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# Urban interventions: understanding health co-benefits

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**Improving aspects of the built environment, such as retrofitting housing and designing transport options that encourage active journeys (cycling and walking), can have significant and demonstrable impacts on health and well-being. Policies that have primary goals such as improving energy efficiency can have important measureable co-benefits for health and well-being, as well as climate change mitigation. The authors carried out two community housing trials to measure the benefits of installing insulation and effective heating on households' health and well-being. These trials have shown that these energy efficiency projects increase health and well-being, reduce hospitalisations and excess winter mortality, and at the same time reduce carbon dioxide emissions. In a third trial, they remediated injury hazards in houses, significantly reducing the household injury rate. Using a quasi-experimental study, the authors evaluated the impact of retrofitting infrastructure to increase cycling and walking. This showed that the distance from housing to the new infrastructure was an important explanatory factor for positive changes in choice of modes of travel. Distance of housing from school was also an important factor in whether children walked or cycled to school. In conclusion, retrofitting urban and suburban infrastructure can increase health and well-being, while reducing carbon dioxide emissions.**

## 1. Introduction

The built environment, including housing and roads, is important for a range of societal outcomes. In policy development, the main outcome sought is often economic benefit. Yet, concurrent gains can be achieved in terms of other outcomes, the so-called 'co-benefits' (Howden-Chapman and Chapman, 2012). These co-benefits can be improved health and well-being, or reduced carbon dioxide emissions, important for mitigating climate change (Cooper *et al.*, 2013; The World Bank, 2012). Climate change mitigation in turn has long-term benefits for health and well-being (WHO, 2011b).

Increasing attention is being given to the design effects of urban design on health and well-being (Rydin *et al.*, 2012). For example, retrofitting housing for energy efficiency has immediate benefits for health, as well as producing quantifiable emission reductions (Chapman *et al.*, 2009; Howden-Chapman and Chapman, 2012), as do measures to increase active transport and public transport (Newman and Matan, 2012).

The WHO (2011a, 2011b) has pointed to the range of health-beneficial and effective policy measures available in housing and transportation domains, in two substantial reviews in 2011, noting that a number of effective urban planning measures have been relatively neglected. The 2014 report of Working Group III of the Intergovernmental Panel on Climate Change (IPCC) underlined the theme of policy co-benefits, noting the good level of agreement in relation to their presence. However, it also identified a shortfall in evidence about exactly how they can be generated. They noted, in particular, a need for evidence that the next two decades 'present a window of opportunity for (carbon) mitigation in urban areas' (IPCC, 2014: p. 25).

In this paper, the authors summarise robust evidence they have generated that adds to the knowledge of which remediable aspects of the existing built environment can effectively lead to improvements in health and well-being and carbon mitigation.

## 2. Health co-benefits of increasing energy efficiency and safety of housing

We spend about three-quarters of our time inside, most of it in our houses; this rises to 90% of our time when we are very young, or very old (Baker *et al*., 2007). Protecting occupants from cold and hot outdoor temperatures, thereby reducing the risk of coronary and respiratory conditions, is one of the most important functions of housing (Howden-Chapman *et al*., 2009). Systematic reviews of the health effects of housing and the indoor environment concur that, apart from protection from temperature extremes, there are many other aspects of housing that affect health and well-being (Braubach *et al*., 2011). For example, dampness and mould increase respiratory symptoms, formaldehyde from combustion or off-gassing increases the risk of cancer, and home hazards contribute to injuries. In some cases, factors such as crowding or second-hand smoke exposure arising from socio-economic deprivation can lead to lower respiratory tract infections, asthma, heart disease and lung cancer or mental health problems. Low-income households' reliance on the use of solid fuel heaters and cooking stoves, or faulty appliances, can also lead indirectly to health effects, rather than arising directly from the built environment (Pachauri and Jiang, 2008).

