundant land, underwent the same changes without producing as much sprawl.
Government	Sprawl is the result of	Poor execution is less a

Shortsightedness	government's inability to plan for future growth or stick to existing plans.	cause than an effect. Had there been a will, governments would have found a way.
		Taken from (Chen 2000)

Using this qualifier many researchers and environmentalists assume population growth does not have a hand in causing sprawl. One of the exceptions to this rule is a paper out of Australia (Hugo 1988) which makes mention that the sprawl occurring in Australia is partially a result of demographic effects due to age structure but does not elucidate on what was meant. Some develop theories regarding urban form and that there has taken place a fundamental change in peoples settlement patterns (Anderson, Kanaroglou et al. 1996; Daniels 1999; Filion 1999). Others cite automobiles and other affluences located in the United States as a whole (Kirk 1973; Bowler 1977; Ewing 1994; Grow Smart Rhode Island 2000). Others (Bloom 1977) cite a lack of affluence as a reason for sprawl as fringe land tends to be cheaper then land inside urban centers.

Other less common causes cited are indirect social influence (Boschken 1998) and automobile dependence coupled with economic incentives and a lack of alternatives with urban decay accelerating the trend to suburbia in the later years (Ullmann 1977). One somewhat demographic theory cites smaller family size and multiple wage earners in a given household which gives rise to a demand for logistics planning in commuting issues (Bloom 1977). A list of generic causes can be found in Table 2

Conclusions on Sprawl in Rhode Island

As has been demonstrated, suburban sprawl is occurring in Rhode Island and the indicators are responding much in the same way conventional literature suggests it would. Table 1 shows that the growth rates of the three main indicators of sprawl are higher the farther out from the urban core one looks. Rhode Island development is characterized by low-density, large-lot residential and commercial development that is scattered across a large land area. The indicators of sprawl in Rhode Island increase over a given time at a significant and proportionately higher rate than the overall population growth for the state. The population rate of increase of rural municipalities and areas is disproportionately higher than that found in the urban centers.

Sprawl is changing the "rural" landscape of farmlands, parks and other "natural" areas into human-made environments faster than in urban areas. This is evidenced by the measures being taken by each municipality in the South County area. Current minimum lot sizes for new construction are 2 or more acres per subdivision in many municipalities and growth caps are becoming the hot new topic among town boards, planners and residents.

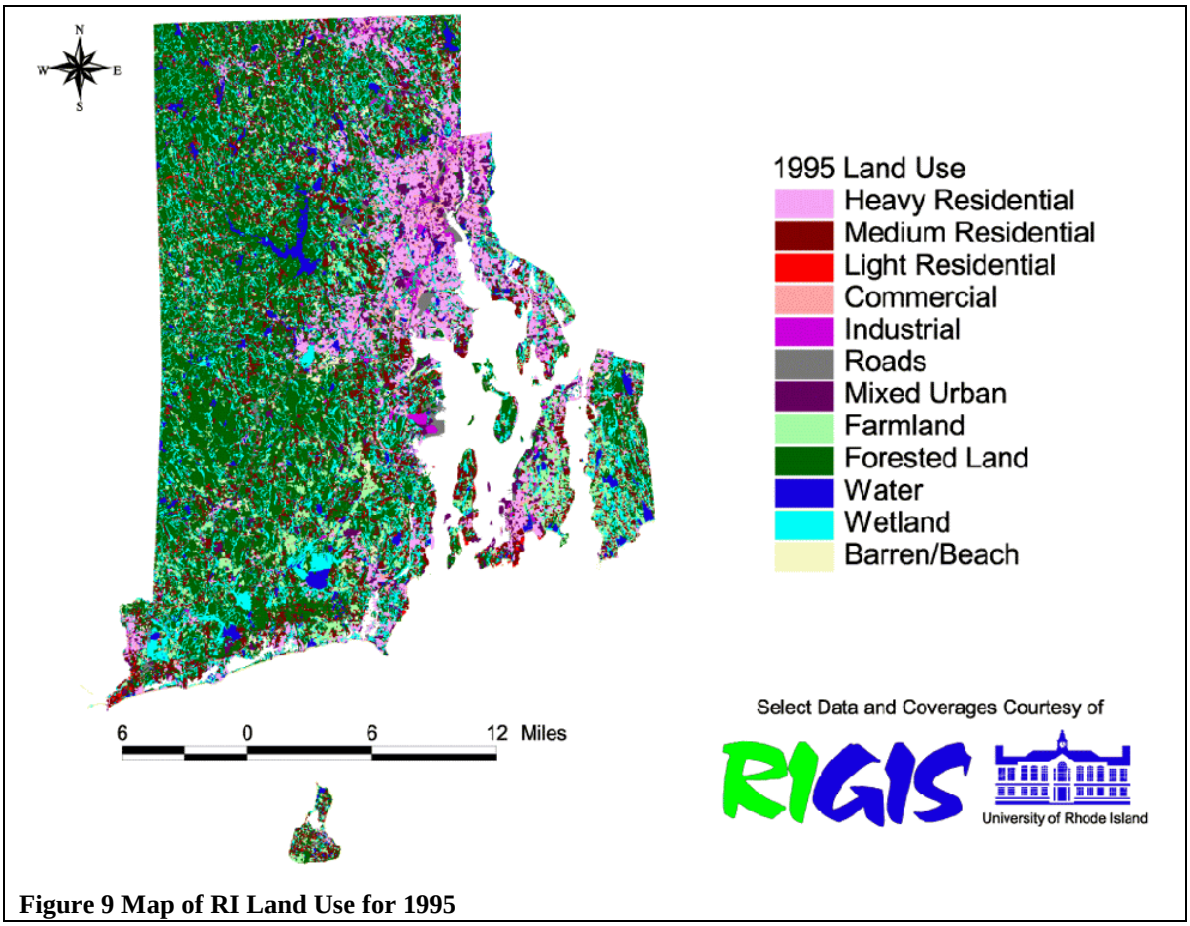


Figure 9 Map of RI Land Use for 1995

Part 2: Research Design and Methods

Introduction

The hypothesis is that sprawl (measured primarily through housing demand) or urban-rural migration is not just a result of a behavior change (changes to the age specific internal migration rates or household size) but also more significantly a result of changes in the age structure of the population (little or no change to the age specific migration rates). Given age-specific migratory patterns driven by residential preference, growth in sprawl indicators will occur cyclically if the age structure is uneven. Growth in sprawl indicators will also occur seemingly independently of population growth unless one corrects for the delay between birth and when the behavior, such as purchasing of a home, is most likely to occur. Therefore, one cause of suburban sprawl is the combined effect of internal life-cycle migration, age specific behavior patterns, age specific residential preferences and the age structure of the population.

At the core of the argument on sprawl is the belief that as time has progressed, people of similar demographic characteristics have had an ever-increasing affinity for the non-urban areas over urbanized areas, thereby increasing housing demand in non-urban areas over urban areas. To determine if that were the case, it would, in part, require knowing the age specific migration rates between non-urban and urban areas. If there existed a rate of people moving from urban to non-urban areas (age specific internal migration rate) and if it were in effect increasing, then this would constitute a behavioral change, or in other words a shift in residential preference. As these internal migration rates were not available for this dataset, an alternative analysis was undertaken to determine residential preference from differences in age structures of populations residing in various regions within the state at multiple points of time. Then an analysis of the age structure will be done to determine the impact of migration and natural increase on each region (urban and non-urban). Finally, an analysis of housing will be done using the results from the first two methods.

Data and Classifications

The census figures used for this study were collected into a database manually from the US Census Bureau books for the years 1970 to 1990 and consisted of counts of people living in the State of Rhode Island on the Census date. Municipality of residence and 5 yr age group (starting 0-4) grouped the data with no delineation between sex and racial composition. Numbers for the state totals were collected and used as a baseline to ensure accuracy. This was accomplished by totaling each municipality by age group and comparing against the collected state totals. All municipalities were classified two ways as described above by the GSRI definitions of Urban and Non-Urban as well as Urban Core, Urban Ring, Sub-Urban and Rural. These classifications were made based on the municipality in the 1990's and were not changed throughout the entire time period covered by the study. Note again that the US Census definitions of Urban and Rural were not employed.

One data abnormality was found with regards to US Military personnel stationed aboard ship but attached to the Naval Base in Middletown, RI outside of Newport, RI. This is an abnormality as only 1970 represents these sailors since the Census Bureau

modified their methods, according to the US Census Bureau 1980 Rhode Island General Characteristics book, to include Naval personnel differently in 1980 and 1990. The most likely explanation was a change in the US Census Bureau's handling of military personnel whose ships are stationed in a particular port but whose housing and family live in another area. Up to and including 1970 ships whose home berth was in an US port had the entire complement of military personnel on board attributed to the homeport city. This was, despite no form of permanent housing on land and that sailors could easily have housing somewhere else in the state or the country where their families lived year round. From 1980 on that was changed to place a sailor in their permanent residence for census enumeration. Compounding this is the base closing which occurred during this time that would impact Middletown and nowhere else in the state (directly at least).

Therefore, Middletown was removed from the study. Three other municipalities out of 39 were excluded from the survey due to lack of data. These were municipalities not represented by name in the state's US Census General Characteristics book so the tract data representing the municipality was found but ultimately not used. West Greenwich, Little Compton and New Shoreham (Block Island) were removed because the data was unavailable in 5 yr. age groups or in 10 yr. age groups where 0-10, etc; was the breakdown due to their small population sizes. These municipalities are very sparse rural areas.

Birth rates for the state were collected from the Rhode Island State Department of Health (RI-DOH) since the Census Bureau does not provide fertility or mortality data. The data was collected for the age groups of 15-44 by five year grouping in per 1000 numbers. The rates were only considered accurate for the Census years[5], therefore only the rates in census years were collected. Birth rates were determined by state only and not on an individual municipality basis as they were unavailable for most of the study period.

Death rates were created for the state using total deaths using data collected from the RI-DOH. This was accomplished by dividing the number of deaths in an age group by the number of people in an age group. Similar to births, this was done statewide and not by municipality, as numbers were unavailable on a place of residence basis for most of the study period and only for place of death.

The classifications of municipalities into urban, non-urban etc; were done in a way to continue an established set of conventions used in other studies regarding sprawl in Rhode Island. This is from the work on the subject by RI Statewide Planning Program (RI Statewide Planning Program 1999). This will promote compatible data and will hopefully allow those studies to re-evaluate their original conclusions from within the new framework the present research. The results of the classifications were shown above in Figure 1 and were based on 1990 data[6].

Municipalities were classified based on meeting the following criteria from Statewide Planning:

Urban

(Urban Ring and Urban Core is delineated out of this larger group by age of city)

- **Population Density:** 2,500 or more persons/mi^2 *and*

[5] Based on footnote information in the RI-DOH data books, the RI-DOH uses census figures to calculate rates for both fertility and mortality and only provides rates for years that a census was taken.

[6] This is also the only year where these classifications would be accurate as they rely on land use data that is not at a very high resolution prior to 1988.

- **Urban Land Uses:** More than 50% of total land developed.

