Occupancy inefficiency of larger detached houses

Helen Viggers
Research Fellow
University of Otago, Wellington
New Zealand
helen.viggers@otago.ac.nz

Associate Professor Michael Keall, Department of Public Health, University of Otago, New Zealand, Michael.Keall@otago.ac.nz
Dr Kristin Wickens, Department of Medicine, University of Otago, New Zealand, Kris-tin.wickens@otago.ac.nz
Professor Philippa Howden-Chapman, Department of Public Health, University of Otago, New Zealand, Philippa.howden-chapman@otago.ac.nz

Abstract

Purpose / Context - New detached houses have been getting larger in New Zealand for several decades. Large houses require more materials to build, and have greater ongoing energy costs than smaller houses built to the same standard. The purpose of this work was to examine whether larger houses are as efficient at accommodating people as smaller houses.

Methodology / Approach - On-line house schematics from major franchise builders in New Zealand were accessed, and a stratified random sample selected based on dwelling floor-area and developer. These schematics were analysed for number and area of bedrooms (and potential bedrooms), and number of toilets/bathrooms. Schematics for older social housing were also analysed. The potential occupancy was calculated using several methods.

Results – Older social housing had similar potential occupancy to new franchise dwellings of similar size. Larger new franchise dwellings tended to have a lower potential occupancy per square metre than smaller dwellings.

Key Findings / Implications – Large houses are built to satisfy current perceived market demands. The ability of the owners to pay for maintenance, and the occupiers to pay for heating/cooling energy will affect both how long the dwelling will last and occupant health. Inefficiencies designed into dwelling structure will remain unless there is a major renovation. Large dwellings with high building, running and carbon costs, which are unable to safely and healthily accommodate an appropriate number of people, are unsustainable for society.

Originality - This paper provides a critique of the trend of increasing dwelling size.

Keywords - Dwelling; size; occupancy
1. Introduction

New stand-alone houses have been increasing in size in New Zealand for several decades (Telfar Barnard, personal communication, 2015), and in Australia since at least the mid-1980s (Becker, personal communication, 2015), although they may have recently reached a maximum.

Larger dwellings take both more materials to build and more energy to heat or cool, than smaller dwellings built to the same standard. Therefore, they need to accommodate more people if they are to be as efficient on an emissions or energy use per capita basis as smaller dwellings.

There is no firm consensus in evaluating how many people it is appropriate to have living in a house of a given design. However, it is known that there is a relationship between household crowding and increased rates of several infectious diseases (Baker, McDonald, Zhang, & Howden-Chapman, 2013).

New Zealand has an official definition of unacceptable crowding defined in legislation from 1947 ("Housing Improvement Regulations," 1947), although this law is rarely used in practice (Bierre, Bennett, & Howden-Chapman, 2014). Perhaps one of the reasons it is rarely used is because it requires knowledge of the area of all the bedrooms in the dwelling, in addition to the household composition. Britain, through the Housing Act ("Housing Act," 1985), and parts of the United States, which have implemented the International Code Council's Property Maintenance Code (International Code Council, 2014), have similar definitions of unacceptable crowding. Table 1 summarises the main comparative points, although all three jurisdictions include additional complications (including some combination of: the ages, relationships and genders that may share bedrooms, the age at which children are considered adults, the weighting given to children, the additional area required for more people, privacy restrictions on what can be used as a bedroom, and rules about toilet access).

Table 1: Required Bedroom Area (m²) for given occupancy by jurisdiction

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>New Zealand</th>
<th>Britain</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.00</td>
<td>6.50</td>
<td>6.50</td>
</tr>
<tr>
<td>2</td>
<td>10.00</td>
<td>10.22</td>
<td>9.20</td>
</tr>
<tr>
<td>3</td>
<td>14.00</td>
<td>--</td>
<td>13.80</td>
</tr>
<tr>
<td>4</td>
<td>20.00</td>
<td>--</td>
<td>18.40</td>
</tr>
</tbody>
</table>

More commonly used is the Canadian National Occupancy Standard (Canada Mortgage and Housing Corporation 1996) (CNOS), which requires knowledge of the number of bedrooms in the dwelling and household composition. This standard allows only one or two people per bedroom regardless of size, but has compositional rules. Other crowding metrics include the Equivalised Crowding Index, and the British Bedroom Standard (Goodyear & Fabian, 2012).

