

Knowledge co-production reveals nuanced societal dynamics and sectoral connections in mapping sustainable human-natural systems

Supporting Information

Katrina Szetey, Enayat A Moallemi, and Brett A. Bryan

S1. Comparative income data

Table S1: Data for Average taxable income in Forrest and nationally (Australia). Sources are listed.

Year	Forrest	National	Data source (3236)	Data source (National)
2012	35901	52810	https://nationalmap.gov.au/	https://data.gov.au/data/dataset/f1a2c3d5-98d0-46b7-8b8c-742e65c6afa7/resource/6e4f9b0f-8183-4659-bbee-e02c4e8876e0/download/ts20individual01byyear.xlsx
2013	35436	55417	https://nationalmap.gov.au/	https://data.gov.au/data/dataset/f1a2c3d5-98d0-46b7-8b8c-742e65c6afa7/resource/6e4f9b0f-8183-4659-bbee-e02c4e8876e0/download/ts20individual01byyear.xlsx
2014	32963	56460	https://nationalmap.gov.au/	https://data.gov.au/data/dataset/f1a2c3d5-98d0-46b7-8b8c-742e65c6afa7/resource/6e4f9b0f-8183-4659-bbee-e02c4e8876e0/download/ts20individual01byyear.xlsx
2015	39818	57335	https://nationalmap.gov.au/	https://data.gov.au/data/dataset/f1a2c3d5-98d0-46b7-8b8c-742e65c6afa7/resource/6e4f9b0f-8183-4659-bbee-e02c4e8876e0/download/ts20individual01byyear.xlsx
2016	44485	58521	https://nationalmap.gov.au/	https://data.gov.au/data/dataset/f1a2c3d5-98d0-46b7-8b8c-742e65c6afa7/resource/6e4f9b0f-8183-4659-bbee-e02c4e8876e0/download/ts20individual01byyear.xlsx
2017	45271	58900	https://nationalmap.gov.au/	https://data.gov.au/data/dataset/f1a2c3d5-98d0-46b7-8b8c-742e65c6afa7/resource/6e4f9b0f-8183-4659-bbee-e02c4e8876e0/download/ts20individual01byyear.xlsx
2018	43598	61003	https://nationalmap.gov.au/	https://data.gov.au/data/dataset/f1a2c3d5-98d0-46b7-8b8c-742e65c6afa7/resource/6e4f9b0f-8183-4659-bbee-e02c4e8876e0/download/ts20individual01byyear.xlsx
2019	44267	62917	https://nationalmap.gov.au/	https://data.gov.au/data/dataset/f1a2c3d5-98d0-46b7-8b8c-742e65c6afa7/resource/6e4f9b0f-8183-4659-bbee-e02c4e8876e0/download/ts20individual01byyear.xlsx
2020	55280	64421	https://nationalmap.gov.au/	https://data.gov.au/data/dataset/f1a2c3d5-98d0-46b7-8b8c-742e65c6afa7/resource/6e4f9b0f-8183-4659-bbee-e02c4e8876e0/download/ts20individual01byyear.xlsx