Suburban

- **Population Density:** 500 – 2,499 persons/mi^2 *and*
- **Urban Land Uses:** More than 25% of total land developed.

Rural

- **Population Density:** 500 or less persons/mi^2 *or*
- **Urban Land Uses:** Less than 25% of total land developed.

Note that Urban is separated into Urban Core and Urban Ring by age of the city, where older cities are pre WWII and new urban centers are post war era.

Methods

Age Structure and Cohort Analysis

The first part of the analysis was to look at the state's overall age structure to illustrate the very uneven nature of the age structure in Rhode Island. It was then necessary to determine what, if any, impact migration out of the state had on the age structure of the population and how individual cohorts had changed over time. Performing a standard cohort analysis on the population using the census data from 1970-1990 accomplished this and showed that the change was minimal (results in the next section).

Components of Change

Next the components of change for the population were decomposed into migration and natural increase. This method uses a standard cohort component population model in use by demographers for modeling population projections. (See Appendix 1 for more information) Running the model yielded the level of natural increase[7] each region would expect given zero migration. The resulting numbers for natural increase were then used to compute net migration for the study period. This showed the impact of each demographic component comprising the total change in the population.

Age Structure Deviation Analysis

The next part of the analysis used a method referred to as Age Structure Deviation Analysis and is detailed further in Appendix 1. This was used to compute the difference in the age structure between a particular region at a particular time and the state age structure as a whole at the same point in time (a period analysis). Any deviation between the two is assumed to represent an age specific residential preference. If a similar pattern of age specific preference occurs year after year, then there must be a pattern of migration occurring internally in the state in order for this to occur. Therefore, in the absence of direct data on age specific migration rates between the two regions, evidence of migration (in net terms) can still be found based on the effect it has on the age structure of the population, providing there is an age specific preference for housing.

[7] Natural Increase is simply the amount of change to an age group from a previous time, absent migration.

Housing Analysis

Decomposing the sources of housing growth in the state and each region by using the demographic components of change and age-specific householder rates will complete the analysis. This will quantify the actual sources of housing change and show to what extent, if any, behavioral changes have contributed to the phenomenon of sprawl.

Part 3: Results and Analysis

Age Structure

The age structure of RI was checked for the presence of an uneven age structure needed to drive an age structure effect. Population profiles for the State of RI for the years 1970, 1980 and 1990 are shown in Figure 10. These illustrate the statewide age structure of the population as a whole and show the large amount of deviation between individual age groups over time. Notice that the groupings move forward in time every ten years by 2 age groups. Notice also the 10-14 age group in both 1970 and 1990. Despite a net increase in total population of 63,677[8] or a 7% increase from 1970 to 1990, the 10-14 year old age group was smaller in 1990 by 28,220 or 33% of the 1970 value.

Another more pronounced example of the extreme difference the age structure has over time is the 30 –34 year old age group. In 1970 there were 47,276 and in 1990 the number had shot up to 87,772, which is almost double its 1970 value. As stated earlier, during this same period of time the population as a whole had only increased by 7%. This later cohort (30-34 in 1990) is part of the generation also known as the baby boom generation. That phenomenon is part of the cause of this significant shift in the population. Another significant cause for this variability is the "baby bust" (born in the 1930's) that preceded the baby boom. As far as a comparison with the US as a whole, Rhode Island has a similar age structure except there is a larger elderly population. This made Rhode Island, in 1990, the state with the third oldest population (percent over 65), with Florida and Arizona 1st and 2nd respectively. All told, the presence of an uneven age structure shows that there is a possible contribution to sprawl from an age structure effect.

[8] Adjusted to not include the four problem towns.

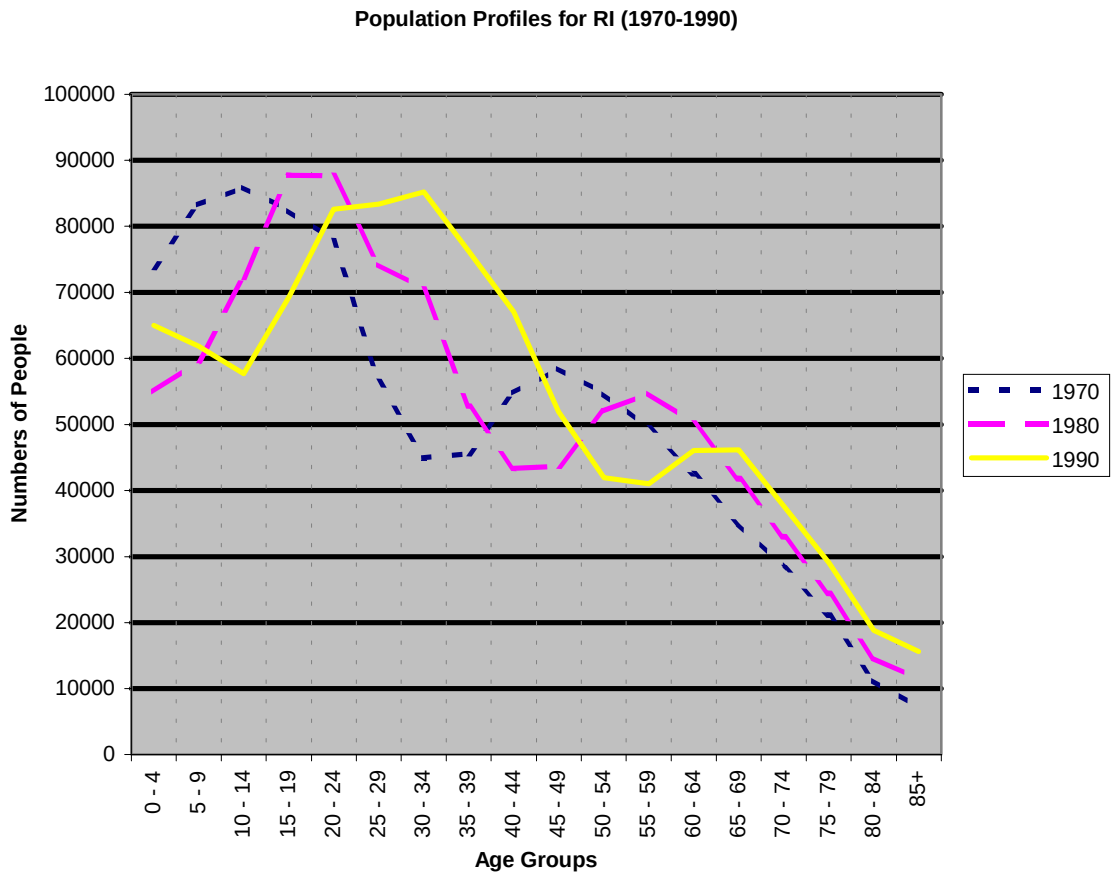


Figure 10 Population Profiles for Rhode Island (1970-1990)

Cohort Analysis

A cohort analysis was done to determine if the cohorts of Rhode Island's population had changed to any great extent over the study period. Figure 11 is a cohort analysis of Rhode Island over the study period that illustrates the fact that each cohort, or group born at the same time, has not changed significantly over the twenty year study period, with two notable exceptions. The first of these two exceptions is the effect of mortality on those born before 1920 over the study period. The second illustrates two things; the period effect alluded to above and the impact of RI's large college population. The period effect is a net out migration during the 1970's for all cohorts born before 1970, which was a combination of military base closings and economic factors which led to a decline in parts of the population. Based on Figure 11, this out migration appears to have affected the cohort of those born between 1945 and 1955 the most, or those most likely in college or part of the military. The differences between the 1980 and 1990 census shows the impact of the college population predominately.

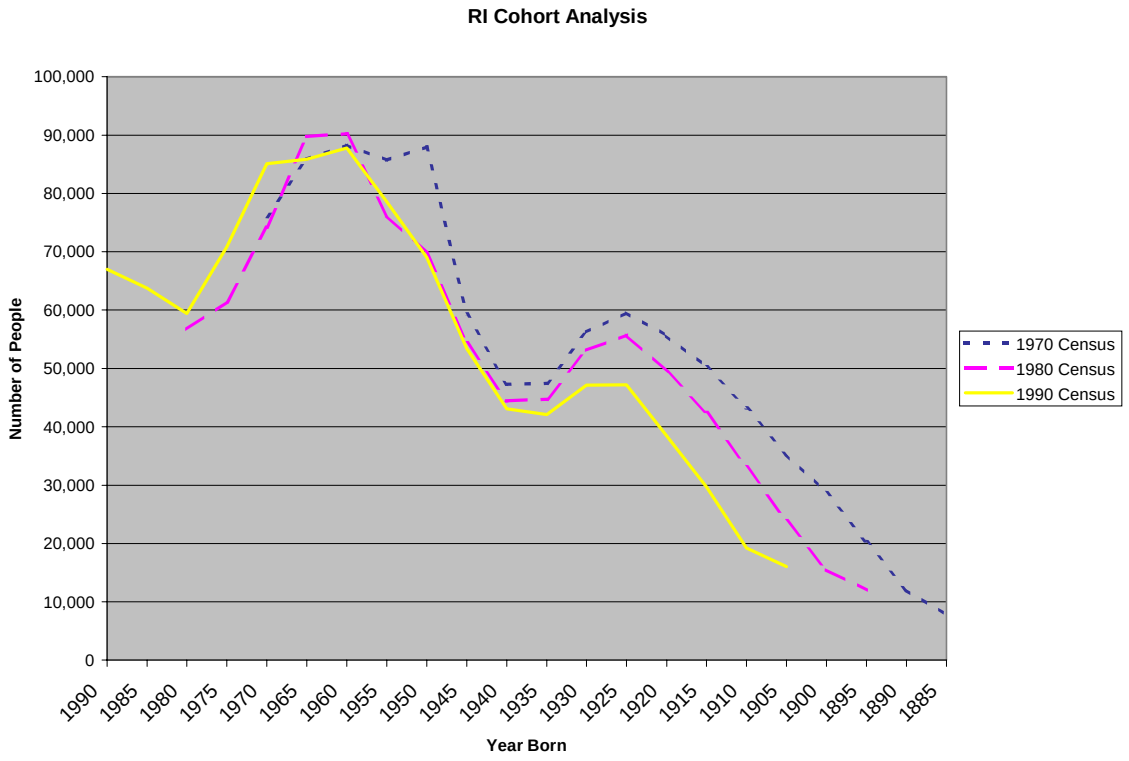


Figure 11 RI Cohort Analysis

Components of Change

The historical population was modeled using birth and death rates for the state while holding migration at zero in order to determine the sources of change in the demographic profiles. Figure 12 through Figure 15 are results from the model runs (Appendix 2 is a table of results) breaking down the overall change in each age group over time into the proportional impact from migration and aging (natural increase is the total amount of the aging column). Keep in mind that out migration is a number that is subtracted from natural increase in order to determine total change. Notice the variability of contributions to change from aging and that in the relevant age groups of 30+ aging is a greater contributor to change than migration is in most of those groups. This is due to the differences in the age structure of the population. Also, notice that although migration has played a significant role in the increase of population in the non-urban areas, natural increase accounts for two-thirds of all increase in that region during the 1970's as seen in Figure 17. However, in the 1980's the contribution is only about a third. This shows that natural increase was a factor in population increases in the non-urban areas but that migration also played a role but over the two decades that role changed significantly. In other words migration from urban to non-urban areas has increased.

