



LOW CARBON LIVING
CRC

Scoping document: The development of the Low Carbon Living calculator



Authors	<p>Dr Jason Thompson – University of Melbourne</p> <p>Professor Mark Stevenson – University of Melbourne</p> <p>Professor Majid Sarvi – University of Melbourne</p> <p>Professor Billie Giles-Corti – University of Melbourne</p> <p>Professor Peter Newton – Swinburne University</p> <p>Professor Susan Thompson – University of NSW</p>
Title	RP2028: DEVELOPMENT OF A PROTOTYPE CO-BENEFITS CALCULATOR FOR LOW-CARBON PRECINCT DESIGN – A SCOPING DOCUMENT
ISBN	
Format	
Keywords	
Editor	
Publisher	
Series	
ISSN	
Preferred citation	



Australian Government
Department of Industry,
Innovation and Science

Business
Cooperative Research
Centres Programme

Acknowledgements

This research is funded by the CRC for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative

The authors would like to acknowledge the contribution to this document by Members of the LCLCRC Co-Benefits Carbon Calculator Steering Committee:

- Mary O’Neill – NSW Office for Environment and Planning
- Brett Pollard – Hassell Studio
- Robina Crook – Hassell Studio
- Jeffrey Robinson – Aurecon
- Suzanne Tombourou – Australian Sustainable Built Environment Council

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- originality
- methodology
- rigour
- compliance with ethical guidelines
- conclusions against results
- conformity with the principles of the Australian Code for the Responsible Conduct of Research (NHMRC 2007), and provided constructive feedback which was considered and addressed by the author(s).

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Aims

The aim of this project is to develop and trial a prototype low-carbon precinct co-benefits calculator for use by urban planners and designers. The calculator will estimate co-benefits associated with a range of alternative precinct designs and transport/land use configurations across health, productivity, and pollution associated with greenhouse gases and particulate emissions.

The calculator will estimate population health status (with respect to chronic disease and injury) and productivity at a precinct (or greater) level. It will enable government regulators, developers, precinct planners, designers and local government officials to estimate the population health and productivity effects of various precinct design scenarios.

Background

What we know about urban design, health and productivity?

Cities around the world are dealing with multiple challenges as a consequence of changing population demographics. In 2007, 51% of the world's population lived in cities and it is estimated that this will increase to 70% by 2050 [3]. These projections are reflected in population growth estimates that will see the world's population increase by 66% from 7 billion people in 2013 to 10.5 billion people over the next 40 years. The design of cities and suburbs in which the world's estimated 7 billion city-dwellers will live, work and play will be key to increasing global productivity and reducing incidence, prevalence and costs associated with chronic illness and injury[4].

Governments are increasingly recognising the importance of land use on transport plans and population health [5, 6]. Single use, large area Sprawling suburbs encouraged as a result of comparative ease and incentive for development at the urban fringe [7] limits people's ability to walk or cycle [8], producing reliance on private motor vehicles for transport [9]. Such planning also hinders the use of public and active transport options and increases the travel distances to work, education and other productive activities [9, 10]. As well, it increases exposure to health risks including traffic speed, traffic volume, vehicle pollution, and physical inactivity [11, 12]. Exposure to these risks is associated with increased rates of road injury and death [13], together with chronic conditions such as cardiovascular disease [14], respiratory illness [15], obesity [16] and related conditions such as diabetes and metabolic syndrome [17-19].

Elements of land-use and behaviour are important?

The association between land use characteristics associated with transport choice and health is well described [20-25]. These include (but are not limited to) [24]:

- Distance
- Density
- Diversity
- Design, and
- Transport mode choice

The land-use element 'Distance' refers to the average shortest street routes from a place of residence or workplace in an area to the nearest public transport option and has been found to be a strong correlate of use [25-27]. 'Density', defined as population density, job density, intersection density, recreation space density or residential unit density has also been shown to directly contribute to transport choice after accounting for socio-demographic factors [20-25, 28-43]. 'Diversity' relates to the range of distinct land-uses (e.g., businesses, residential, recreation) assigned to a given area. Often termed 'mixed-use', it has been consistently associated with travel behaviour and transport mode choice, especially the tendency for increased walking, cycling and public transport use [21, 29, 32, 34, 37, 41, 44-49]. The fourth element, 'design', refers to the physical characteristics and layout of precincts including streets, building setbacks, intersection connectivity, aesthetics, footpaths and other infrastructure. Design characteristics that facilitate reductions in motor-vehicle use and facilitate walking and cycling include those that incorporate 'grid-pattern' streets and restricted parking [46], increased street connectivity [47], provision of walking and cycling-specific infrastructure [39, 50, 51], increased access to parks and recreational facilities, and improved aesthetics [20, 52, 53].

Understandably, there is both conceptual and material overlap between these factors and their ultimate impact of population health and transportation patterns.