Rules that focus on domestic housing typically require that there is both a bathroom and a separate living room (except for very small dwellings), but do not specify the maximum number of people expected to use a single bathroom. Boarding or dwelling house regulations may specify a maximum number of residents per bathroom or toilet.

The CNOS definition of crowding is used in many Australian documents, although critiques note its lack of correlation with how indigenous Australians view crowding (Memmott, Birdsell-Jones, Go-Sam, Greenop, & Corunna, 2011; Memmott, Birdsell-Jones, & Greenop, 2012). The CNOS definition is similarly used in many reports on conditions in New Zealand, as it is amenable to calculation from census data.
Those definitions of crowding which include a firm cut-off between crowded and non-crowded dwellings can also be used to define the maximum number of people who could acceptably live in a dwelling.

2. **Aim**

The aim of this work is to assess whether larger houses can appropriately accommodate as many people per square metre of floor space as smaller houses.

3. **Methodology**

3.1 **House plans**

A random sample of ten of the twenty largest franchise builders in New Zealand in 2012 (Curtis, 2013) was selected after weighting by the proportion of completed 2012 consents. Basic details including floor area of each plan were collected from the developers’ websites. This yielded 540 plans, ranging in area from 50 to 484 square meters. The nominal dwelling sizes were broken into ten categories, and one dwelling of each size randomly chosen from each developer. This yielded 62 plans for closer analysis.

A sample of older plans was also consulted. A series of State house plans (plans drawn up by the predominant supplier of Social Housing in New Zealand) at Archives New Zealand were consulted (Archives New Zealand). There were 599 plans from which the number of bedrooms was the main searchable size feature. A stratified sample was drawn to encompass a range of dwelling sizes, while keeping the majority of the dwellings as the most common two- and three-bedroom sized dwellings.

The area of each living or bedroom, and overall building area, was calculated using whatever scaling information was available. Additional information, such as the number and accessibility of bathrooms, whether living rooms were potentially suitable to be bedrooms, and the presence of garages were noted.

3.2 **Occupancy metrics**

Seven methods of calculating potential maximum occupancy were used.

(i) The New Zealand 1947 regulations applied to every room described as either a bedroom or a study.

(ii) The Canadian National Occupancy Standard applied to every room described as either a bedroom or a study.

(iii) Both the New Zealand 1947 and Canadian National Occupancy Standard applied to every room described as either a bedroom or a study.

(iv) A “cultural aspirational norm” of two people in the largest bedroom and one in every other room designated a bedroom.

(v) Applying the CNOS and the New Zealand 1947 regulations, to every room described as a bedroom or study, along with privacy and a maximum of 7 residents per bathroom/toilet.

(vi) Applying the CNOS and New Zealand 1947 regulations to every room that can be used as a bedroom (except for one living area), with privacy and a maximum of 7 residents per bathroom/toilet. Not using garages as bedrooms.

(vii) Applying the CNOS and New Zealand 1947 regulations to every room that can be used as a bedroom (except for one living area), with privacy and a maximum of 7 residents per bathroom/toilet. Allowing garages to be used as bedrooms.
3.3 Calculations

The potential occupancy of the dwellings was determined under each of the methods. Normalised occupancy levels (people per 100 m² of floor space) were calculated, both including and excluding the area of any garages attached to the dwelling.

4. Results and Discussion

The older social housing plans ('State Houses') were chosen to be representative of the plans and the era. They were, on average, much smaller than the plans for the modern franchisee dwellings. The State house plans examined ranged in area from 59 to 133m², with an average of 90m², in contrast the modern plans ranged from 51 to 478m², with an average of 207m². In comparison, the median surviving dwelling from the 1950s in the mid-2000s was 111m², and the average recent dwelling was 194m² (Telfar Barnard, personal communication, 2015), so the dwelling sizes in the plan database are broadly representative of the eras.