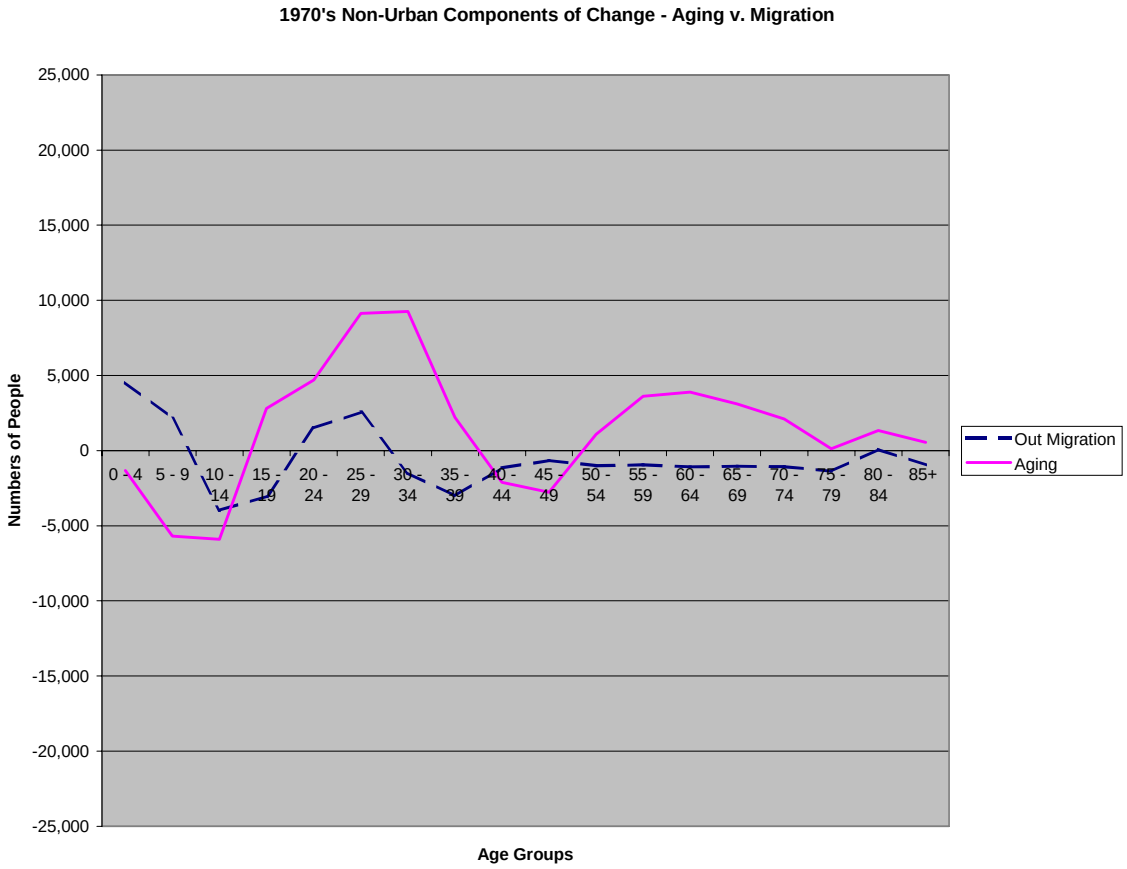


Figure 12 1970's Non Urban Components of Change - Aging v. Migration

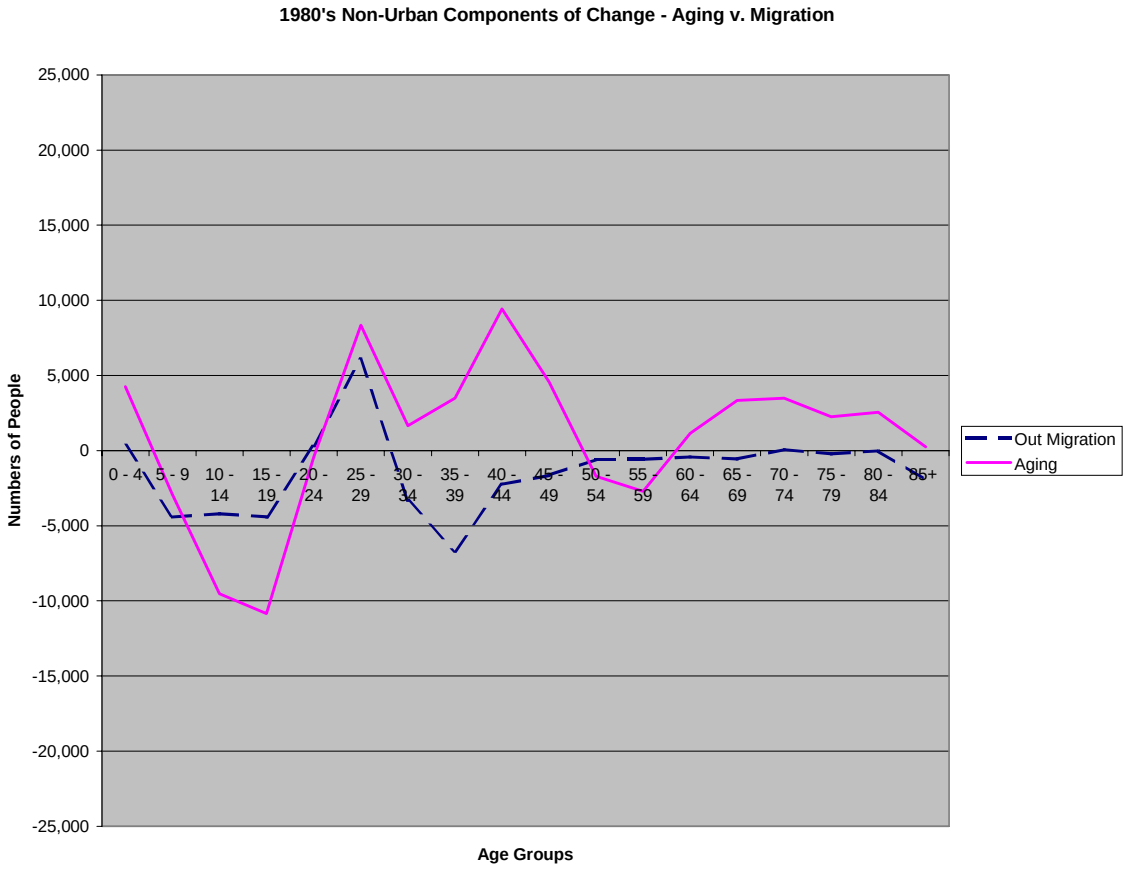


Figure 13 1980's Non Urban Components of Change - Aging v. Migration

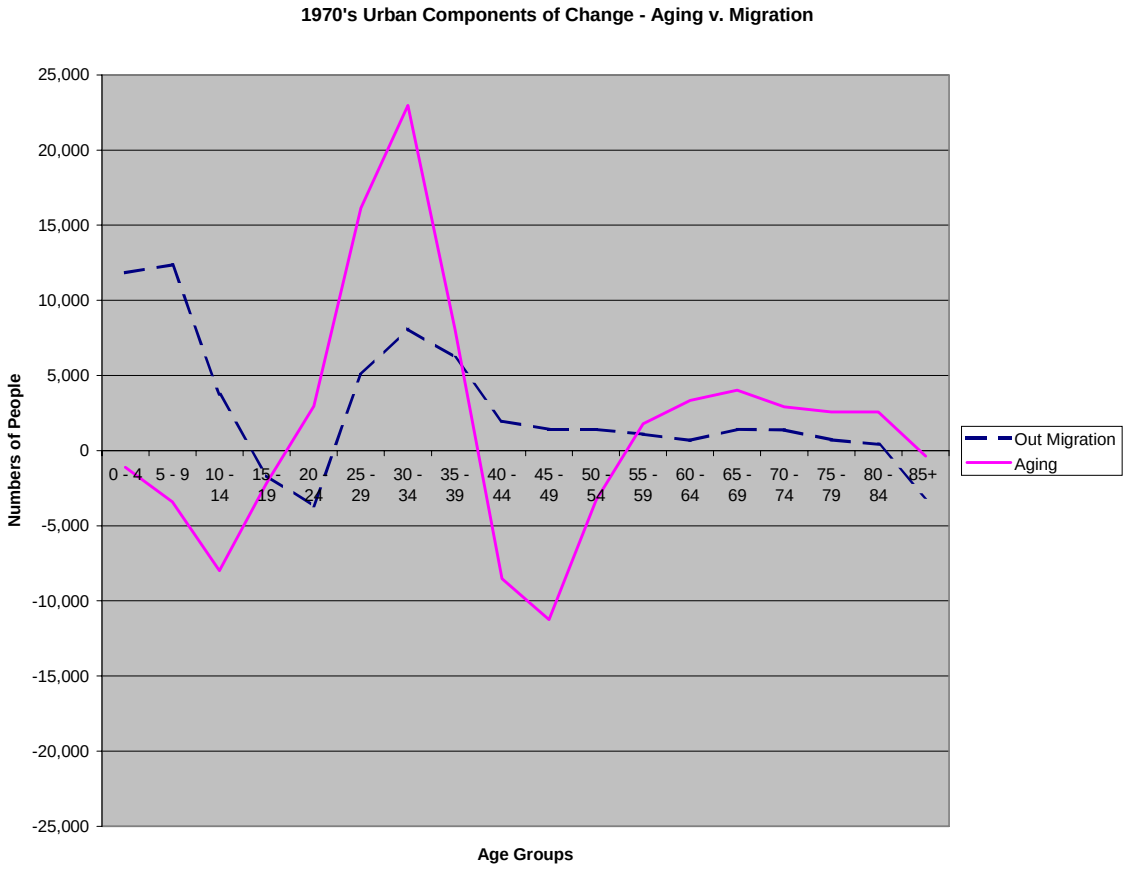


Figure 14 1970's Urban Components of Change - Aging v. Migration

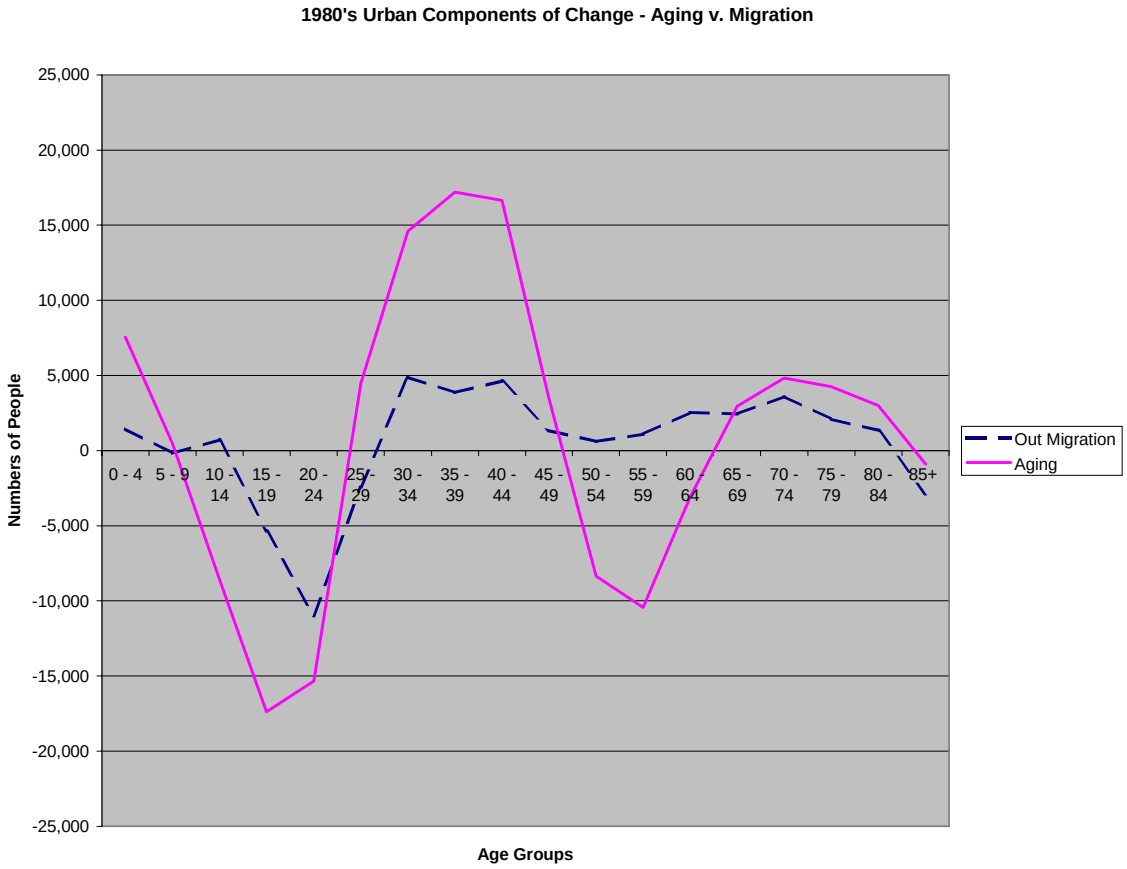


Figure 15 1980's Urban Components of Change - Aging v. Migration

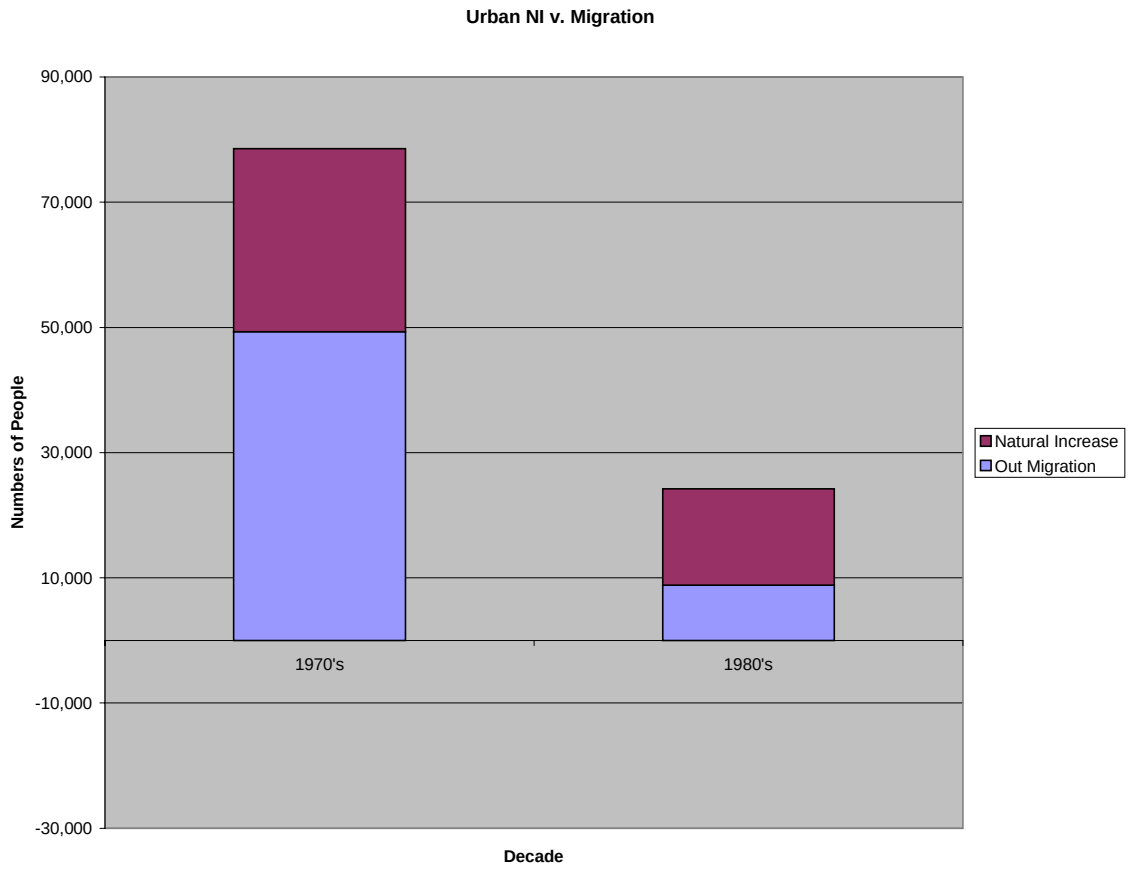


Figure 16 Urban Natural Increase v. Migration

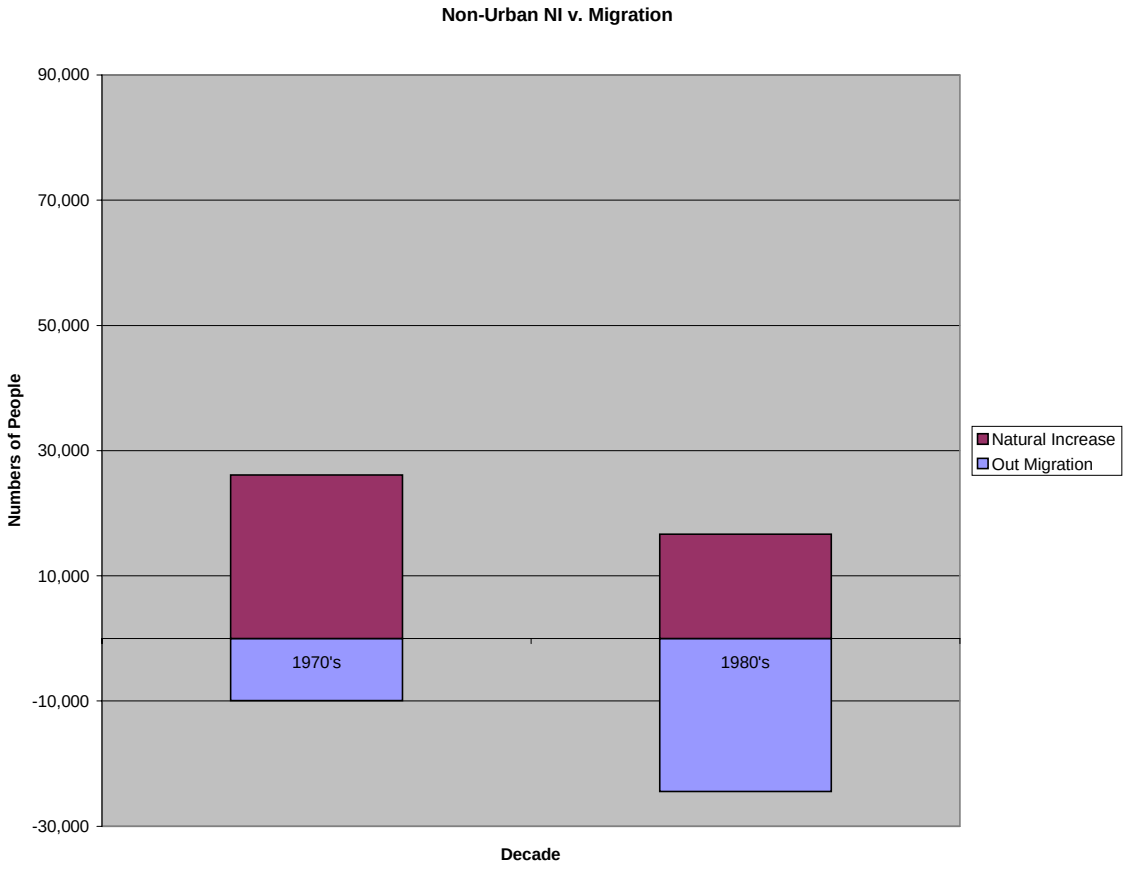


Figure 17 Non Urban Natural Increase v. Migration

Internal Migration and Age Structure Deviation Analysis

At first glance, there does appear to have been an increase in migration into the non-urban areas. It appears that migration has doubled into the non-urban region. Assuming that the migration rate to and from the non-urban areas is equal for all people, this is where the analysis would stop. However, as seen in Figure 18, there appears to be a residential preference of those under 18 for certain areas of the state. At first glance these areas seemed to correlate with the location of the non-urbanized areas. Assuming that each age group had a preference for one area over another, there was a way to determine if that preference had changed over time. This is where Age Structure Deviation Analysis was used to ascertain if age-specific residential preference, and therefore internal life-cycle migration[9], did in fact exist and had it changed over time.

[9] Defined as the migration occurring at specific points in one's life (distinct from yearly migration patterns), tied to the person's age and between two or more destinations that are generally within boundaries normally associated as one unit when discussing migration.