The effect of urban form on transport modal choice and health

The range and availability of transport mode choice is particularly important element associated with urban design. Dispersed, low-density car-dependent suburbs [9] exposes populations to risk associated with motor vehicle use. The relative risk of death and injury associated with transport varies by mode [54], by the interaction of mode and location [55], and by proportional traffic volumes within transport systems [56-58]. Transport mode choice exposes individuals to varying levels crash risk (e.g., motorcycles vs cars), and exposure to fine particulate matter through vehicle emissions and raised dust. Rates of physical activity are also dependent upon mode choice, especially when contrasts are made between walking or cycling and other forms of powered transport (e.g., motor vehicles, public transport) [59]. In turn, increases in physical activity are consistently linked to reductions in chronic disease risk [60-67]. Non-communicable diseases are now the world's greatest contributors to illness and disability [68]. There is therefore incentive at both the individual and societal levels for change.

In addition to other noxious and greenhouse gas emissions arising from the production and operation of motor vehicles [69, 70], fine particulates from internal combustion engines and suspended road dust from vehicle movement have been associated with increased risk of respiratory and cardiovascular disease [71-76]. Importantly, it has been suggested that the effects arising from vehicle emissions may offset the

benefits of increased physical activity gained within walkable neighbourhoods [77, 78].

Far from being eliminated through the delivery of a safe-system approach focused on 'safer cars, safer drivers and safer roads' [79] deaths associated with vehicle crashes are again increasing in Australia, registering a 15% jump between June 2014 and 2016. Unfortunately, the significant reductions in death and injury derived from investments in 'safe-system' models may be nearing the end of their useful life. New urban design that appreciates the influence that land-use can have on transport mode options and risk-reduction may be key to reversing such trends.

Links between urban form and productivity

It is evident that urban design is associated with the health of populations particularly in relation to chronic disease and road trauma [80]. Similarly, urban form can positively increase population productivity [10]. Elements of urban design namely, distance, density, diversity and design, are demonstrated to be associated with a range of direct and indirect productivity gains. Larger (by measure of population) cities are able to take advantages of economies of scale that bring people, resources, ideas and goods together at rates that outstrip rates of population increase [81]. However, whilst it has been demonstrated that a range of socio-economic factors such as GDP, number of patents, creative industries, and wages increase at rates disproportionately higher than population size, so too may some negative consequences including communicable disease and crime [81, 82], which detract from productivity.

In general, it is proposed that productivity gains are achieved in cities with greater populations through efficiencies in use of

resources (e.g., fuel, roads, and infrastructure) and higher rates of production (wealth, resources and ideas)[81]. The potential for planners to facilitate such gains through urban and precinct planning and design is pronounced.

The scale of precinct development

The evidence presented highlights that elements of urban form have significant direct and indirect consequences for population health and productivity. Quantifying these effects is important if we are to understand the costs and benefits associated with various urban designs.

The development scale (defined as the size of area or precinct at which differences in urban design should be considered) at which the health of cities can be affected is important to consider. Whilst research focused on population health effects of urban planning, shape and overall size has occurred at the city-level [81], analysing and estimating effects at smaller scales is difficult due to the fact that health events (e.g., road trauma) are rare, absolute numbers of people affected can be low, and statistical power needed to identify differences within or between comparison groups is low.

Therefore, although 'redevelopment' of single houses, or small-scale 'groups of houses' (e.g., townhouses) is commonplace, individual, small parcel development cannot alter aspects of population density, diversity or distance at a scale required to make significant improvement to overall health of neighbourhoods or city populations. Only medium to large-scale developments or critical volume of smaller developments have such capacity.

However, development at such scale is challenging, especially in existing grey and brownfield locations. Australian cities face a

number of structural, social, and legal barriers to the initiation and construction of medium-density developments (e.g., 10-100 dwelling units) of scale or numbers large enough to affect population health and city performance [7, 83]. As a consequence, urban growth and redevelopment is often pushed toward the 'greenfield' urban fringe, undermining the likelihood it will positively contribute to population health and wellbeing.

Yet it is at this neighbourhood precinct level that opportunity for improvement exists [84]. The consideration of precinct-scale development not only has the ability to directly affect people who chose to live within the precinct, itself, but provides a scale of development that may also significantly affect surrounding neighbourhoods and communities either positively or negatively.

'Green Urbanism' (see Figure 1) is one recently introduced concept that attempts to capture combined desires for city redevelopment and rejuvenation in existing grey and brownfield precincts with principles of economic, social, transport and broader environmental sustainability crucial to the health of cities and their populations [7]. Broadly, green urbanism encourages principles of energy efficient buildings as well as the 'compact city'; prioritising regeneration of 'middle' suburbs with medium-density housing, reducing mean distances between people and amenities. In turn, this creates economies of scale for urban infrastructure (e.g., transport), increasing mean per-capita energy efficiency and resource utilisation [82]. Also identified in Figure 1 is the policy alternative of Green Sprawl, recognising that if greenfield sites are to be developed, they should contain building and precinct design elements that minimise resource inefficiencies associated with Standard Sprawl development.