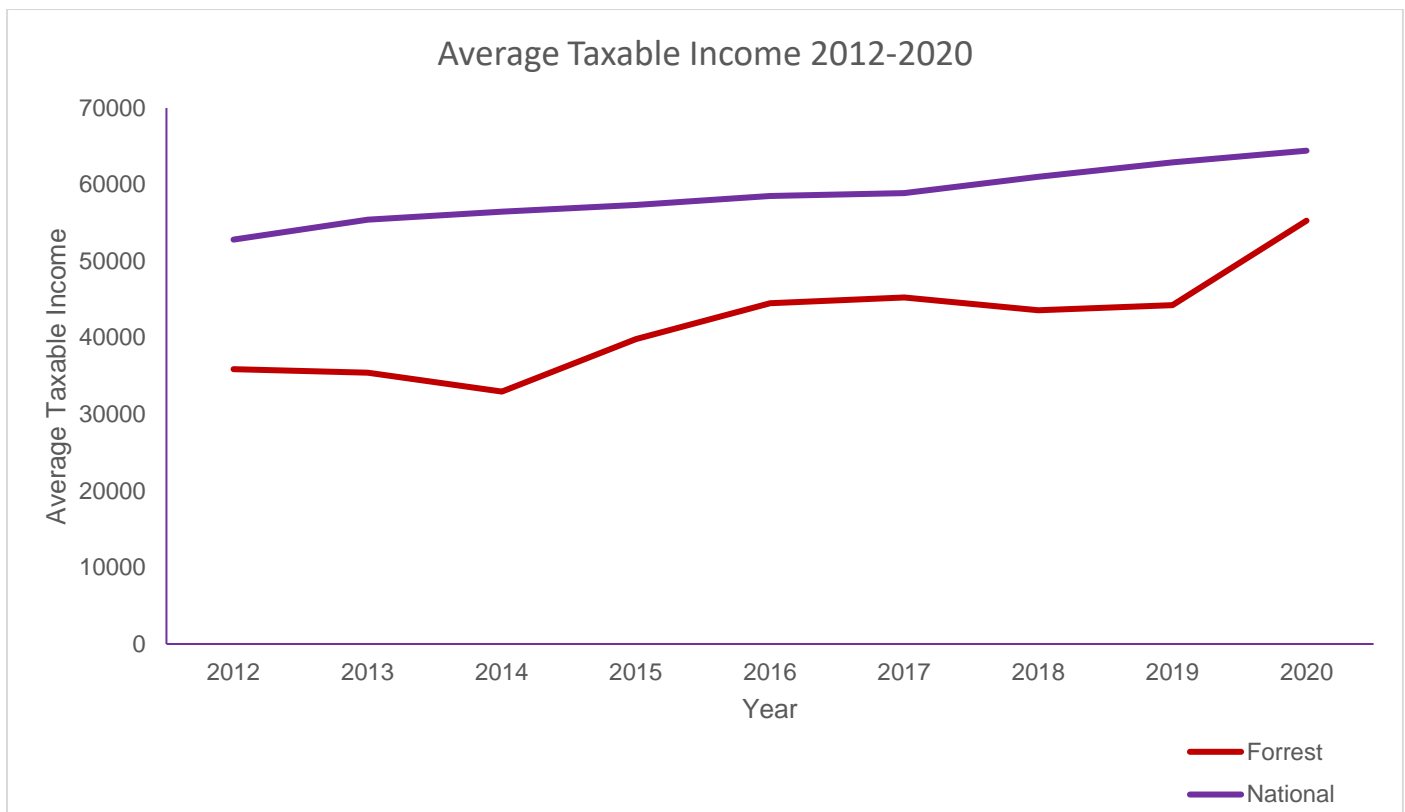


Figure S1: Graph of data in average taxable income data table (Table S1)

S2. Systems mapping workshop design

The running sheet that was used for the workshop.

Mins	Outcome	Activities	Requirements
			Print posters (A1), cue cards (A5) Set up, table layout, chairs Hang posters around workshop room (need blu-tak)
10	All comfortable, late start etc	Welcome, COVID regulations in force at time, toilets, intros, Acknowledgement of Country	ID toilets, emergency meeting point, Traditional Owner Acknowledgement
10	Participants talk to one another	Sociometric ice breaker. Line up of participants, how many years of living in Forrester, then by age.	Ensure sufficient linear space available.
12	Memories refreshed	In small groups, what do you know about this project? (Use cue cards) (in 10 words or less) Explain what to talk about, for how long, where to go. Report back method (write on card)	Provide cue cards including: Pic of front cover of Forrester Plan Logos; DELWP, Deakin, Forrester Pic of earlier engagement activity SDGs poster image (with icons of 17 goals)
5	Memories refreshed in more detail	Presentation: Forrester and District Plan	Powerpoint presentation reminding of the outcomes of Forrester and District Plan 5 goals 9 priority projects to achieve the goals
15	Break	10 minute break	
5	The focus for today	Presentation: Intro to what the model is at a conceptual level	Powerpoint: What is a model? Cat example