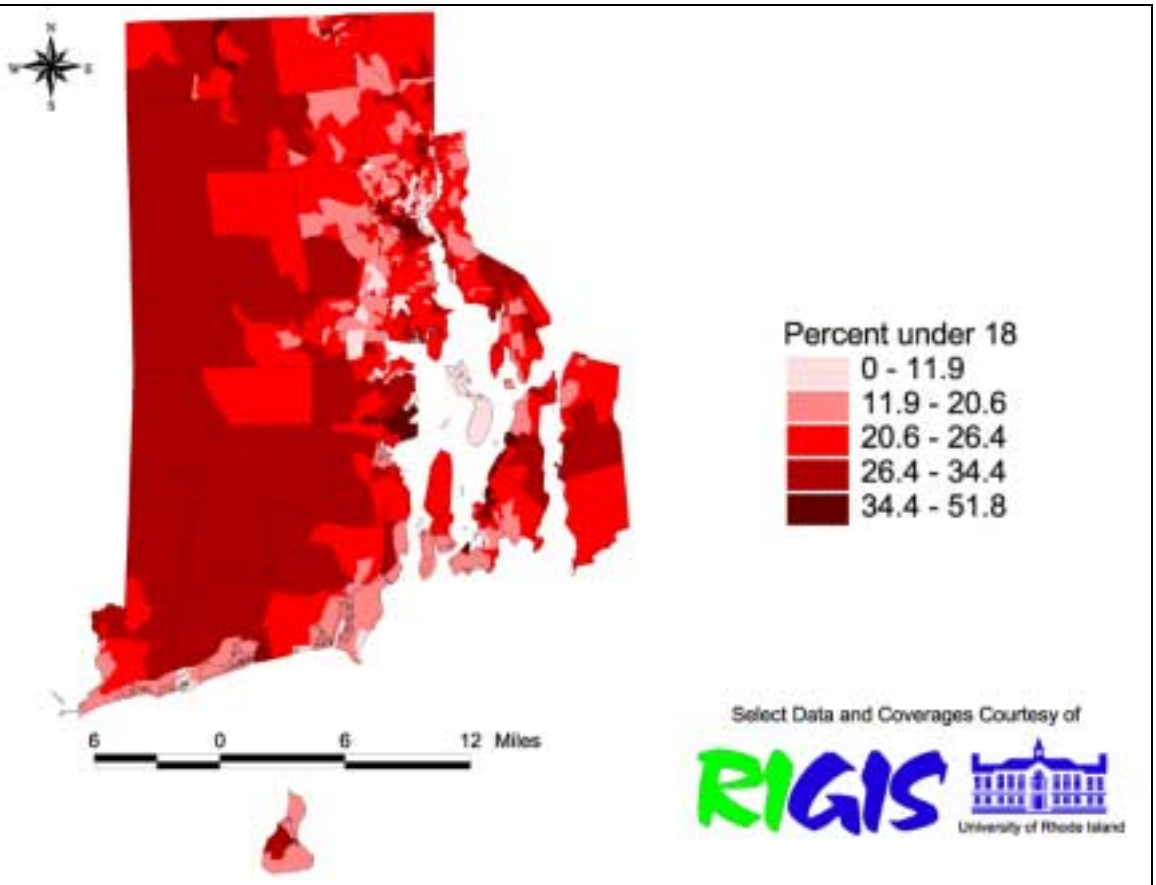


Figure 18 Relative Concentrations of those under 18 in RI - 1990 Census

Age Structure Deviation Analysis relies upon comparing the age structure of two regions (assuming there are differences between them) against a baseline (or average) age structure. In this case the baseline is the state age structure and the two regions are subsets of that overall age structure. It is assumed that the differences seen between the age structures constitute a deviation in residential preference. Figure 19 represent the results of the deviation analysis method for the years 1970, 1980 and 1990 where positive numbers represent the residential preference for that region. Note that the representations here are simply snapshots of the population at a given time. Therefore this is a period analysis and not a time-series analysis. Notice that there is a significant preference towards non-urban areas for those under the age of 40 in 1970. It is not until 1980 that a slightly different pattern begins to emerge. There is a preference of those under the age of 20 towards non-urban residence that is then seen again in the 30 to 49 year age groups. What is also significant is this latter group happens to be, statistically speaking, the parents of the former group, the sub 20 year old age groups. Those in the 20 to 30 year range prefer the urban areas as well as the 55+ age ranges. This pattern continues, with some variation, in 1990. Most notably there is a shift in the observed residential preference from non-urban areas to urban in the age groups spanning 55-65.

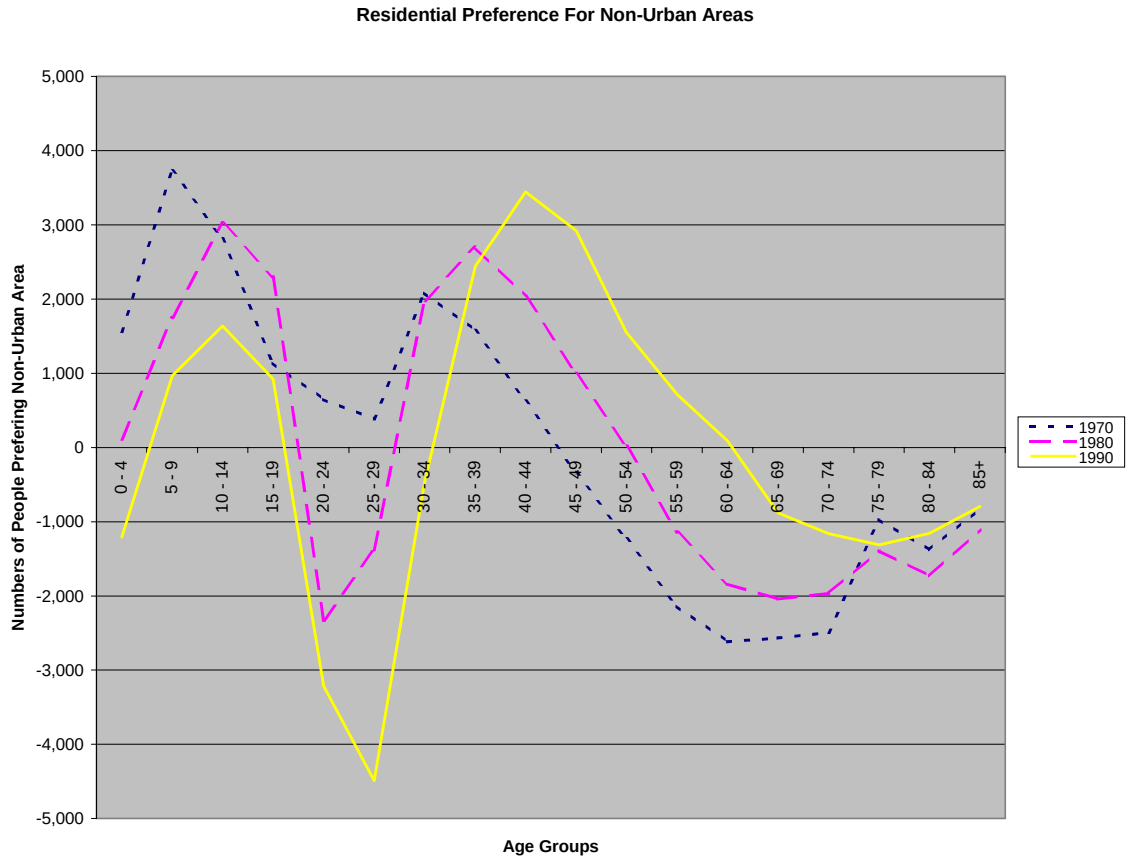


Figure 19 Residential Preference for Non-Urban Areas

This appears to confirm that migration had in fact changed over the study period and increased migration was most likely having an effect on sprawl.

Age-Structure Effects and Residential Preference

Referring back to the original hypothesis, a changing age structure, age specific behavior patterns and a residential location preference that is driving internal migration between regions are working in conjunction to drive sprawl rates much higher than overall population increases. Until now all of these issues have been treated separately but when combined some significant findings are elucidated.

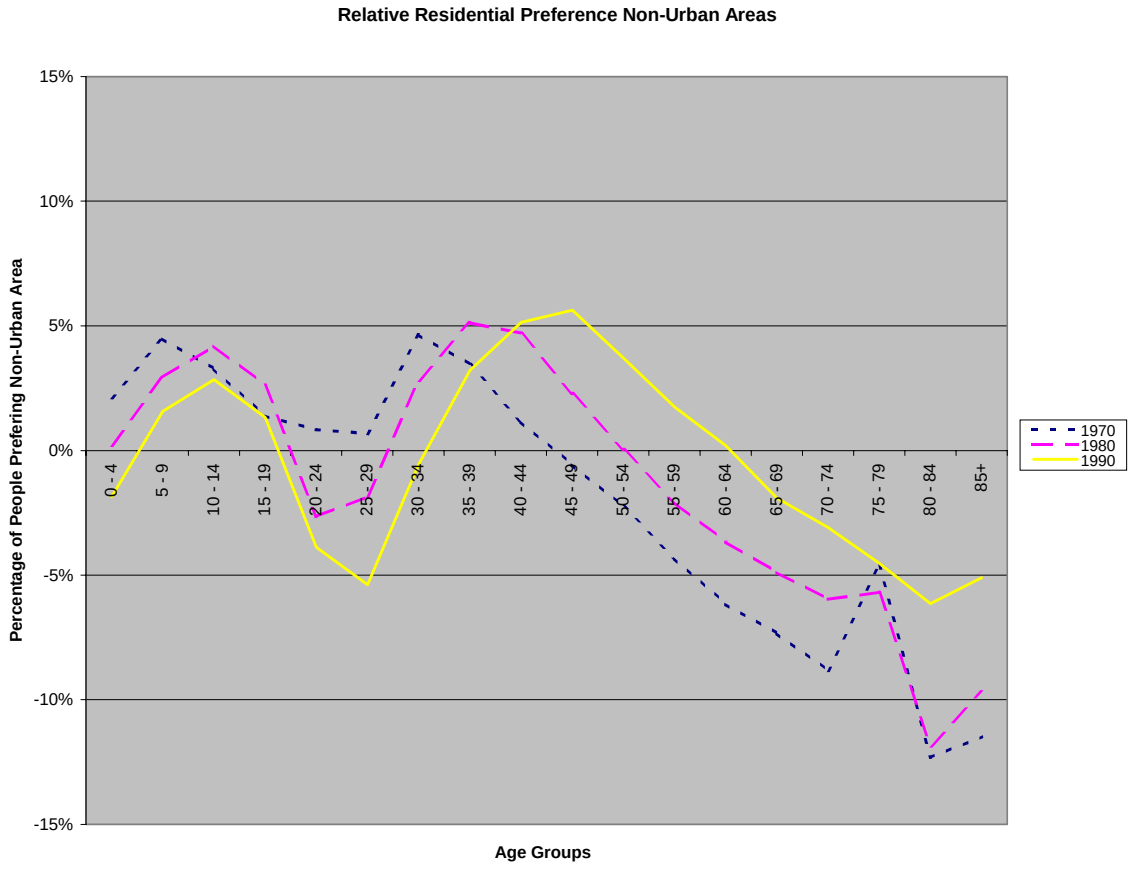


Figure 20 Relative Residential Preference for Non-Urban Areas

Looking back at the deviation analysis graph Figure 19, it appears that the age specific residential preference over time has changed significantly for different cohorts from 1970 to 1990 denoting a possible fundamental change in the preference for housing location.

Notice also that these graphs are in numbers and not in percentages (or relative proportions). Taking into account an uneven age structure, comparing these charts over time may prove misleading since at one point an age group may be larger or smaller than at another point. This is because of the amount of variation in a short period of time that was shown to be possible in the example above in Figure 10 when the 30 –34 year group doubled over the study period. Therefore changes over time may appear to be of a different magnitude but in reality, they may be relatively similar. This adjustment can be seen in the graph Figure 20 where, contrary to the trend occurring above, it appears that the age-specific residential preference over one's lifetime has not changed significantly between generations and therefore migratory patterns have not changed greatly over the study period. This calculation was accomplished by taking the size of the deviation and dividing it by the number of people expected in that age group, assuming the age structure of the region matched the age structure of the state. This made the numbers relative percentages to the size of the age group.