4.1 Permissible occupancies - Comparing major metrics

Table 1 shows the required sizes of bedrooms to accommodate varying numbers of people under the rules of three countries. The bedroom size required for one person varies between 6.0 and 6.5 m², and for two people between 9.2 and 10.22m². These figures are similar; in two of the countries (New Zealand and the United States) further occupants are allowed if the rooms are sufficiently large. The British rules allow a maximum of two people per bedroom. The Canadian rule allows a maximum of two people per bedroom regardless of bedroom size.

Three methods of permissible occupancy are calculated here and capture the breadth of this variation. The New Zealand rule is applied and then the Canadian one, when both are simultaneously applied the result is similar to the British rule.

The graphs in Figure 1 show the maximum number of people who would be allowed to live in the dwelling under the different sets of rules. Figure 1a shows the New Zealand rules, with a strong increase in people permitted with increasing dwelling size. Figure 1b shows the Canadian method, after a strong initial increase with dwelling size, the allowed number of occupants levels off. This is because even very large dwellings do not have more than five rooms designated as bedrooms. Figure 1c shows allowable occupancy when both sets of rules are applied (thus similar to the occupancy allowed under the British rules).

The New Zealand and United States rules, which allow a maximum occupancy dependent only on bedroom size, unsurprisingly allow more people in larger houses, which tend to have larger bedrooms, than the Canadian or British rules. The Canadian, New Zealand and British systems, as well as setting a limit on the maximum number of people per bedroom, also have additional constraints on the sex, ages and relationships of people deemed appropriate to share a bedroom. Indeed, in current Western culture most adults would prefer to only share a bedroom with an intimate partner. Thus, although under the rules the dwellings could accommodate the calculated maximum number of people, it is also very possible that the relationship restrictions mean that a specific family, or household of the maximum number, may actually be unable to be appropriately accommodated by the house. Therefore, even if applying only the 1947 regulations, it may be more valid to use the additional CNOS rules to give an effective actual maximum occupancy for a dwelling.
Figure 1: Maximum permitted occupancies under different country rules, allowing studies to be repurposed as bedrooms

4.2 Permissible occupancies - Effect on potential occupancy of room repurposing

Figure 2 shows the potential occupancy, normalised to people per 100 square metres, of the dwellings under the four occupancy scenarios of increasing room usage while still remaining inside both the New Zealand 1947 regulations and the CNOS criteria, and in addition requiring that there is at least one toilet and washing facility available for every seven people in the dwelling, without requiring access through a bedroom, which they do not occupy. Figure 2a shows the potential occupancy rate using the cultural aspirational level (with a maximum of two people in the largest bedroom, and one in all other bedrooms), with only rooms annotated as bedrooms used for sleeping. It shows that as the dwellings get larger the potential occupancy per square metre strongly declines. Figure 2b shows the potential occupancy, if there are a maximum of two people per bedroom, and rooms marked as studies can be repurposed for sleeping. It shows a substantial increase in the potential occupancy rate beyond that of the cultural aspirational level. Figure 2c shows the potential occupancy when in addition to two people sleeping in each bedroom or study, rooms marked as living areas can be used for sleeping, so long as the area to be used for sleeping is private, and at least one living area is left as a living space. Figure 2d shows the potential occupancy when in addition to living areas being used for sleeping, garage spaces can also be used.
The increase in potential occupancy when other spaces are repurposed is not as great as the increase in potential occupancy when all bedrooms in the dwellings are expected to accommodate two people.

Except for the cultural aspirational occupancy level, where smaller dwellings had much higher potential occupancy rate than larger dwellings, dwellings of any size could have relatively low potential occupancy rates, but only dwellings of less than about 150sqm had high potential occupancy rates.

Normalising by the footprint of the whole dwelling is appropriate when considering the carbon cost of the building materials and maintenance. Normalising excluding the area of any garages might be appropriate for considering heating costs, but only if the garage is unheated and the wall between the house and garage is insulated to exterior wall standard. Even in uncrowded houses, garages can be turned into games or exercise rooms and may be heated, so excluding the area of the garage when normalising may not always be appropriate.