5	The idea of an interactive system model	Presentation: The sectors in the model for Forrest, and how they relate to the plan.	Powerpoint: What sectors are in the Forrest model? Why these?
25	Understand the idea of systems modelling	By table group. Discuss what you've heard about the model, and develop the top 2 questions you need for clarification. (10mins to develop Q's; 15mins to answer)	
30	Interactive exercise based on model sectors (gallery process) (30mins)	Participants to write on posters hung around room how they think the sectors interact in Forrest	Powerpoint: Instructions for how to perform the activity.
10	Wrap up and thanks, next steps.	Reflection on activity Presentation: what's next?	Powerpoint: What's next? What will we do with these posters

Your turn!

- Posters around the room with every sector
- There are arrows linking to every other sector
- Write on posters how the sectors interact
 - They might not! This is OK.
- Write on/along the arrow
- Be as specific as you can
 - For example



- Ask questions if you need to!

Figure S2: The slide with the instructions for how to perform the group model building activity.

S3. Problem articulation and dynamic hypotheses

Table S2: Problem articulation and dynamic hypotheses for the sectors in Forrest

Problem	Dynamic hypothesis
Demographic sector	
Between 2006 and 2016, Forrest experienced a 35% increase in population. Over that time, the number of children aged 0-14 decreased by 14% and people over 55 increased by 26%. The median age of a person living in Forrest has increased from 41 to 52. Forrest has a slowly increasing and ageing population, which will influence the needs of residents in the future.	The population in Forrest is ageing due to in-migration of couples without children, and out-migration of young people for school and work after they finish high school. It is limited by housing availability and a lack of diversity in job opportunities.
With Forrest Primary School being the central school, pre-school, and childcare service for the community	The location of the primary school in Forrest makes it a central hub for the neighbouring communities. This

and neighbouring townships, it creates traffic for local businesses in town. It also works with many of the community groups in Forrest. If Forrest were to lose its primary school, there would be many negative knock-on effects causing harm to Forrest's future, such as out-migration of families seeking access to closer schools.	brings in regular visitation from people outside of the township who may then go and patronise local businesses. If the school were to close, this regular visitation would likely slow down or cease, and have effects upon those businesses.
Land Use sector	
Agricultural land fertility is a driver of agricultural business profits. In general, the world needs to use less additional fertilisers to improve the health of ecosystems. Forrest is a hub for regenerative agriculture – where the land is improved as a result of agriculture, rather than stripped of nutrients as in traditional farming.	Regenerative agriculture limits the use of fertilisers, which reduces agricultural runoff into waterways, improving local water quality and the environment generally. It also boosts agricultural profits.
There is not currently a great deal of land use change in Forrest. Agricultural businesses and housing demand are the greatest pressures on land use.	Residents have suggested petitioning Council to change the laws restricting multiple buildings on agricultural land (the '40ha' rule), which may increase land transfer between ag and housing, and an increase in agricultural business may increase land transfer between bush and agriculture.
Housing sector	
Colac Otway Shire have designated that Forrest remain a low growth community and estimated a release of 3.5 permits per year for residential land development. There has only been one permit issued per year since 2011, so development has been below expected levels. There is scope for greater development in the future.	Building permits are not being granted by Council because potential developments cannot meet septic tank regulations. New wastewater infrastructure is required before any significant development may occur.
Cost and availability of housing is an issue. Tourism businesses purchase properties for accommodation, removing them from the pool of available residential housing. This in turn drives up prices due to scarcity of supply. Other potential new residents also struggle to find housing, and anecdotally must wait until existing residents move away or travel.	Lack of housing development due to wastewater issues is constraining the housing and tourism accommodation supply.
Median house prices have increased 188% since 2009, while median rents have increased by 30%. This puts a number of residents into mortgage or rent stress.	House prices are artificially high in much of Victoria (property market bubble), and the housing supply issue additionally inflates prices. Social housing (hypothetical) may relieve rent stress.
Economy sector	
The development of the Mountain Bike Trail system began the transition to a primarily tourism-based economy. This transition was enhanced with private investment in local small businesses catering to both tourists and local residents. The expansion of the tourism industry is hampered by limited housing supply for both accommodation and employees, and by ageing and failing infrastructure.	There is a tension between tourism, housing and the economy, especially while new housing development is stymied. Residents resent tourism for its impact on housing and housing prices, while also benefitting from its positive economic impact. New wastewater, enabling housing development, would ease this tension.
Agriculture is still a major part of Forrest and District. There are local dairy and beef farms, mushroom growers. Community members have noted the future viability of these as an uncertainty.	Climate change will have a diminishing effect on agricultural profit in the long term. Land fertility may be able to combat this effect, especially through the impact of regenerative agriculture.
The local community are happy to have tourism in Forrest, except where there is conflict with housing availability, but have expressed a desire for diversification of the economy so there are other options for employment growth within the town	Local small businesses are dominated by tourism/hospitality and farming. Other sectors (e.g. accountants, hairdressers, tradespeople etc) are constrained by a lack of housing and office space, and poor internet.