Age Shifts in the Thirty-Something and Middle-Aged Transitions

Looking back on Figure 20 there is a shift in the residential preference for those in the middle-aged and thirty-something groups while no shift in preference is occurring for the under twenty set (statistically the children of those in their thirties and forties) and the over seventy groups. If the shift were due to aging-in-place there would likely be shifts in all of the age groups towards the right on the age axis and that is not being observed. However, these shifts may be the result of a much more complex interaction between the age-specific fertility rate (and possible deviations of that rate between the various regions of urban and non-urban) and other factors. The most likely of these explanations is that a delay in childbearing has pushed the 30+ age groups to the right as seen in the shifts in age-specific rates for fertility in Figure 21. As you can see the peak in the fertility rates has shifted somewhere between five and ten years. This entire issue is worthy of more study by modeling these interactions in a hope to better understand what it is people are valuing the most when then they choose a new home and choose to leave that home for another.

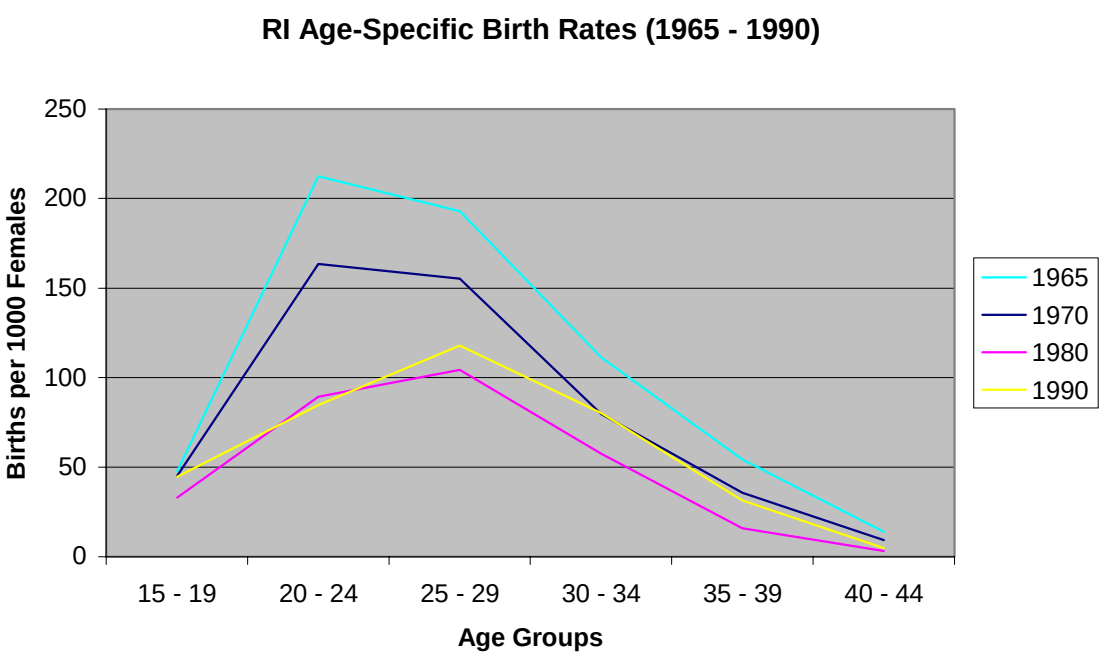


Figure 21 RI Fertility Rates

Another interesting result of Figure 20 is that there is a change in the magnitude of people in the 20-39 age groups where they are increasingly looking to the urban areas for residential housing. The reasons for this are not clear but this behavior is actually beneficial as it means at least some age groups in the population are beginning to favor the urban areas more than they had historically.

Housing Analysis

Household Size

Since housing is a big component of sprawl an analysis of these demographic components effects on housing will show what effect demographics has on sprawl. Growth rates of sprawl indicators have been higher than the growth rate of the population as a whole for Rhode Island over the study period. As noted earlier, one demographic explanation for this deviation of rates is that the average household size has changed over time. The implication of a shift in this metric is that individual behavior has changed and people are settling in different patterns than before. With regards to Rhode Island, in 1970 there were 3.24 people per household whereas in 1980 that number had fallen to 2.8. In 1990 the number had fallen a bit more to 2.65. The impact of this shift in average household size led to 46,493 more housing units, assuming all households count as one housing unit[10], needed during the 1970's. Over the 1980's, had the average household size stayed at 1970 levels, there would have been 22,021 less housing units demanded, *ceteris paribus*. This raises the grand total of additional housing units needed due to the shift in average household size, again assuming all households count as one housing unit, to 68,514 for 1970 - 1990. Over that same 20-year period the number of housing units built was 106,172. The shift in average number of people per housing unit seemed to account for more than half of all construction during the 1970's and 1980's.

Interestingly enough, even this explanation is not entirely sufficient. For starters, the population of Rhode Island has an age structure that is rather uneven. An analysis of average household size does not take this into account nor does it explain the increases in the other indicators of sprawl in the state such as demand for motor vehicles and average VMT per person (used as indicators of sprawl) as each of these would be affected by variation in the age structure because they impact people in different age groups differently. Therefore, shifts seen in the averages of a specific behavior (such as home buying) per person do not necessarily constitute proof that a shift in that behavior has occurred. Since it is this change in behavior that most people cite for causing sprawl, the research from here out will seek to quantify what portion of the change in the number of people per household is due to behavioral changes and what are simply changes due to the composition of the population.

As stated above, the age structure effect has a large effect on the significance of this metric. Using an example to illustrate this point, assume there is a hypothetical population of 10 people. The population consists of two couples, two children to each couple and living in two housing units. There are two other people in the population who are single and each has their own housing unit[11]. That makes 4 housing units to 10 people or an average household size of 2.5 people per household. Assuming no one else enters the population (births or migration) or leaves (death), 10 years go by but the population now looks somewhat different. First the children have all grown up to the age where they move out of the house. None of the four are married and all have their own housing unit. The two people who were single and living apart 10 years earlier have gotten married and are living in one housing unit. The two couples are still married and each couple occupies one housing unit. The average household size is now 1.43 people per household as there

[10] The impact of this assumption is most likely minimal but no quantitative value is known at this point.
[11] Housing unit = household for purpose of this study

are 7 housing units occupied by 10 people. The important aspect of this is there has been no shift in behavior as there has been no change in the age specific behavior patterns. Those who recently left their parents homes are younger than the age at which people get married and cohabitate. The two newly weds, although being married, are not at the age where people normally have children. The two original couples are past the age of giving birth but are still married and therefore continue to cohabitate but have no children. Therefore, the age specific rates for these behaviors have not changed but the proportion of people engaging in those behaviors has changed.

Age-Structure and the Components of Change Effect on Housing Demand

One way to adjust for age structure effects is to look at age specific headship rates[12] for the population in question. Change over time in these rates constitutes a shift in behavior pattern. When there is no shift then all change is attributable to the age structure. However, there may be a combination of both and to adjust for this headship rates are held constant at 1990 levels. Doing this shows what number of housing units would have been needed for any period of time given a particular set of rates. The difference between that number and the observed number is considered the impact of the shift in behavior patterns.

Past Historic Housing Activity

During the 1970's the number of housing units in net demand, attributed to migration, was 3,692 while in the 1980's the net demand attributed to this same in migration was 7,464. Table 3 shows the total number of estimated housing demand (determined by using 1990's headship rates) and the observed numbers of housing demand (See Table 4 for Age Specific numbers). Note that using 1990's headship rate yielded rather accurate housing demand numbers for 1980 but was a little high for 1970 showing that there was likely no significant change in headship rates during the 1980's but some change in the 1970's. Also, note that there is a distinction between actual units and occupied units and that the headship rates yield only the number of occupied units. As noted earlier, the number of occupied units is being used as a proxy for housing demand.

In Table 3 it is clear that the change in housing stock and the change in current total population size was uncorrelated, as most studies have suggested it would be. However, demand based on headship rates shows that as the age structure changes through time, the estimated demand correlates with the observed demand. This is because the age structure changes the proportion of people likely to head a household out of the total population. But what does not change is the likelihood that, at a given age, someone is more or less likely to be the head of a household. The later being an example of a shift in behavior.

Future Projections

Table 5 shows projected housing demand (AKA: occupied households) for the state of RI from 2000 through 2025. The population projections are based on US Census Bureau Estimate A for RI (graphed in Figure 22) and the housing projections use 1990 headship rates applied to all years (Seen in Table 6). Headship rates were unavailable in prior census years due to a lack of age specific household headship numbers from the Census Bureau for renters[13]. One issue with the population projections (2000-2025) is the totals

[12] Defined as the proportion of people in a specific age group who are claimed as head of household.
[13] They have owners in age specific numbers but only a total is available for renters

are low (2000 Census totals for RI came out in time for this study and were higher than expected), most likely due to the higher than expected migration into the state during the 1990's.

As time goes on, the age structure will most likely begin to stabilize as Figure 22 illustrates with 2025's population profile. With this stabilization of the age structure will come a stabilization of the housing construction. This means only that there will be less variability in housing demand. One thing that will remain is the fact that housing will continue to outpace population growth as the population growth rate continues to decrease. However, the disparity will be far lower than had been in the past and given enough time (and no more period events such as that causing the baby boom), over which no population growth occurs and the disparity will likely be completely removed. This phenomenon of disparate growth rates is due to the delay between housing demand attributed to one person and the event of their birth. In other words, increases in housing demand occur 30-40 years after an increase in population (providing births is the driving force behind the increase). This displacement is anchored primarily against births because birth rates (and immigration) will be the primary component of change in the population where death rates are considered to be roughly constant into the future.