Housing is also one of the key drivers of energy demand (WHO, 2011b). Better location and construction of new dwellings can make a vital contribution in reducing carbon dioxide emissions. However, most housing in the developed world that will be lived in during this century already exist. Much of it was built at a time when energy for heating and lighting was cheaper and less was known about the implications of burning fossil fuels for health and well-being, and the full impacts of carbon dioxide emissions on climate and the environment. Since the oil shocks of the 1970s and the peaking in the last decade of global conventional oil production (Murray and King, 2012), developed countries have increased the energy efficiency requirements for building and housing and mandatory standards have been introduced in the European Union. While the need to increase energy efficiency provided the initial motivation for concerted efforts, there has subsequently been growing recognition that retrofitted insulation and effective non-polluting heating have co-benefits for health and well-being, as well as climate change mitigation (Howden-Chapman and Preval, 2014).

Of the total global greenhouse gas (GHG) emissions, the building sector is responsible for about 6% directly and 12% indirectly, or about 19% together (Lucon *et al*., 2014). Housing construction and operation in turn represent a substantial part of the building sector. The portrayal of emission reduction opportunities in marginal abatement cost curves commonly shows that increasing the energy efficiency of housing is a 'negative' cost opportunity, since the health benefits outweigh the investment cost of undertaking retrofits. The International Energy Agency (IEA, 2014: p. 9) has noted that the benefits of energy efficiency measures can be 'difficult to monetise', impeding their measurement and take-up (Ryan and Campbell, 2012), although recent research is increasingly quantifying these benefits.

## 3. Health effects of retrofitting insulation and heating on health

Against this background, the authors summarise the results of two of their randomised community trials of retrofitted insulation and installation of effective heating, focusing mainly on health co-benefits. These studies were set up to test whether these retrofits first improved aspects of health and well-being, and second, improved energy efficiency. Both self-reported and independent measures were collected. The studies were carried out in New Zealand, a temperate developed country with relatively large, poorly heated, standalone wooden houses (Howden-Chapman *et al*., 2009). These robustly designed studies quantified significant benefits for population health and well-being, and energy efficiency.

The Housing Insulation and Health Study was carried out in partnership with seven communities (Howden-Chapman *et al*., 2005) and examined the effects of retrofitting insulation in 1350 houses, containing 4407 participants, where at least one occupant in each house had chronic respiratory problems. Retrofitting insulation was associated with a small increase in bedroom temperatures during the winter (0·5°C) and decreased relative humidity (−2·3%), despite energy consumption in insulated houses being 81% of that in uninsulated houses. Bedroom temperatures were below 10°C for 1·7 fewer hours each day in insulated homes than in uninsulated ones (Howden-Chapman *et al*., 2007). These changes were associated with reduced odds in the insulated homes of 'fair' or 'poor' self-rated health (adjusted odds ratio: 0·50, 95% confidence interval (CI): 0·38–0·68), self-reports of wheezing in the past 3 months (0·57, 0·47–0·70), self-reports of children taking a day off school (0·49, 0·31–0·80) and self-reports of adults taking a day off work (0·62, 0·46–0·83). Visits to general practitioners were less often reported by occupants of insulated homes (0·73, 0·62–0·87). Hospital admissions for respiratory conditions were also reduced (0·53, 0·22–1·29), but this reduction was not statistically significant ($P = 0{\cdot}16$). A broad cost–benefit analysis found that the benefits of retrofitted insulation outweighed the costs by a ratio of almost two to one (Chapman *et al*., 2009).

A subsequent community trial, the Housing, Heating and Health Study examined the effect of home heating on health, through installing effective, sustainable heaters in the insulated homes of 440 children with doctor-diagnosed asthma. It again found significant improvements in independently measured health symptoms, a significant reduction in children's absences from school as measured in formal school records and a small reduction in energy costs (Howden-Chapman *et al*., 2008). The intervention was associated with a mean temperature rise in the living room of 1·10°C (95% CI: 0·54–1·64°C) and in the child's bedroom of 0·57°C (0·05–1·08°C). Lower levels of nitrogen dioxide were measured in the living rooms of the intervention households than in those of the control households (geometric mean 8·5–15·7 μg/m$^3$, $P < 0{\cdot}001$). A similar effect was found in the children's bedrooms (7·3–10·9 μg/m$^3$, $P < 0{\cdot}001$). While improvements in lung function were not significant compared with children in the control group, children in the intervention group had 1·80 fewer days off school (95% CI: 0·11–3·13), 0·40 fewer visits to a doctor for asthma (0·11–0·62) and 0·25 fewer visits to a pharmacist for asthma (0·09–0·32). Children in the intervention group also had fewer reports of poor health (adjusted odds ratio: 0·48, 95% CI: 0·31–0·74), less sleep disturbed by wheezing (0·55, 0·35–0·85), less dry cough at night (0·52, 0·32–0·83) and reduced scores for lower respiratory tract symptoms (0·77, 0·73–0·81) than children in the control group. If families with asthma (or similar health sensitivity) continue to live in these houses, this heating intervention is also cost beneficial (Preval *et al*., 2010).