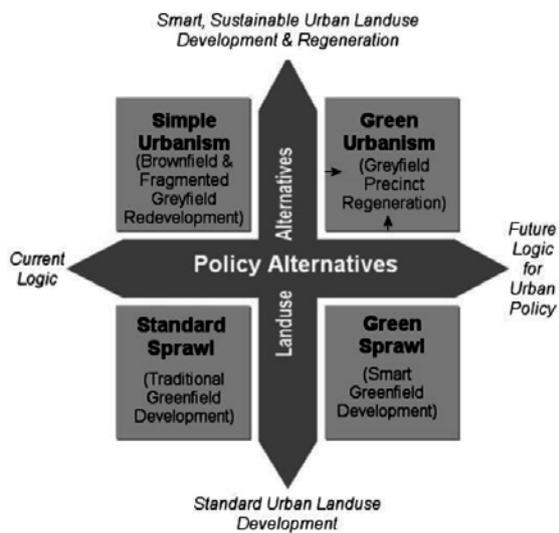


Figure 1. Conceptualisations of urban land-use policy alternatives available to planners (adapted by Newton (2013) from presentation by P.Schwarz , World Cities Summit, Singapore, 29 June 2010).

Developing a Prototype Co-Benefits Calculator – Compact Cities Model

The first stage of this research builds on extensive work led by CI’s Prof Stevenson and Giles-Corti who have developed respective conceptual and operational models for understanding and estimating the health benefits associated with macro-scale urban design, social and policy changes. Referred to as Compact Cities Models (CCM) for the purposes of this document both form part of a Lancet series launched in September 2016 [1, 2].

At present, the CCM uses broad, city-scale associations between urban design changes and health outcomes obtained from meta-analytical studies [25]. Figures 2 and 3 illustrate the pathway from land-use to health and wellbeing as measured in existing CCM and adapted model from Giles-Corti, respectively, which has been applied to the Melbourne metropolitan area in addition to a number of alternative international cities.

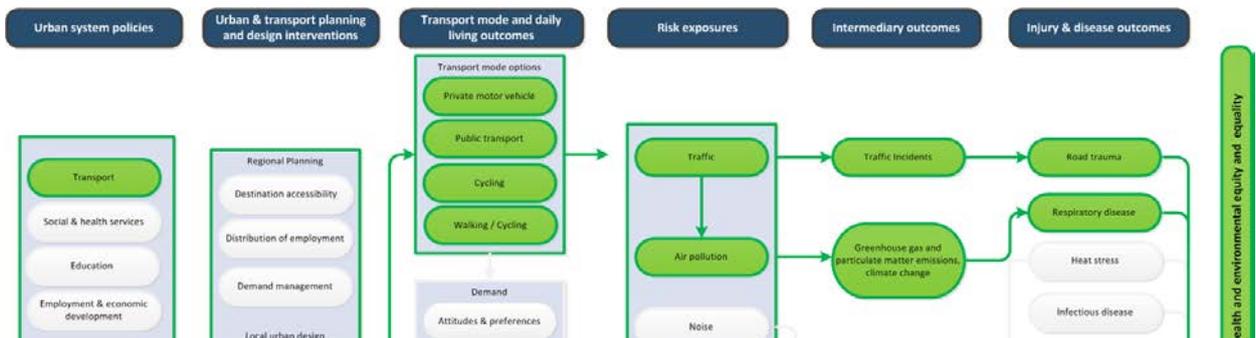
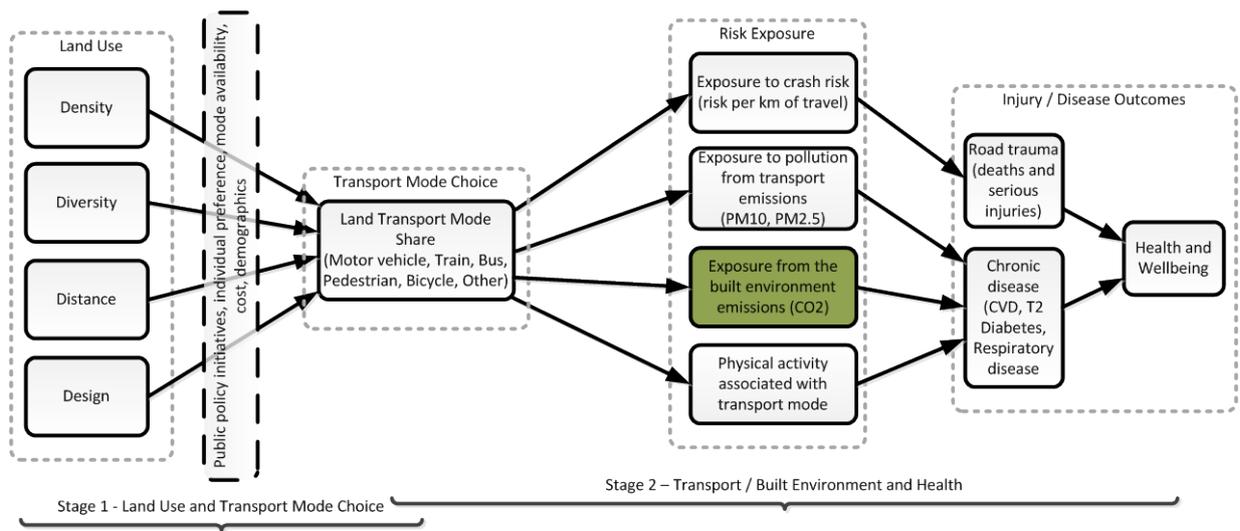


Figure 2. A model for understanding the relationship between urban land-use, transport, risk exposure and injury / disease outcomes, which will assist to form a conceptual basis of the co-benefits calculator.