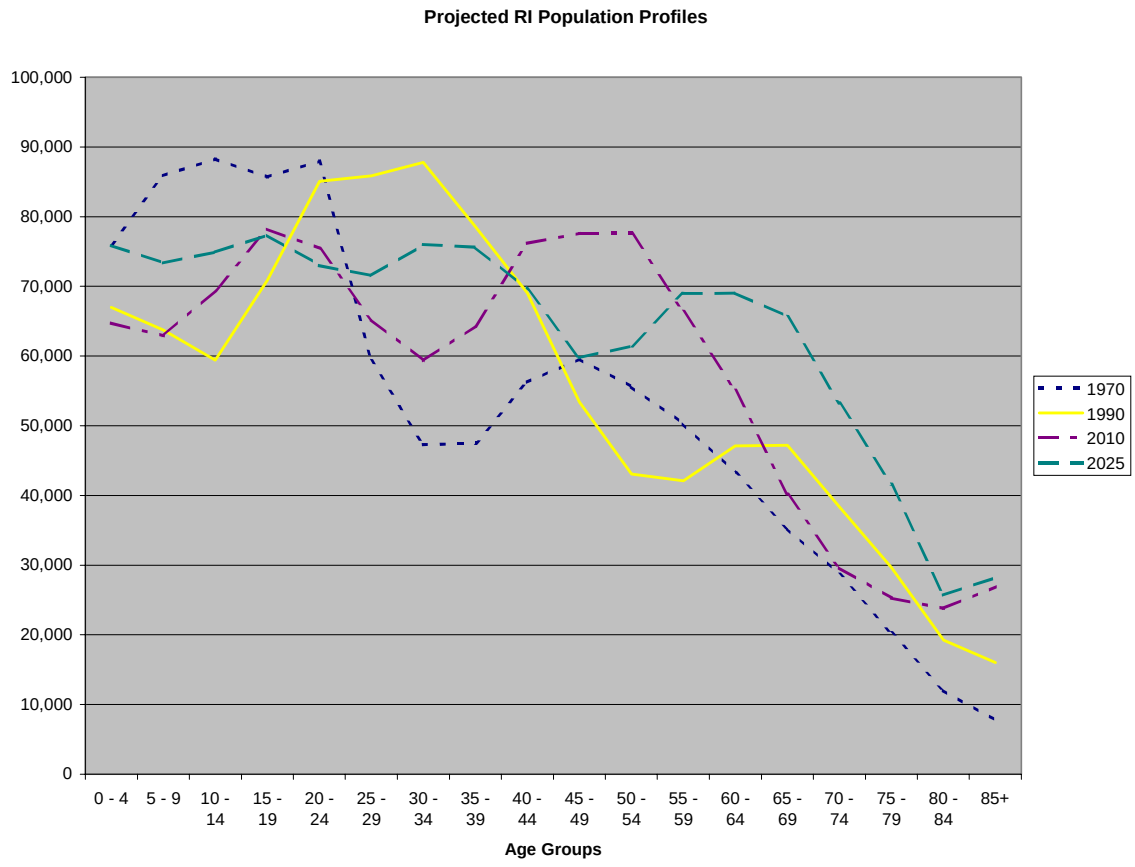


Figure 22 Projected RI Population Profiles

Table 3 Historic Housing Demand and Construction

(Estimates Based on 1990 Headship Rates)

	1970	1980	1990
Est. total occupied housing units (ie: Housing Demand)	310,663	337,718	377,977
Observed occupied units	291,965	338,590	377,977
Observed total units	307,999	372,667	414,171
New HU demand since last census	9,460	46,625	39,387
Constructed units since prior Census***	25,394	64,668	41,504
Percent change housing demand from prior Census	16.45%	8.01%	10.65%
Percent change of population	9.21%	0.05%	5.61%

Table 4 Historic Housing Demand

Estimated Housing Demand			
	1970	1980	1990
15 - 24	21,543	22,332	19,347
25 - 34	47,448	65,004	77,285
35 - 44	56,068	53,452	79,811
45 - 54	65,716	55,814	55,027
55 - 64	54,716	61,562	52,201
65 - 74	40,422	47,788	54,146
75 and over	24,750	31,766	40,160
Est. Total Occupied Housing Units (ie: Housing Demand)	310,663	337,718	377,977
(Estimates Based on 1990 Headship rates)			

Table 5 Projected Housing Demand

Projected Housing Demand	(Estimates Based on 1990 Headship rates)			
	* 2000	* 2010	* 2020	* 2025
15 - 24	15,832	19,061	18,568	18,652
25 - 34	62,340	55,453	66,079	65,687
35 - 44	88,281	75,965	70,555	78,484
45 - 54	75,834	88,596	76,766	69,144
55 - 64	48,161	71,097	83,931	80,751
65 - 74	44,408	44,115	66,428	75,219
75 and over	48,465	46,980	49,460	59,070
Est. Total Occupied Housing Units (ie: Housing Demand)	383,320	401,266	431,787	447,007
* Projected Population				

Table 6 Rhode Island Headship Rates

Age of household head	1970	1980	1990
Under 25	N/A	N/A	12.41%
25 - 34	N/A	N/A	44.51%
35 - 44	N/A	N/A	54.07%
45 - 54	N/A	N/A	57.07%
55 - 64	N/A	N/A	58.52%
65 - 74	N/A	N/A	63.24%
75 and over	N/A	N/A	61.85%

Table 7 Projected Housing Demand and Construction

(Estimates Based on 1990 Headship Rates)

	* 2000	* 2010	* 2020	* 2025
Est. total occupied housing units (ie: Housing Demand)	383,320	401,266	431,787	447,007
Constructed units since prior Census***	** 23, 028	N/A	N/A	N/A
Percent change housing demand from prior Census	1.39%	4.47%	7.07%	3.40%
Percent change of population	-0.59%	3.91%	6.05%	3.13%

* Estimated Population

** Observed Through 1998

Effect of Vacancy Rate and Other Factors on Housing Demand

As Table 8 demonstrates, the vacancy rate has fluctuated over the study period with a sharp increase over the 1970's and a slight rebound in the 1980's. This is probably a result of a period effect on the population where in the 1970's there was a large out migration of people from the state. It is important to note that although the number of vacation homes has increased, its proportion to the total housing stock has decreased over the study period. The 2000 Census will probably show a further decrease in the vacancy rate.

Table 8 Vacancy Rates Table for RI

Year	All Housing	Vacation Homes	Percent	All Vacancies	Percent
1990	414,572	12,053	2.90%	36,194	8.73%
1980	372,672	12,057	3.20%	34,077	9.14%
1970	316,477	11,621	3.70%	16,034	5.07%
1960	286,757	14,521	5.10%		
1950	244,147	11,024	4.50%		
1940	203,469	9,130	4.50%		

Summary of Age Structure Effect on Housing Demand

Housing demand across the whole state was much higher than population growth during the period of 1970-1990 due to the long-term effects of the "baby bust" of the 1930's (the cohort aged 50-60 in 1990) and the subsequent "baby boom" of the 50's and 60's. Appendix 3a and Appendix 3b contain a full breakdown of the housing demand per age group, region and component of change. Using these numbers, housing demand over the study period in non-urban areas, absent migration, had a net gain of 34,563 housing

units attributed to aging in place. In the urban areas net gain of housing units attributed simply to aging in place would have been 36,579. Adjusted for net in migration, the total demand on the non-urban areas rose to 45,917 while net out migration from the urban areas dropped the demand there to 25,847 housing units. Notice that aging in place accounted for over two thirds of the increased housing demand in the non-urban areas. This leaves a third of the increase in housing demand as a result of migration.

Part 4: Discussion

Summary

As the research has shown, sprawl, or urban-rural migration, is not just a result of a behavior change but also more significantly a result of changes in the age structure of the population. Given age-specific migratory patterns driven by residential preference, coupled with age specific behavior patterns and a changing age structure, growth in sprawl indicators will occur seemingly unrelated to the overall growth of the contemporary population. Therefore it is necessary to compare the growth of sprawl indicators not to the growth of the total population at the time in question but to the growth of a subset of the population (a specific age group for instance) most likely to engage in the behavior associated with that indicator. Using age structure deviation analysis and a decomposition of changes in population by age group, it has been concluded that a significant portion of Rhode Island's problems with high levels of development is due to these demographic effects. This study suggests programs designed to stop sprawl should focus on specific age groups in a population to create more tailored programs. It was also determined that suburban sprawl is intimately linked to population growth displaced in time by about 30-40 years. As a result of not accounting for these demographic dynamics, the measure of success or failure of policy decisions currently risks being over or under stated if the policies are designed to decrease certain indicators of sprawl that appear may not be tied directly to sprawl. Also the research suggests that other indicators of sprawl may be susceptible to the age structure effects detailed here.

Caveats

The Possible Effect of Reclassification of Towns as Cities on the Analysis

One possible problem with the approach taken in the above analysis is that municipalities evolve and change in character as time moves on. This is perhaps one of the greatest sources of error on the analysis as all classifications were done during the 1990's and don't actually reflect what these areas may have been classified as in earlier times. The reason why this may be important is as people "sprawl" into a municipality they are changing that area. First increased housing construction brings new roads, more people and a larger market. Businesses are created or expanded to service this larger market and more infrastructure is needed to service all of this development. If there is enough of this development than that area may begin to qualify as the next higher classification type. This is clearly an issue that may be affecting the accuracy of the study.

Application of Analysis to Other Areas of the US

Some of the insights of this study will have direct application to other areas of the US, as Rhode Island's age structure is similar to that of the US as a whole. However zoning, migration and other factors make this a limited comparison. Many of the other areas experiencing large volumes of development seen as sprawl have had large influxes of

population as people migrate from one region of the country to another for economic reasons. The age structure effect may be exacerbating the larger issue of migration into the receiving region but it is by no means the only cause. However, the idea of residential preference can help explain the choice of housing location once the decision to move to a region, such as Atlanta, is made based on economic factors. Zoning is also an issue along with whether or not the area in question has fixed borders, such as the North Eastern US. One last issue with this analysis is that since it is on a statewide basis, it may be hiding more localized behavior patterns. The conclusions drawn are on aggregate regions (e.g. urban and non-urban) within one state and may not hold for particular subgroups, including individual towns, populations categorized by race or ethnicity, or socio-economic class.

Conclusions

Implications for Future Study on Sprawl Indicators

The above research raises questions regarding some of the metrics currently being used to measure sprawl, as it appears some may not be directly tied by causation to sprawl. One example of this is the aggregate increase in housing starts or construction. As the above has shown, the housing demand has changed significantly over time but the underlying age specific behavior patterns have had very little change over the same period of time. One issue arising from this that needs to be more closely looked at is the idea that sprawl is a behavior that, as it has changed through time, has done increasing harm to the environment. Better definition as to exactly what the behavior component is and how it manifests itself is needed.

Using the indicator of open space as an example of something needing further research, the above research may have implications with regards to how much land a person aged 20 uses for residential purposes and a person aged 45 uses. If there is a difference then does one adjust for that, as this research suggests the implications of not doing so could be significant, thus measuring the change in age specific rates of land use to determine if behavior has changed? Getting around this by simply measuring the amount of land dedicated to each housing unit is a possible issue as, given unchanged age specific demand but an uneven age structure, there may be more people needing the living arrangement of a 20 year old over that of a 45 year old. Therefore a different overall amount of land per person will be picked up by such a measure but will most likely not truly reflect any change in behavior.

Another example is the VMT per person and any increases in this measure. Since two year olds do not drive, is it a valid argument to assess vehicle miles traveled to said two year old? Logic would say that a two year old does require specific trips by a licensed adult for the purpose of doctor’s visits, day care, etc; However is it important to try and separate that or, assuming a relationship with fertility rates and child rearing, is age specific VMT for 30-35 year olds (the most likely to have a 2 year old) adequate since it is change in behavior that seems to be more important? This system of focusing in on drivers only is methodologically similar to how headship rates function.

Implications on Measures of Policy Effectiveness

Given possible issues with some of the common sprawl indicators, there may be issues with measurements of policy effectiveness. For instance, if a Transfer of Development Rights (TDR) program is placed into effect to limit housing construction and development during a period of high housing demand and then ten years later housing demand is markedly lower due to purely demographic effects, the program may appear to be effective at curbing development when in reality it may have had little or no impact on the levels of development.

The Costs of Suburbia Known But Ignored

There have been studies (Burnley, Murphy et al. 1997) that seek to determine if people who are looking to live in suburban environments are aware of the costs associated. The results show that most know that suburban living is more costly, economically and socially, than urban living but were willing to sacrifice significantly for suburban life. What this study did not do is try to ascertain what benefit these people felt was derived from a life in the suburbs. This is where age-specific residential preference may have something to offer. There is correlation as to what may in fact be the reason for the sacrifice of these people. That is the presence of children under the age of twenty and the likelihood of living in a suburban environment. Although there is no direct evidence, this follows a logical framework most would relate to.