Figure 3 shows analogous graphs when potential occupancy rates are calculated excluding the areas of any garages. Overall, they look similar to the earlier figures, with only small increases in the potential occupancy rate. Figure 3a showing the cultural aspirational occupancy scheme is
especially similar to Figure 2a. Figure 3b (analogous to Figure 2b) showing the effect of minor room repurposing, shows that when the garage areas are excluded, the dwellings with very low potential occupancy rates show an improvement, but the dwellings with high potential occupancy rates do not show a similar improvement. Figure 3c (analogous to Figure 2c) shows a similar effect for areas designated as living areas that can be repurposed as sleeping areas. There is no figure equivalent to 2d, as if the garage is repurposed for sleeping then the normalisation should not exclude it. Overall excluding the garage area from the dwelling area does not change the relationship between dwelling size and potential occupancy rates.

Although smaller dwellings often had greater potential occupancy rates than the larger dwellings, there was a sharp cut-off point when bedrooms were so small that they were not large enough under the 1947 regulations for two people to sleep there. Two of the smaller dwelling plans analysed had the largest bedroom under the two-person cut-off size.

![Figure 3a: Cultural Aspiration Occupancy](image1)

![Figure 3b: Occupancy if study repurposed](image2)

![Figure 3c: Occupancy if living areas and studies repurposed](image3)

Figure 3: Normalised occupancy against dwelling area (excluding garage) for different maximum occupancy calculations

### 4.3 Comparing newer and older designs

Figure 4 shows the occupancy of the smaller dwellings by the design era of the dwelling. It shows that the older State house designs tend to be able to accommodate slightly more people than designs of equivalent size in the modern era. The occupancy here is calculated from the combined...
1947 regulations and CNOS, while allowing study repurposing, but no repurposing of other spaces in the dwelling.

The newer designs accommodate an average of 0.9 fewer people (p=0.008). This difference is partially caused by the absence of garages in the older designs, if only the area excluding garages is considered then the difference reduces to an average of 0.5 fewer people (p=0.06) in the modern smaller designs.

![Figure 4: Effect of design era on potential occupancy of smaller dwellings](image)

5. Conclusions

Dwellings currently being built in New Zealand are substantially larger than those of 50 years ago. This in itself need not be a problem, and houses that are built to the specifications of the intended occupiers, may well suit the first occupiers very well. However, these dwellings are also the current era’s legacy to future housing needs, and therefore consideration needs to be given to other future occupiers. Other things being equal, larger dwellings require more embodied energy to build, more materials to maintain, and more energy to heat/cool. As we are moving into an era of constrained resources, where there will be considerable externalities from resource use, it is appropriate for larger dwellings to also be able to adequately accommodate more people.

A number of English-speaking jurisdictions have compiled rules on the maximum number of people who ‘should’ live in a dwelling. Despite being developed at different times - the CNOS criteria were developed in Canada in the 1980s through consultation between provincial housing agencies and the Canadian Mortgage and Housing Corporation (Statistics Canada, 2013), whereas the New Zealand and English rules were developed during the early and mid-twentieth century - they have some similar features. The similar features include similar break-points for allowed occupancy by room size, sometimes a similar maximum allowed occupancy, and similar breakdowns for the age, gender and relationships of people deemed appropriate to share a bedroom.

Applying these rules to New Zealand dwelling plans of different sizes shows that although larger dwellings can accommodate more people than smaller dwellings, and even small dwellings can be designed inefficiently, generally the number of people able to be accommodated per square metre...
of floor area decreases as the dwelling size increases. This result remains even if rooms initially not designated as bedrooms (including garages) are repurposed as bedrooms.

That occupancy rules remain in force in diverse countries, strongly suggests that there is some physical, social or biological merit to them, whether to avoid excessive wear and tear on the dwelling which reduces its longevity, or because increased crowding results in increased disease transmission.

Given the increasing pace of climate change, with energy prices likely to rise and growing shortages of housing in fast-growing cities, there is an increasing need to build dwellings with low running costs that will remain usable many years into the future. The trend towards large dwellings, which cannot be appropriately occupied at the same density as smaller dwellings, is undesirable.

6. References

Archives New Zealand Photographs of State Housing plans [Archives Reference: AALF 6114 W1559/1] The Department of Internal Affairs Te Tari Taiwhenua


Housing Act, United Kingdom § X (1985).

Housing Improvement Regulations, New Zealand, SR 1947/200 (1947).