Taking into account the co-benefits demonstrated in these two community trials, following the 2008 global financial crisis, the New Zealand government made a multi-million dollar investment towards retrofitting the approximately one-third of New Zealand dwellings still uninsulated and poorly heated, primarily on the grounds of energy efficiency and job creation. Unlike the community trials that informed this programme, it was initially not targeted on the basis of low income and had no requirement that the households eligible for it had health problems. An independent evaluation of the roll-out of this programme was carried out on a matched sample of the first 47 000 houses retrofitted, a sufficient sample size to also consider the reduction in mortality for older people previously hospitalised for respiratory and coronary conditions. The benefit-to-cost ratio, which considered health, energy and employment benefits, was almost five to one (Grimes *et al*., 2011).

A third randomised community trial in New Zealand focused on the safety gains possible from addressing home hazards. This trial, the Home Injury Prevention Intervention (HIPI) study, centred on a community-based retrofitting programme and is the first randomised controlled trial to examine structural house modifications as a means to reduce injury in the general population. Despite the considerable injury burden arising from falls in the home among the general population, few interventions have been found to reduce home fall rates (Keall *et al*., 2008). The intervention in the HIPI study was a customised modification of 842 houses that had already had retrofitted insulation installed. A qualified builder systematically identified home hazards by using the validated Healthy Housing Index (Gillespie-Bennett *et al*., 2013) and then undertook remedial home modifications, such as handrails for steps and stairs, grab rails for bathrooms, outside lighting, edging for outside steps and slip-resistant surfacing for outside surfaces such as decks.

The measured outcome was the rate of medically treated home falls (derived from administrative data on insurance claims) among a predominantly low-income population (Keall *et al*., 2010a). Home fall injury rates showed a reduction of 26% (95% CI: 6–42%). The results, as with the two earlier community trials, show the important benefits to population health and safety of a relatively low-cost intervention in the built environment, in this case home repairs and the installation of safety features (Keall *et al*., 2015).

These three community trials clearly showed that improving several common elements of existing housing improved health and well-being. The authors now discuss the results of their quasi-experimental study of retrofitting existing road patterns to encourage safe cycling.

## 4. The health co-benefits of increased walking and cycling

There is a critical connection between active journeys (walking and cycling) and health outcomes. Moreover, carbon dioxide emission reductions will also contribute to better health and well-being outcomes over time. Drivers and their passengers who do not take the travel opportunity to walk or cycle instead of driving are generally creating problems for their health. Physical inactivity is responsible for more than 3·2 million deaths per year globally (WHO, 2011a) and obesity and diabetes problems associated with it are growing (IDF, 2012). Although active journeys that increase physical activity are associated with lower body mass index and improved cardiovascular functioning (both indicators of better health), rates of active transport have steadily declined in most cities in New Zealand (Keall *et al*., 2010b).

The transport sector is responsible for about 14% of GHG emissions globally (IPCC Working Group III, 2014). It is also one of the major sources of urban air pollution, and there are clear synergies in terms of GHG and air pollution outcomes from policies to improve urban transport (WHO, 2011a). For example, Woodcock *et al*. (2009) modelled the health benefits in Delhi and London of increasing active travel and reducing vehicle use, and found that these policies were more effective in health terms than reducing the emissions intensity of vehicles. Technological advances such as electric vehicles can contribute to reducing emissions, but such vehicles still temporarily embody considerable carbon, and most countries use electricity, that remains largely fossil fuel sourced (Pasaoglu *et al*., 2011).