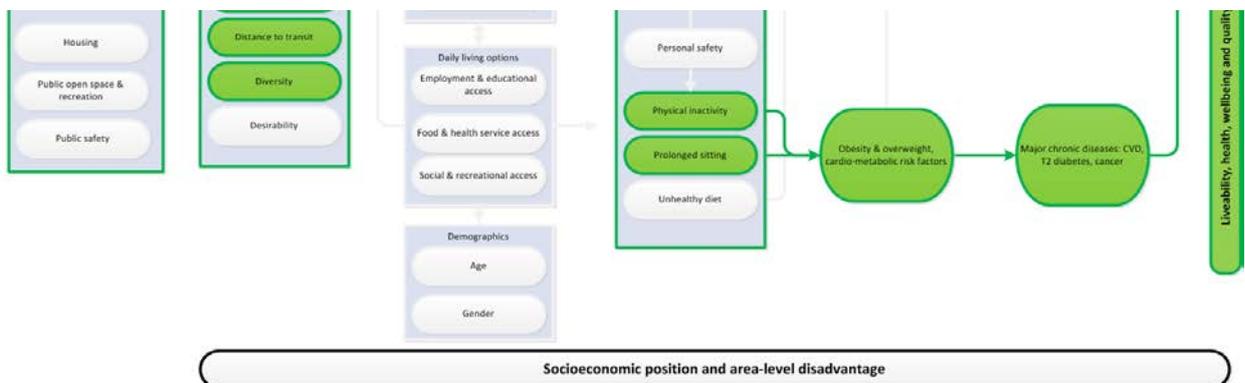


Figure 3. Combined conceptual model of Stevenson and Giles-Corti[1, 2], identifying relationships between urban policies through to population health and wellbeing outcomes.

Background development of the CCM

The CCM incorporates four main land-use elements when estimating changes in population health status:

Density, defined as population density, residential unit density, employment density, intersection density or recreation space density has been shown to directly contribute to transport choice after accounting for socio-demographic factors [e.g., 20-25, 28, 29-42].

Diversity, defined as the number of separate land-uses (e.g., businesses, residential, community centre) assigned to a given area. Often termed 'mixed-use', it has been consistently associated with travel behaviour and transport choice, especially the tendency for increased walking, cycling and public transport use [21, 29, 32, 34, 37, 41, 44-49].

Distance, defined as the average shortest street route from a place of residence or workplace to the nearest public transport option. This has been found to be a strong correlate of use [25-27] and:

Design, referring to characteristics and layout of land including street networks, building setbacks, intersection connectivity, aesthetics, footpaths and other physical infrastructure. Design characteristics that facilitate reductions in motor-vehicle distances travelled and increase active transport such as walking and cycling for, include those that incorporate 'grid-pattern' streets and restricted parking, [46] increased street connectivity,[47] provision of walking and cycling-specific infrastructure,[39, 50, 51] and increased access to parks, recreational facilities and improved aesthetics.[20, 52, 53, 85]

The CCM uses the weighted average associations between land-use and transport choice derived from Ewing and Cervero [25] which were derived as a basis upon which to

conduct 'sketch planning' of urban planning directions. The associations range from 0.02 to 0.29 per unit change in the relationship between one of the four land-use elements and the respective transport mode choice.

Beyond decisions related to land-use, the influence of transport-mode choice on health is well understood with respect to physical inactivity, which in turn affects levels of overweight and obesity, [32, 37, 47, 86-94] cardiovascular disease [35, 95] and other respiratory conditions [96]. However, the impact of land-use on motor-vehicle use goes beyond physical inactivity levels to affect communities more broadly [97]. For example, exposure to vehicle emissions increase the incidence of asthma and cardiovascular disease [69, 77, 95, 98-109] whilst increasing exposure to motorised vehicles heightens the risk of death and injuries among not only drivers but among pedestrians, cyclists and other vulnerable road users [110]. The CCM attempts to incorporate these effects into its design.

The key drivers of population health outcomes associated with transport mode choice as identified in the literature and applied within the CCM are:

Per km exposure to risk of injury or death associated with the mode of travel in the current environment [56, 57, 111].

Level of physical inactivity (as measured by metabolic equivalents METS [59, 112]) associated with the mode choice [32, 37, 47, 86] and its effect on cardiovascular disease and type 2 diabetes.

Exposure to fine particulate matter (PM10 and PM2.5) associated with emissions from transport [113].

The CCM considers a broad range of land-based travel mode choices. However, it excludes heavy vehicle travel for commercial

purposes and does not take into account mode choice based on factors such as speed of the alternative transport modes, costs, or other personal preferences. Importantly, current baseline population, travel mode, road deaths and serious injury counts, levels of physical activity and air quality data are required as city-specific inputs.