Tourism sector	
Forrest's major tourism drawcards are its beautiful natural environment and the Mountain Bike Trails. It follows that these are also its vulnerabilities.	Tourist numbers are affected by the incidence of bushfire either locally or elsewhere in Victoria, by flooding, and by the quality of local infrastructure (including the MTB trails and wastewater).
Because tourism accommodation is primarily sourced from residential housing stock, neither residential housing nor dedicated tourism accommodation is able to be built because of the wastewater problem.	The current state of wastewater in Forrest impacts the development of housing and tourism accommodation, thus impacting growth in tourist numbers
Forrest is virtually inaccessible unless you have a car, thus it excludes tourists who do not drive	The frequency of bus services in Forrest is inadequate for residents, let alone to support tourist movement. An increase in bus frequency would enable growth in tourist numbers.
Biodiversity sector	
Forrest is located in a biodiversity hotspot, and the Great Otway National Park provides protection for some of that biodiversity. The local residents are proud of their pristine surroundings and dedicated to ensuring they remain so. Climate change and potential bushfire impact are both threats to the local environment, as well as any land use change which reduces the amount of bushland. Fertiliser runoff from agriculture is also a potential danger.	Climate change and land use change are the fundamental drivers for biodiversity risk. They both increases bushfire risk and land use change reduces habitat. Indigenous cultural burning may be a way to mitigate biodiversity loss (by healing Country) but has a significant lead-in/preparation time.
Climate change sector	
Human-induced climate change is a problem that will require a united, global effort to combat. However, the effects of climate change do and will continue to affect Forrest at a community level. Such affects include increasing temperatures, drying climates, increased and more serious bushfires, droughts, and more extreme weather. To remain safe and stay resilient in the face of climate change, Forrest must anticipate more frequent bushfires, flooding and drought, and develop plans for sustainable recovery.	Forrest is vulnerable to bushfires and drought, and the negative effect of climate change on biodiversity may affect Forrest's eco-tourism economy. More frequent heatwaves will put older people, more susceptible to heat-induced illness, at risk. Forrest is occasionally subject to flooding and with the increase in extreme weather events this could become more frequent.
Inequality sector	
In the greater Otway region, 19% of people live in poverty and the median family income in Forrest is 55% lower than for the rest of Victoria (2016). Twenty percent of all families in Forrest are single-parent families (and all single parents are women). The SEIFA score (a measure of socio-economic conditions) puts Forrest in the 30% most disadvantaged areas in the country, and the 20% most disadvantaged in Victoria.	Intergenerational inequality is only one factor. Other contributing factors are income inequality, employment, the social gradient of health, housing stress, travel inequality, and internet access.
Health and wellbeing sector	
Being in a regional area, Forrest does not have local access to healthcare services (closest hospital is Colac).	Living in regional areas impacts life expectancy.
Potential disease burden in Forrest has been estimated to be approximately 80-90,000 times greater than the WHO target because of failing septic systems in Forrest.	Building new wastewater infrastructure will reduce disease burden
Climate change and bushfire are risks to the local environment and population.	People like to live in Forrest because the local bush has a positive effect on wellbeing but there is a trade-off from bushfire risk
There is a wide income distribution in Forrest, with a larger proportion of people in lower income brackets compared to the state.	People experiencing income inequality have poorer health outcomes (social gradient of health)