To date, although modelling studies exist, as noted above, there have been almost no rigorous empirical studies of the effect of interventions to change modes of transport and therefore the impacts on carbon dioxide emissions and health (Shaw *et al*., 2014). To remedy the lack of empirical evidence on the changing modes of urban travel from passive car travel to active journeys, the authors conducted a quasi-experimental study, ACTIVE (Activating Communities to Improve Vitality and Equality). This evaluated the impacts of providing government-funded walkways and cycle ways in two New Zealand 'intervention' cities, New Plymouth and Hastings, whereas two 'control' cities, Whanganui and Masterton, received no such funding. Government funding was competitively allocated for the construction of new infrastructure for walking and cycling in the two intervention cities, either dedicated cycling and walking routes, or delineation of cycling lanes on existing roads with sufficient width. The intervention included an educational programme.

In this study, households were randomly selected from council records of residences and informed consent was obtained from the members of the households aged 10 years and over to answer an initial face-to-face questionnaire, and two subsequent annual follow-up questionnaires about travel behaviour and attitudes to cycling and walking (Chapman *et al*., 2014). Here, the authors report a sub-analysis, focusing on the physical activity in one of the cities, New Plymouth, where the District Council's intervention programme was branded 'Let's Go'. The main infrastructure components were improving surface quality and the connectivity of existing shared pathways, as well as providing marked cycle lanes within the central business district and connecting neighbourhoods. In total, 5 km of additional shared pathways were built and 40 km of on-road painted cycle lanes were added in New Plymouth (see Figure 1).

In the sub-analysis, the authors looked at the distance between trip origins (the houses where people live) and walking and cycling infrastructure, to see whether proximity to the newly installed or improved infrastructure encouraged