As mentioned above, estimates for the urban design elements of the CCM were derived from meta-analyses predominantly from studies undertaken in North America and suitable only for city-wide estimates of effect. Although useful for comparing between cities, this approach lacks the necessary detail required for precinct-based models as is required here. Therefore, an alternative design is required.

Potential modelling approaches for the co-benefits calculator

At its most basic level, a 'calculator' is a machine that takes inputs, performs a function on those inputs, and provides an output. The concept of a precinct-level co-benefits calculator, can be thought of in a similar manner.

The model depicted in Figure 1 is an example of a linear, deterministic model that 'calculates' an output expressed as units of health and wellbeing. Here, a number of data inputs relating to land-use exist on the left hand-side of the model, which produce outputs at the following stage. Second stage outputs then act as inputs to the third stage outputs and so-on. In this model, the calculations that occur between each stage are deterministic, meaning that outputs will be identical for each trial under the same input conditions.

From a practical perspective, deterministic models demonstrate a number of clear

strengths when being considered for use in a project such as the co-benefits calculator namely:

- As in the CCM, deterministic models can be built to bring a degree of simplicity to otherwise complicated or complex structures and issues. Both the components of the models (e.g., the boxes) and the relationships between them (arrows) can be defined and explained.
- The simplicity of deterministic models assists to make them transparent. Deterministic models can be broken down into modules, each of which can be explained, adjusted and / or altered if desired or when new information comes to light. The transparency of deterministic models also makes them relatively easy to communicate and more likely to be adopted[114].
- Because the development of deterministic models is generally based on the combination of components and relationships that have been studied and published independently, deterministic models can identify the latest and 'best evidence' relating to model components for inclusion. Again, this evidence can then be adjusted if 'better evidence' is found.
- Once a deterministic model framework has been agreed upon and the best evidence has been gathered to support the components and relationships within the model, deterministic models can be fast to develop from concept to application. They generally do not rely on specialised software or interfaces and can be implemented and executed on generally available and accessible

software platforms (e.g., Excel, HTML).

- Beyond extremely complicated, probabilistic examples using distributed computing platforms, in general, deterministic models can be run on generic desktop computers and interfaces. This provides the ability to present ‘instant’ answers based on input data.

However, despite their strengths, deterministic models also experience significant shortcomings, especially if being relied upon to guide policy or decision-making. Some of these are detailed below:

- The ‘point estimates’ that are often produced from deterministic models provide an illusion of accuracy that is unlikely to be valid. In reality, estimates of relationship between variables are subject to error and variation that is not captured in their final form. Similarly, derived relationships between variables are often based on ‘average’ associations that may not be applicable at either an individual level, different spatial scale, or circumstance in which other variables not captured in the original model are present.
- The ‘instant’ nature of the estimates from deterministic models can reduce the opportunity for users to understand the mechanisms and assumptions contained within them. In order to understand the sensitivity of outputs to variations in the input parameters, a user must provide various planning scenarios to deduce relationships. If the user does not have a range of scenarios to present, even apparently transparent deterministic models are at risk of appearing ‘black box’.
- The simplicity and transparency of deterministic models is attractive, however, a trade-off of this is their inability to capture many real-world issues such as feedback mechanisms, interactions between variables and ‘side-effects’. As described above, many deterministic models are collated or ‘stitched-together’ from collections of individual studies. Each of these studies may have been based on their own research methodologies including choice of variables and time-scales, are likely to have studied unidirectional effects, only, and are unlikely to have explicitly modelled downstream implications of their findings. Together, this can decrease model validity, despite apparent transparency.
- The very nature of models is that they are simplifications of reality. However, deterministic models demonstrate extreme observer dependence. Potential model effects are totally dependent on the inclusion or exclusion of factors. The introduction of unexpected factors or feedback mechanisms that drive results is impossible.
- Whilst the production of numbers and outputs may assist decision-making, the engagement that a planner may feel with a model that looks and behaves more realistically should not be underestimated.
- Disagreement between experts and users may sometimes arise in models that prioritise particular evidence over others, or where evidence of relationships between variables is either contested or volatile. This can result in mistrust of models or volatility in outputs when new evidence is provided or prioritised.

Dynamic models contain elements of deterministic models, but as their name suggests, have additional dynamic qualities that are advantageous under certain circumstances. Dynamic models include examples such as agent-based models (ABMs) and System Dynamic Models (SDMs) among others. Whilst the variety and application of dynamic model types is broad, in general dynamic models:

- Are live and interactive. The 'live' qualities of dynamic models generally enable users to interact and experiment with model settings during or between model 'runs'. This functionality allows potential policy-makers or planners to conduct thought experiments or run scenarios under various conditions to test the boundaries of outputs, and determine which input factors have the greatest effect on outcomes.
- Whilst not all dynamic models contain realistic visual representations, many use 2D or 3D real or abstract representations of phenomena to communicate their inputs and outputs. An example of this may be a traffic simulation model that not only produces data outputs of the number of trips made by commuters, but shows these trips occurring in a scaled-down visualisation of a city
- Dynamic models will often contain elements of probability and feedback that mean results obtained between trials may approximate one another but are not guaranteed (unless a consistent random-seed generator is used). Practically, this means that users of dynamic tools will not obtain a 'point estimate' of effect, but estimates within a range. On occasion, the combination of

stochasticity and feedback may produce results that are in contrast to the 'average' result. Whilst potentially more realistic in this regard than deterministic models, wide variations in model outcomes can produce distrust in the model assumptions by users.