Telecommunications sector	
The NBN has been rolled out in Forrest, but the service can be poor. NBN Fixed Wireless is known to suffer from congestion issues, and the distance to the fixed wireless tower can also affect internet speeds. The nearest tower to Forrest is in Barwon Downs, and towers have an effective range of 14kms, which can be disrupted by terrain (trees, mountains, etc.), and precipitation. There is also limited mobile reception throughout Forrest.	Poor internet and mobile phone service impacts establishment of new businesses and growth of existing ones. Improved internet access (fixed and mobile) would encourage new businesses which rely on connectivity, and better support the existing residents and businesses. It is also necessary for education and better health outcomes.
Infrastructure sector	
In the past, on-site septic systems were adequate for a town the size of Forrest, which did not have many visitors. With the change to a tourism economy, there are many more people that come to town, particularly for events, and the now ageing septic infrastructure requires upgrading. The limits of septic infrastructure for waste are hindering attempts to increase housing in the town. Studies have been undertaken by Barwon Water to upgrade wastewater infrastructure but there has been no progress, partly due to funding issues. The current option on the table expects the community to contribute, which may delay or entirely derail the development.	Ageing septic systems that don't meet current safety standards are no longer adequate and new infrastructure is urgently needed. This affects the local environment and biodiversity, the local economy (by limiting tourism), health of local residents, and additional development in the town.
The Forrest MTB Trails were first opened in 2005, encompassing over 60km of trails. A proposal was released in December 2019 to increase the MTB trail network by approximately 38kms, including restructuring the existing trails and creating a new Trail Head. This plan is aimed to revitalise mountain bike tourism and re-establish Forrest as a nationally significant mountain bike destination.	Mountain bike trails in Forrest are already a major tourism drawcard but upgrades to the trail network would encourage more visitation to the town. This is a benefit to the tourism economy but issues still remain around accommodation (i.e. housing supply) and wastewater.
The Forrest Common is a piece of public land which could be put to better use for the community. After several years of consultation with Colac Otway Shire, a plan has been approved but it is beyond the ability of Council to fund.	A revamped Forrest Common would benefit tourism and in-migration of families (due to new play equipment).
The community identified that a bushfire safer place is necessary for the community, and that one of the DELWP parcels of land could be used to achieve this. A feasibility study and preliminary plans have been completed, but funding needs to be found to build it.	If funding can be obtained for the Gateway to The Otways Centre, this would have a positive impact on community health and wellbeing in the event of a bushfire and potentially prevent loss of life.
Transport sector	
Forrest lies on the route between Apollo Bay and Colac. It is a feeder route to tourism along the Great Ocean Road and the Great Otway National Park. Recent upgrades to the channel routes to Forrest make it easier for tourists to visit the area, and safer for residents to drive.	Forrest is midway between Colac and Apollo Bay, and the road between them is a key route to the tourism of the Great Ocean Road. It is important that these roads remain in excellent condition for safety of road users. Road deaths on rural roads far exceed those in metropolitan areas.
There is one bus line that runs through Forrest, the Colac-Marengo route. This service runs only on Wednesdays and only once in each direction. There is a V-Line station in Birregurra, but apart from the once-weekly bus, there is no connecting service from Birregurra to Forrest, and there is no alignment of the bus timetable with the train timetable. This puts a	There is poor public transport service from Forrest to Colac or Birregurra. One service per week does not enable general uptake of public transport. This is also an inequality issue, as people of lower incomes may not be able to afford to own or use a car, and this also restricts mobility for those unable to drive, due to age

severe limit on residents who may want to avoid driving, and for tourists who wish to visit that do not drive.

or disability. More tourists may visit if there was better public transport access.