What this suggests needs to happen is the traditional economic decision model for migration should be viewed in a different light. This decision model looks at the benefit of staying in the city, the benefit of leaving the city for a new area and the cost associated with moving. What many claim needs to happen is a punishment model whereas the costs associated with moving are jacked up to prevent migration out of the urban areas. However, if children and family environment are the primary source of utility for moving then a more rewarding system can be implemented which allows for programs that enhance the utility of staying in the city by creating a more family friendly urban environment.

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Appendix 1

Cohort Component Population Model

The model[14] was run over a 5-year time-step and alternated using observed values in census years (effectively resetting the "projections" model) and calculated values stored from the previous step as seed for inter-decadal years. The birth and death rates for census years were used as is and in inter-decadal years were created from an average of the bordering observed census years. Again, the state rates were applied to each municipality individually with no regards to sex or race composition. This application of state rates onto individual municipalities may introduce error in the output of the model if each area has significantly different birth and death rates[15]. The model is shown in Equation 1 where t is time, P_i is the population of a single age group, B_i is births for that age group, A_i is the number of people aging out of the group and D_i is the number of deaths for that group. Note that A_{i-1} is the number of people aging out of the younger age group and moving up.

Equation 1

$$\frac{dP_i(t)}{dt} = B_i(t) + A_{i-1}(t) - A_i(t) - D_i(t)$$

Age groups were comprised of five-year increments starting at 0-4 and ending at 85+. Migration was set to zero as rates for entering and leaving the state were unavailable and the results were then compared to the observed numbers. The difference between these two sets of numbers is then attributed to migration. This is a similar method to what Kenneth Johnson has used to determine migration rates between counties. (Johnson 2000) The model was run on each individual municipality and the state as a whole to represent a baseline for comparison. This method yielded results only for the decades of the 1970's and 1980's and not the 1990's since the 2000 census numbers were unavailable at the time of this research.

Age Structure Deviation Analysis

Age Structure Deviation Analysis relies upon taking the overall non-age group specific totals to each region (i.e.; urban and non-urban) in the state and creating a factor representing the proportion of the state's total population that lived in that region (See Equation 2). For example, if 60% of the state's total population lived in the urban areas and 40% of the state's total population lived in the non-urban areas then the factors would be 0.60 and 0.40 respectively. The factor is then multiplied against the state total

[14] The model consisted of a custom written application in the programming language known as PERL (Practical Extraction and Report Language) and a mySQL Structured Query Language (SQL) database server used as a datastore.

[15] This may be the case here as one part of the hypothesis is there exists a residential preference. For example, if those of "family" age, i.e.: 0-20 and 30-55, have been consistently shown preferring the non-urban areas and if the preference is related to the raising of a family, those who reside in the non-urban areas may be more likely to have children then those of similar age living in urban areas.

for each age group (0-4, 5-9, etc…) and the result is the expected number of people, in that age group, that should exist in that region, assuming that the age structure of the region and the state are the same (See Equation 3). Any deviation between the value computed and the observed value is the number of people not in the region but should be if the age structures were the same[16] (See Equation 4). This value is assumed to be an age specific residential preference. The value is then made relative, to adjust for the age structure effect, by dividing by the total number of people in that age group in the state (See Equation 5).

If a similar pattern of age specific preference occurs year after year, then there must be a pattern of migration occurring internally in the state in order for this to occur. Therefore, in the absence of age specific migration rates between the two regions, evidence of migration (in net terms) can still be found based on the effect it has on the age structure of the population, providing there is an age specific preference for housing. Equations:

Equation 2

$$F_{R1} = \frac{T_{R1}}{T_{State}}$$
$$F_{R2} = 1 - F_{R1}$$

Where F is the factor and T is the total number of people in the region (R) denoted by the subscript.

Equation 3

$$E_{R_x(i)} = T_{State(i)} \times F_{R_x}$$

Where E is the expected number of people in the region (R_x) and age group (i) denoted by the subscript.

Equation 4

$$N_{R_x(i)} = E_{R_x(i)} - O_{R_x(i)}$$

Where O is the observed number of people in the region and age group denoted by the subscript and N is the difference between expected and observed values.
Adjusting for the uneven age structure by dividing the result by the total number of people in the state belonging in that age group to yield P. P is the percentage of people preferring one area to another.

[16] This may appear confusing but all calculations are based on a base of expected – observed and keeping this convention requires everything be expressed as ***out migration*** = positive and ***missing people*** = positive where these numbers would then be subtracted from the total number in the respective age group. (Think age groupB[Time2] = age groupA[Time1] – deaths of age groupA[Time1] – migration of age groupA[Time1])

Equation 5

$$P_{R_x(i)} = \frac{E_{R_x(i)} - O_{R_x(i)}}{T_{State(i)}}$$

Appendix 2

Components of Change

Non-Urban

1970's	Total Change	Out Migration	Aging in Place
0 - 4	-5879	4553	-1326
5 - 9	-7832	2154	-5678
10 - 14	-1918	-3975	-5893
15 - 19	5839	-3043	2796
20 - 24	3190	1505	4695
25 - 29	6561	2567	9128
30 - 34	10724	-1476	9248
35 - 39	5230	-3010	2220
40 - 44	-952	-1156	-2108
45 - 49	-2127	-655	-2782
50 - 54	2099	-1006	1093
55 - 59	4552	-944	3608
60 - 64	4982	-1078	3904
65 - 69	4147	-1039	3108
70 - 74	3182	-1071	2111
75 - 79	1505	-1383	122
80 - 84	1262	81	1343
85+	1497	-958	539
Total	36062	-9934	26128

Urban

1970's	Total Change	Out Migration	Aging in Place
0 - 4	-12955	11838	-1117
5 - 9	-15766	12370	-3396
10 - 14	-11714	3739	-7975
15 - 19	-503	-1656	-2159
20 - 24	6629	-3679	2950
25 - 29	11119	5020	16139
30 - 34	14865	8114	22979
35 - 39	1884	6194	8078
40 - 44	-10493	1969	-8524
45 - 49	-12668	1416	-11252
50 - 54	-4728	1414	-3314
55 - 59	693	1086	1779
60 - 64	2678	675	3353
65 - 69	2598	1413	4011
70 - 74	1528	1384	2912
75 - 79	1855	712	2567
80 - 84	2147	422	2569
85+	2726	-3098	-372
Total	-20105	49333	29228

1980's	Total Change	Out Migration	Aging in Place
0 - 4	3912	337	4249
5 - 9	1518	-4428	-2910
10 - 14	-5314	-4201	-9515
15 - 19	-6439	-4414	-10853
20 - 24	-739	334	-405
25 - 29	2264	6078	8342
30 - 34	4970	-3316	1654
35 - 39	10171	-6688	3483
40 - 44	11687	-2257	9430
45 - 49	6213	-1643	4570
50 - 54	-1125	-596	-1721
55 - 59	-2137	-575	-2712
60 - 64	1556	-414	1142
65 - 69	3900	-555	3345
70 - 74	3411	74	3485
75 - 79	2472	-222	2250
80 - 84	2577	-20	2557
85+	2217	-1958	259
Total	41114	-24464	16650

1980's	Total Change	Out Migration	Aging in Place
0 - 4	6105	1446	7551
5 - 9	666	-177	489
10 - 14	-9274	717	-8557
15 - 19	-12032	-5346	-17378
20 - 24	-4356	-10985	-15341
25 - 29	6916	-2422	4494
30 - 34	9709	4902	14611
35 - 39	13335	3868	17203
40 - 44	12018	4632	16650
45 - 49	2089	1345	3434
50 - 54	-8953	605	-8348
55 - 59	-11534	1093	-10441
60 - 64	-5637	2537	-3100
65 - 69	532	2437	2969
70 - 74	1224	3598	4822
75 - 79	2162	2092	4254
80 - 84	1656	1342	2998
85+	1980	-2873	-893
Total	6606	8811	15417

Appendix 3a

Non-Urban						
1970-1980	Total Change	Out Migration	Aging	Total Housing Unit Demand	Migration Housing Unit Demand	Aging HU Demand
under 25	-6,600	1,194	-5,406	-819	-148	-671
25 - 34	17,285	1,091	18,376	7,694	-486	8,180
35 - 44	4,278	-4,166	112	2,313	2,252	61
45 - 54	-28	-1,661	-1,689	-16	948	-964
55 - 64	9,534	-2,022	7,512	5,579	1,183	4,396
65 - 74	7,329	-2,110	5,219	4,635	1,334	3,301
75 Plus	4,264	-1,221	3,043	2,637	755	1,882
Total	36,062	-8,895	27,167	19,876	3,692	16,184
1980-1990	Total Change	Out Migration	Aging	Total Housing Unit Demand	Migration Housing Unit Demand	Aging HU Demand
under 25	-7,062	-12,372	-19,434	-876	1,535	-2,411
25 - 34	7,234	2,762	9,996	3,220	-1,229	4,450
35 - 44	21,858	-8,945	12,913	11,818	4,836	6,982
45 - 54	5,088	-2,239	2,849	2,904	1,278	1,626
55 - 64	-581	-989	-1,570	-340	579	-919
65 - 74	7,311	-481	6,830	4,624	304	4,319
75 Plus	7,266	-262	7,004	4,494	162	4,332
Total	41,114	-22,526	18,588	25,843	7,464	18,379

Appendix 3b

Urban						
1970-1980	Total Change	Out Migration	Aging	Total Housing Unit Demand	Migration Housing Unit Demand	Aging HU Demand
under 25	-34,309	22,612	-11,697	-4,257	-2,805	-1,451
25 - 34	25,984	13,134	39,118	11,566	-5,846	17,413
35 - 44	-8,609	8,163	-446	-4,655	-4,413	-241
45 - 54	-17,396	2,830	-14,566	-9,927	-1,615	-8,312
55 - 64	3,371	1,761	5,132	1,973	-1,031	3,003
65 - 74	4,126	2,797	6,923	2,609	-1,769	4,378
75 Plus	6,728	1,556	8,284	4,161	-962	5,124
Total	-20,105	52,853	32,748	1,471	-18,442	19,913
1980-1990	Total Change	Out Migration	Aging	Total Housing Unit Demand	Migration Housing Unit Demand	Aging HU Demand
under 25	-18,891	-14,345	-33,236	-2,344	1,780	-4,123
25 - 34	16,625	2,480	19,105	7,400	-1,104	8,504
35 - 44	25,353	8,500	33,853	13,707	-4,596	18,303
45 - 54	-6,864	1,950	-4,914	-3,917	-1,113	-2,804
55 - 64	-17,171	3,630	-13,541	-10,048	-2,124	-7,924
65 - 74	1,756	6,035	7,791	1,111	-3,817	4,927
75 Plus	5,798	4,776	10,574	3,586	-2,954	6,540
Total	6,606	13,026	19,632	9,495	-13,928	23,423