- The inclusion of dynamic elements produces inherent uncertainty in model outcomes and potential volatility. This creates issues for calibration against historic data which is more easily matched by deterministic models, or stochastic models of narrow range. Despite the overfitting that can occur in calibration, again, dynamic models that do not behave in predictable ways (potentially due to real-world unpredictability) may be less likely to be trusted by users.
- Dynamic models often contain greater complexity than deterministic models, with their assumptions and interactions more challenging to understand. This is simply because each element of a dynamic model is more likely to be connected to other elements in a non-linear manner, producing complex interactions and feedbacks. Users therefore often require more time with dynamic models learning to understand the ways in which they work.
- The more complicated nature of dynamic models can make them more difficult and time-consuming to construct. This can be because they are often built from scratch rather than by using 'off the shelf' packages. To achieve engagement, they also require development of intuitive user interfaces, the development of which

must be considered alongside the tool, itself.

- Due to the bespoke nature of the model build process, dynamic models often need to run in ‘unusual’ software environments, uncommon for most users. Whilst many of these are ‘free’ or open-source, others may be proprietary, requiring payment of software licenses. The combination of reduced familiarity with software and high license costs may reduce take-up of developed dynamic models. Solutions, however, do exist where results of dynamic models can be translated to interactive, web-based graphics packages (such as D3).

Therefore, to achieve the dual goals of the Low Carbon Living CRC co-benefits calculator project as both a valid and engaging tool, it is proposed that a model be built that combines both deterministic and dynamic elements. Deterministic elements will maximise reliability and validity, whilst dynamic elements will improve levels of exploration and engagement. The following analytical plan is therefore proposed.

Analysis and exploration plan

Analysis principles

Given the interdisciplinary nature of the LCL Low Carbon Living Co-Benefits calculator project, the analytical approach we take must be flexible enough to incorporate data inputs that will be 1) collected, 2) calculated or 3) derived for the urban form. This is particularly important to be able to incorporate inputs and expertise from the wide range of participants involved in this project. The focus of creating an analytical framework is therefore on flexibility.

Collection: Data relating to basic variables such as population density, residential density, and demographic profiles is available

at various levels of granularity. Barring unavoidable modifiable areal unit problems (MAUPs), collecting and incorporating such data into precinct-level parcels is relatively straightforward. Where health or demographic data is not available at a sufficiently small scale, there remains the opportunity to collect it through health surveys.

Calculation: Next, there is a range of calculated variables that will need to be incorporated. For instance, urban street design qualities such as intersection density, access to amenities, street connectivity and integration [115, 116] may need to be calculated for each parcel. Incorporation and calculation of these variables will be driven by existing theory and practice, relying heavily on academic and industry input.

Derivation: Finally, it must be recognised that precincts and neighbourhoods do not exist in isolation; they may be latent variables made up of a suite of factors and qualities, or adjacent to roads, parkland, shops, or other areas that fall just outside the precinct boundaries. The relationship between the parcel under study and its neighbouring parcels must therefore be accounted for. A range of derived variables for each precinct will need to be generated that estimate characteristic groups (e.g., cluster groups), distances and adjacency to amenities, employment, transportation and any other theoretically recognised influential factors.

For example, in Figure 3, below, precinct 2 is residential-only and is surrounded by ‘local’ 40kph streets. However it has adjacency to precincts 1 and 3, which are mixed use residential and commercial, and 3 and 4, which also have frontage to a major 70kph arterial road. Additionally, precinct 2 is 4.5km from the city centre and 300m from the nearest public transport stop. In any analysis of precinct 2, the influence on health and productivity of its surrounding areas must be incorporated.



Figure 2. Analysis of any precinct should include the influence of adjacent or surrounding urban form and amenity.

Overall Analysis Plan¹

The purpose of the co-benefits calculator is to assist planners and policy-makers to understand the health and productivity consequences of various urban forms. Melbourne has a range of urban form that transfers from high density, short distance, high diversity (e.g., the CBD) to low density, long distance, and low diversity (e.g., the outer suburbs). To determine the influences of the various changes in urban form on health and productivity, the following approach is proposed:

The analysis will occur across the following four stages:

Enhancement of the existing Compact Cities Model

1. The existing compact cities model (above) will be enhanced to incorporate reduction in greenhouse gas emissions (CO₂) associated with changes in urban form.