S4. Conceptual models of each sector

Demographics

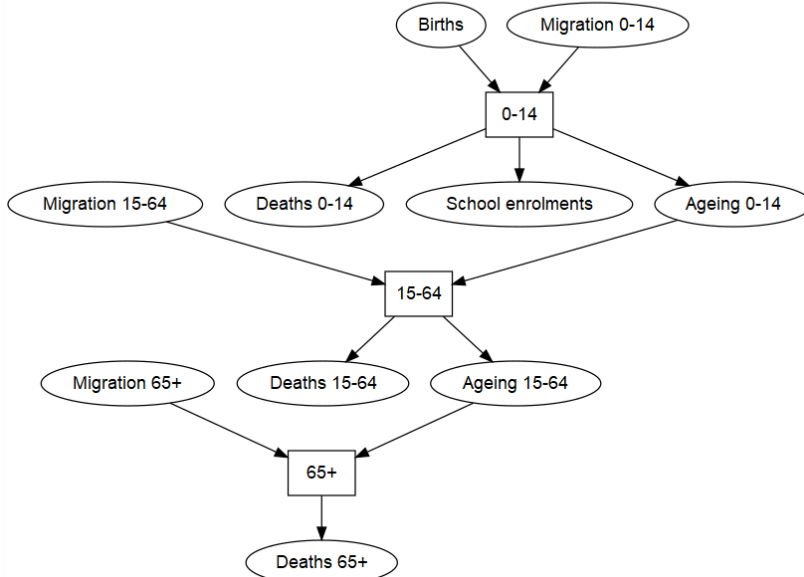


Figure S3: Demographic sector of local SDGs systems model

Land Use

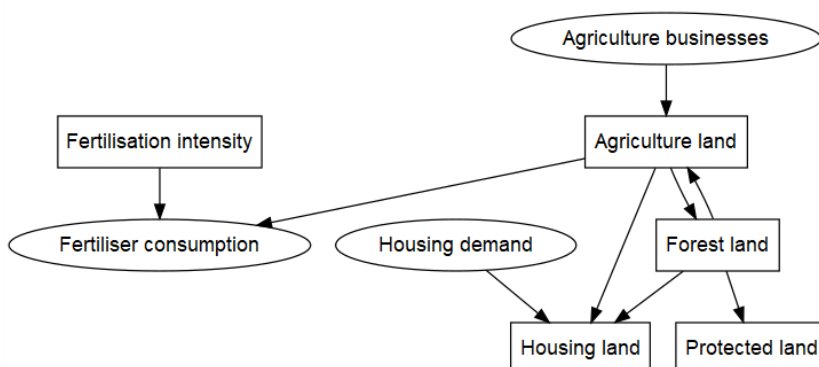


Figure S4: Land Use sector of local SDGs systems model

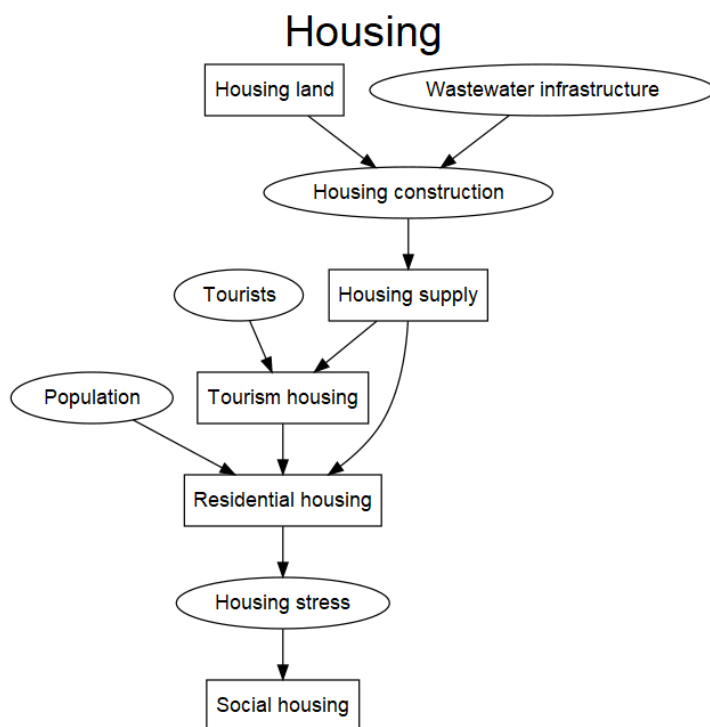


Figure S5: Housing sector of local SDGs systems model

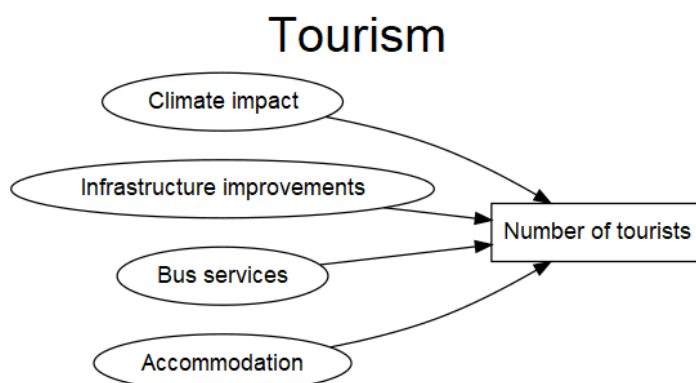