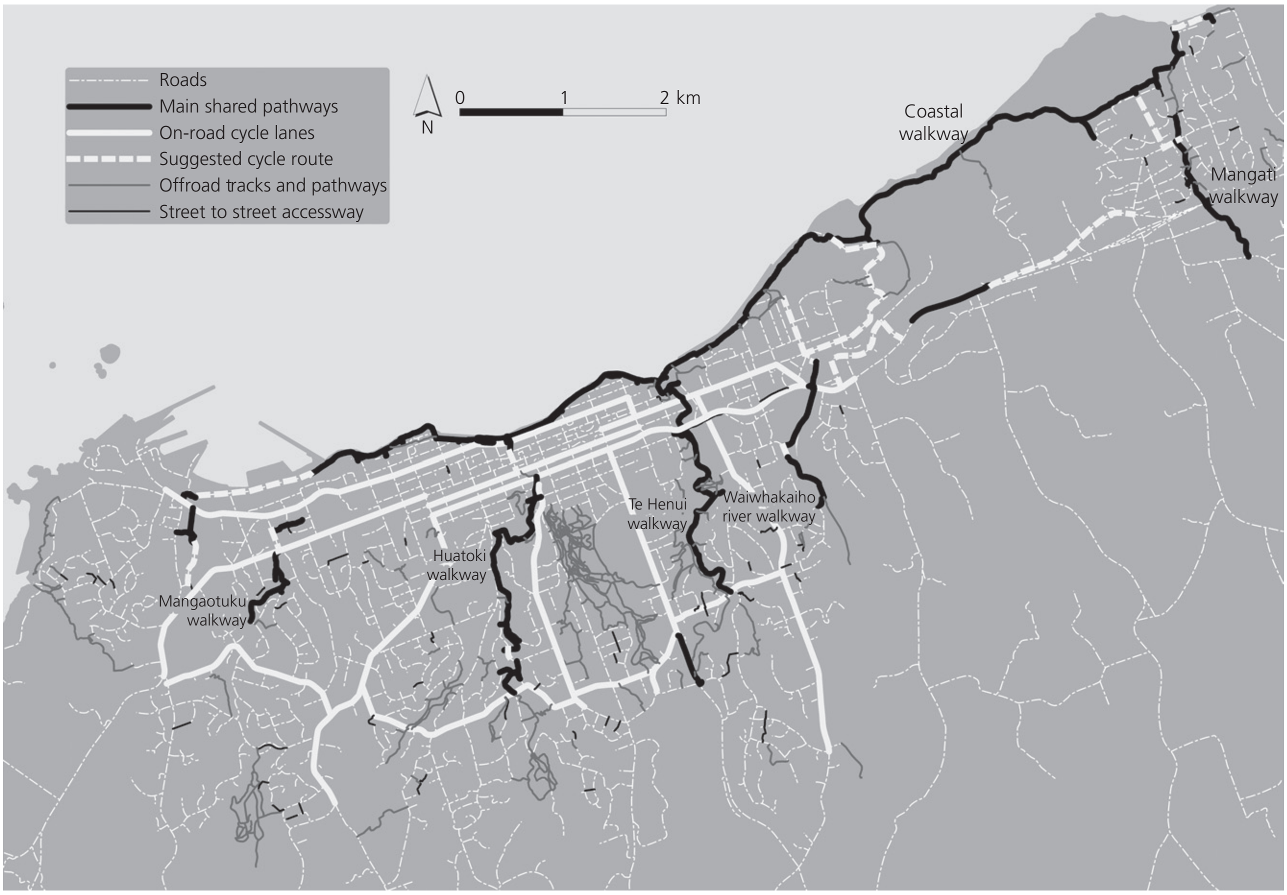


Figure 1. Cycling and walking paths in New Plymouth's Let's Go Project, 2015

additional walking and cycling. They analysed changes over time in the proportion of reported trips to main destinations according to the mode of transport (active or inactive) in relation to the distance from home to the new cycling and walking infrastructure.

Respondents' home addresses were geocoded and distance was measured from the centroid of the home meshblock (approximately a city block, typically consisting of between 10 and 50 dwellings) to any new infrastructure constructed since 2011. If the new infrastructure passed through the meshblock, or ran immediately alongside the meshblock, this distance was recorded as zero. These distance measurements enabled an analysis to be made of changes in travel behaviour in relation to the distance from this new infrastructure.

During the interviews, participants were asked about the number of trips they had made in the previous 7 d to several key destinations. These were: work, education, shopping, leisure and accompanying someone else (e.g. driving or walking with a child to school). The number of trips made by different modes over this period was also recorded. The total number of trips recorded by distance from the new infrastructure for the period before the intervention (2011) and the year after most infrastructure was established (2013) is shown by the bracketed figures in Table 1. These show that more than half of all trips made were by respondents whose homes were very close to the new infrastructure (the row corresponding to 0). The reduction in the number of trips surveyed from 2011 to 2013 reflects attrition from the survey over time. The same households were surveyed from year to year, where possible, but only 80 people were interviewed in 2013, compared with 133 in 2011.

Table 1 uses the data weighted to account for differences in initial probabilities of sampling houses and the size of the household in relation to the number of householders interviewed. The results are affected by a number of factors, including real changes in behaviour, sampling variability and any unusual weather that might have occurred in the previous week for which travel behaviour was sought. The figures show no change in active travel as a proportion of all journeys from 2011 to 2013 (first row of Table 1). For those participants closest to the new infrastructure, there was nevertheless a small increase in the proportion of trips that were active over the period shown. This is consistent with a positive influence on active travel mode choice associated with the installing of the new infrastructure, as long as that infrastructure was close to the home of the respondent.

| Group | 2011 | 2013 |
|---|---|---|
| All participants | 19% (947) | 19% (685) |
| Distance 0[a] | 20% (486) | 28% (359) |
| Distance $\leq$ 1 km | 21% (292) | 11% (168) |
| Distance over 1 km | 11% (169) | 11% (158) |

Total number of trips studied is shown in brackets
[a]Zero indicates that there was new infrastructure constructed either within or immediately bordering the city block containing the household

**Table 1.** Percentage of trips by New Plymouth residents to main destinations by active modes (cycling and walking) according to the year of survey and distance from home to new infrastructure, using weighted data

This sub-analysis showed that the distance from the new infrastructure was an important explanatory factor for changes in walking and cycling and modes of travel, indicating that an important aspect of urban design that reduces carbon dioxide emissions and encourages the health-promoting behaviour of cycling and walking is to construct infrastructure that supports walking and cycling close to as many households as possible.

## 5. Co-benefits of more active travel among school pupils

At a time when obesity is rapidly increasing internationally (OECD, 2014), active travel can provide exercise for children and a chance to develop independence and self-confidence (Garrard, 2011). Cycling and walking to school have been found to be associated with higher levels of physical activity and cardiovascular fitness compared with passive means of transport to school (Cooper *et al.*, 2008; Davison *et al.*, 2008). Studies have consistently shown a positive relationship between cycling and health (Møller *et al.*, 2011; Oja *et al.*, 2011). Even for subjects with low initial fitness, frequently cycling short distances (minimal daily distance of 6 km three times per week) is enough to improve physical performance (Hendriksen *et al.*, 2000).