Individual precinct analysis

1. An analysis of the entire Melbourne land area is to be conducted.
2. Areas of analysis will be broken into the smallest-scale 'fishnet' precincts or individual land-use scale parcels available (see Figure 4). These individual polygons will constitute 'parcels' for analysis.
3. Characteristics of land parcel attributes and surrounding buffers will be collected. Data collected will align with the conceptual model of Stevenson et al., (2016) (see Figure 1) and Giles-Corti, et al., (2016) and include:
 - a. Density (housing, persons per square km)

- b. Distance (transport, amenities, recreation, pathways, employment, etc.)
- c. Diversity (land use mix / atrophy)
- d. Destination accessibility (e.g., stores, public facilities, banks, medical care)
- e. Road hierarchy
- f. Accessibility of transportation modes and available mode type
- g. Topography
- h. Transport-related injury and death
- i. Chronic disease incidence and prevalence (raw and categorised scores)
- j. Demographic characteristics (age, gender, socio-economic status, employment status, industry, etc.)
- k. Data for CO, NoX, Pm_{2.5}, and PM₁₀ concentrations
- l. Potential latent health variables made up of a combination of health and productivity inputs
- m. Aspects of location 'liveability and desirability'
- n. Both generated and derived variables as described above
- o. Any other characteristics available and of relevance as advised & being collected by AURIN, CI's or steering group members (e.g., items contained within Figure 3)**

Additional datasets available through other sources will also be sought. For example, the project has access to the WorkHealth dataset held by the Institute for Safety, Compensations and Recovery Research at Monash University. This dataset contains chronic disease indicators for over 800,000 working Victorians. Where

¹ Whilst the aims of the project remain consistent, the analysis plan is subject to review and revision throughout the duration of the project.

geographic information is associated with these, it will be recorded. In addition, individual population health surveys may be designed and conducted in order to fill 'gaps' in understanding of population health factors within specific locations.

Integration of results into a co-benefits calculator

1. Prior to analysis, all input datasets will be converted to parcel-size polygons, with each polygon representing a unique combination of recommended variables collected through stage 3, above. This individual-level parcel size will ensure that analysis occurs at the smallest feasible level, limiting potential issues associated with aggregation and scale. Multivariate analyses will then be conducted to determine primary factors associated with land-use typologies on health outcomes. Consistent with the approach of Ewing, Meakins [16], a principle components analysis may also be conducted to simplify factors associated with the model (practical interpretation of principle components, however, is limited).
 - a. Based on these results, estimates regarding the relationship between land-use characteristics derived through both methodologies and overall population health outcomes for people who live in each precinct will be made. Estimates will be made for each health and productivity outcome variable under study as well as a 'latent' health and latent 'productivity' variables which may be linear combinations of health outcomes or combined Disability Adjusted Life Year (DALY) estimates.
- b. Functions for the relationship between land-use variables and health will then be estimated via separate regression analysis, producing an algorithm that can then be used to estimate the relationship between known land-use elements and health and productivity outcomes.
2. The validity of the presumed relationship between selected land-use factors and carbon pollution will also be tested in these alternative locations (change from baseline' or background pollution may be the ultimate measure rather than absolute levels).
3. Consistent with [16], factor scores will be standardised to z-scores and each precinct will be provided a standardised or 'rank-order' rating on each estimated illness and chronic disease outcome.
4. The combined estimated outcomes will be converted to DALY's per 100,000 persons to produce a total precinct star-rating, independent of SES, demographic details and all other theoretically confounding factors. The rating system will break existing precincts into deciles, reserving the top-ranking (six-star) for developments that achieve estimated outputs beyond current benchmarks.