Figure S6: Tourism sector of local SDGs systems model

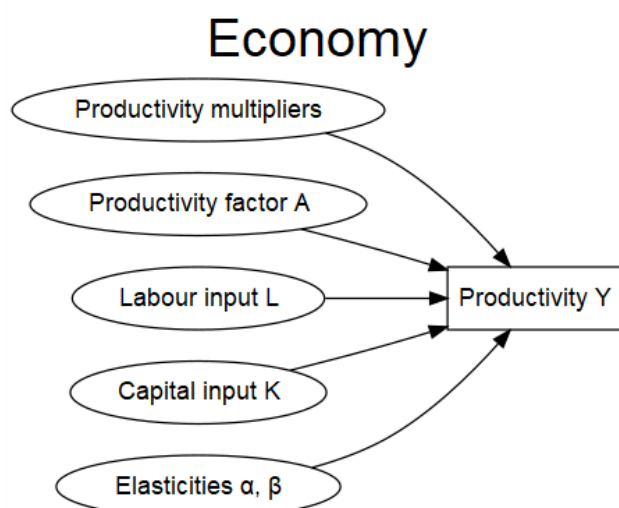


Figure S7: Economic sector of local SDGs systems model

Biodiversity

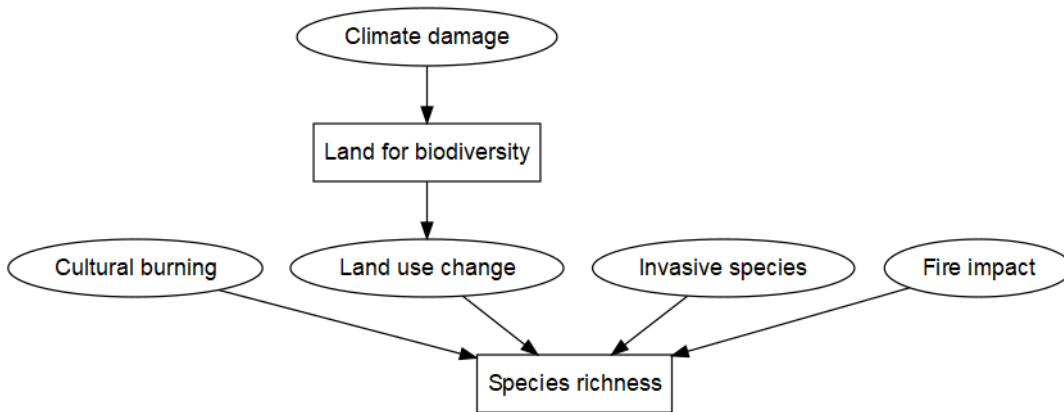


Figure S8: Biodiversity sector of local SDGs systems model

Inequality

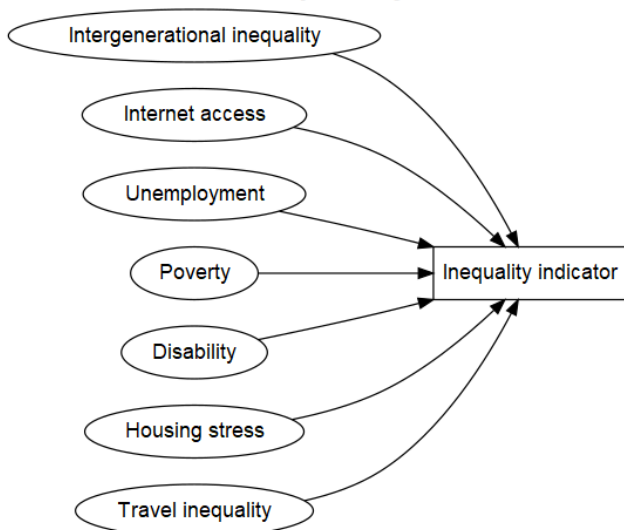


Figure S9: Inequality sector of local SDGs systems model