Increasingly New Zealand school-aged children are being driven to school, rather than walking, cycling or taking public transport. During 1989–1990, 31% of primary school children were driven to school, but over the period from 2009 to 2013 this increased to 56% (Ministry of Transport, 2014). The 2012/2013 New Zealand Health Survey reported that one in nine (11%) children aged between 2 and 14 years of age were obese, a significant increase since 2006/2007 (Ministry of Health, 2014).

Previous research has shown that there is a direct relationship between the distance between home and school, and reduced walking (Giles-Corti *et al.*, 2011). Using data from both the two intervention cities in the ACTIVE study, and two control cities where there was no extra government funding for walking and cycling infrastructure, the journeys to school of children between 10 and 18 years of age and their parents/caregivers, living in four provincial cities were explored (Conlon, 2013, unpublished thesis). In this descriptive sub-analysis from the ACTIVE study, Google Maps and Street View were used to measure the children's distance to school and the numbers of arterial (high traffic connector) roads children either travelled along, or crossed on their journey to school. Regression analyses were undertaken to determine what factors, if any, influenced the children's walking and cycling.

A shorter distance between home and school was the strongest predictor of active travel mode choices. Approximately half the children in the study used active transport and of those over half (57%) lived within 2 km of their school. Those children who used active transport were more likely to attend a school the closest to their home (78%) compared with those who travelled to school by car (43%). Further, an increase in the number of arterial roads either traversed or crossed on the journey decreased the likelihood of active transport use. Children who used active modes of transport were also more likely to have a parent who did moderate or vigorous exercise.

As expected, distance from home to work or school is the principal explanatory variable for cycling and walking in both these sub-analyses. However, there are indications from the demonstrable effect of infrastructure in the ACTIVE study, that modifiable aspects of the built environment, such as the placement of walking and cycling infrastructure, can also be an important determinant of active travel.

## 6. Discussion

The health and well-being of the people who live in cities should be one of the main considerations in the design and governance of the built environment (Cooper *et al*., 2013; Rydin *et al*., 2012). Urban planning involves an understanding that the city is a complex system and that addressing in a coordinated way the challenges of multi-level, multi-sectoral policymaking is needed to improve urban sustainability and resilience. Realising this goal requires not only greater policy integration across different sectors, but an emphasis on carefully appraising the desired outcomes, including any potential co-benefits. Designing and incorporating policy evaluations and particularly policy experiments into the policy process is an important and necessary step to improve urban outcomes, including health and environmental outcomes (Wanless, 2004).

In this paper, the authors have summarised the result of four community trials, all of which can be seen as policy experiments, designed to measure the range of benefits of interventions that benefit health and well-being, including by way of lowered injury, and climate change mitigation. The results show the potentially significant range of benefits to population health and well-being, and the environment, of relatively low-cost improvements of urban infrastructure.

Retrofitting insulation and installing effective heating in existing homes improve both health and well-being, as well as increasing energy efficiency, thereby reducing carbon dioxide emissions. A modest home repairs programme to improve the safety features in existing homes significantly reduces health service claims for home injuries. Installing improved cycling and walkways as part of urban infrastructure leads to an important increase over time in the number of active journeys for those who live close to the new infrastructure. Moreover, children who have access to safer routes to cycle or walk to school and have fewer arterial roads to cross are more likely to walk and cycle to school.

In addition, the active travel study raises the interesting question of the link between housing location and available transport to amenities. Public health efforts to increase rates of active transport to school may need to focus on encouraging children to attend school closest to their home if the barrier of distance (either perceived or real) is to be addressed. It is worth remembering that the built environment and the social environment interact in multiple ways, and patterns of behaviour are adaptable and socially constructed. While in the short term our cities seem set in stone, in the medium to longer term, our cities are amenable to being redesigned and the ways we live in them can be changed. Indeed, such reshaping is a necessity if our health and well-being are to be enhanced, and climate change is to be effectively mitigated.

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