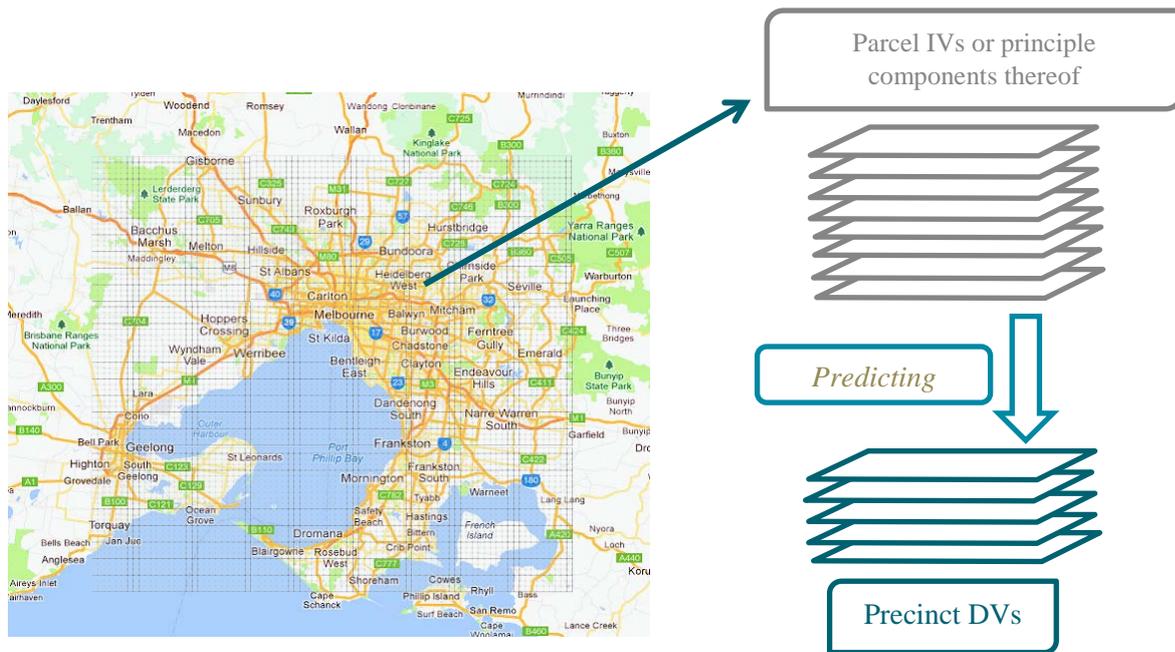


Figure 4. Simple representation of a parcel allocation with each area containing characteristic independent and dependent variable values used to determine relationships between land-use, planning and health outcomes. Either a small-scale ‘fishnet’ or individual parcel allocation with specified buffer (smallest land-use scale available) may be used.

Interaction and engagement tools

To achieve the dual goals of analysis and community and industry engagement with the co-benefits calculator, it will be important to provide minimal barriers to entry and to make the tool as accessible as possible[114]. In this regard, the project will learn from existing models implemented in urban planning contexts such as Envision [117] and may create ‘bolt-on’ applications for these existing tools.

Options for further refinement and consideration are discussed below.

To analyse a proposed precinct, planners may be presented with three options. Firstly, a web-based tool could be developed into which known or estimated values associated with proposed precinct across each of the land-use and demographic variables can be entered. This simple, traditional approach would calculate estimates for the proposed precinct across each of the individual health

outcomes as well as an overall, latent health variable.

The individual precinct analysis may also show urban areas of similar performance to that being proposed (e.g., “Your proposed precinct performs like East Brunswick”). Guidance material (potentially contributed by the WA Healthy Active by Design tool healthyactivebydesign.com.au) for improvements may also be made available.

This tool may not be for analysis, per-se, but could host pre-populated results from the analysis that planners and the public could interact with, demonstrating the likely health outcomes associated with various urban planning scenarios and producing a ‘star-rating’. Ultimately, the calculator would be hosted on either the CRC website, AURIN, or that of the Melbourne School of Design.

An interactive web-based application may contain two levels of interaction – **Visitor** and **Client**, receiving different levels of service.

Visitors to the site could input their data into the model and receive an 'estimated' star-rating of co-benefits across health variables and productivity, comparing the performance of their proposed precinct with that of existing areas. This could be implemented in a simple platform such as Google charts or D3. Clients of the site would not only be able to utilise the Visitor functions, but will be able to input data into the calculator, itself (as opposed to the web-application) to then receive official, verified customised estimates of performance. This functionality could potentially be provided as a fee-based service and will provide developers with an endorsed Low-Carbon CRC 'star-rating' for their development that they can then use for promotion and marketing purposes.

Such dual functionality provides two advantages. Firstly, it would enable low-maintenance, wide-spread engagement with the basic concepts and functionality of the tool through an accessible, web-based platform. The number and locations of people that interact with the tool could be tracked and traced, as well as the types of precincts that were being proposed and generated. Secondly, it could create a secondary, more formal engagement area, branding and potential accreditation mechanism based on a standardised 'star-rating' system or similar.

Testing and Evaluating the Performance of the Co-Benefits Calculator in a Range of Existing Precincts

Traditionally, the purpose of model validation is to determine whether the predicted outcomes from a modelled scenario accords with real-world events. However, validation in this sense is not always possible – especially in 'what-if' scenarios as is required here. Instead, other validation techniques will be used to ensure models are viewed with sufficient levels of confidence.

The validation of our model will take 3 forms:

1. 'Hold-out' samples with known outcomes will be tested for categorisation sensitivity and specificity against estimated outcomes, enabling classification sensitivity and specificity estimates (ROC curves) to be examined.
2. 'Expert opinion validation' will be used to test the assumptions of the model with expert groups that may comment on the mechanisms driving the results it produces[118].
3. Lastly, 'Model replication' will be conducted whereby the outputs of the co-benefits calculator will be compared against models with similar objectives or overlapping sub-components to ensure inconsistencies are either minimised or understood where identified. For example, under the CRCLCL's Integrated Carbon Metrics project, two precinct carbon calculators to which outcomes may be compared: 1) the PIM carbon app, and; 2) UniSA precinct C model.

Conclusions

The model approach proposed here is truly interdisciplinary. Based on existing epidemiological and public health evidence, it attempts to draw these together with disciplines of urban planning, spatial science, engineering, and public health. It is a reflection of the interdisciplinary team contributing to the Low Carbon Living Co-Benefits calculator that these perspectives are to be incorporated.

The project is ambitious, however project team members are confident that each stage and step is achievable. To our knowledge, the types of inputs, outcomes, and analyses being proposed within a single model such as this have not previously been attempted.

The project must balance important requirements of methodological purity and pragmatism. Investigators must be satisfied that the exercise is robust and produces valid information. Meanwhile, users must be satisfied that the tool is useful and engaging. Success of this project will be measured by the extent to which the project achieves both aims.

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