Telecommunications

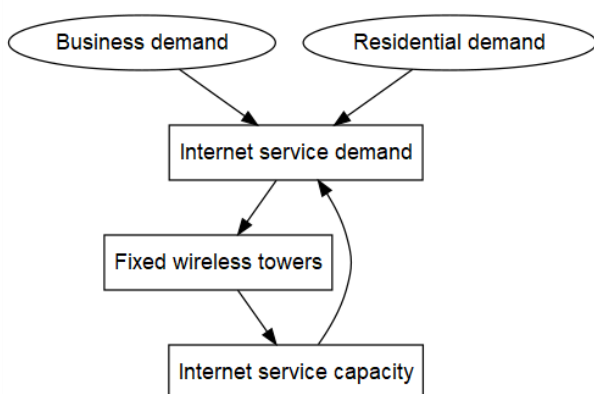


Figure S10: Telecommunications sector of local SDGs systems model

Infrastructure

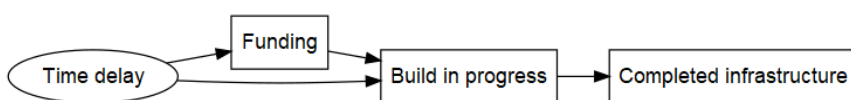


Figure S11: Infrastructure sector of local SDGs systems model

Transport

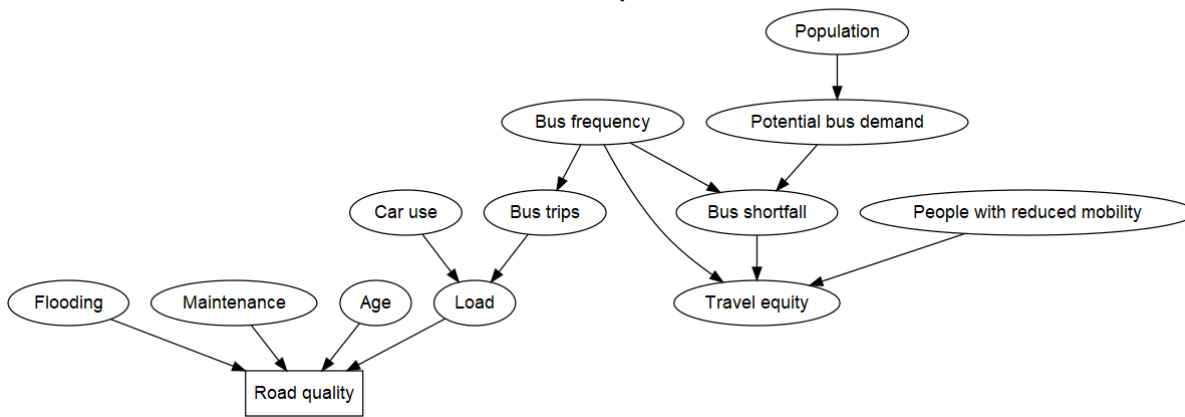


Figure S12: Transport sector of local SDGs systems model

Health and Wellbeing

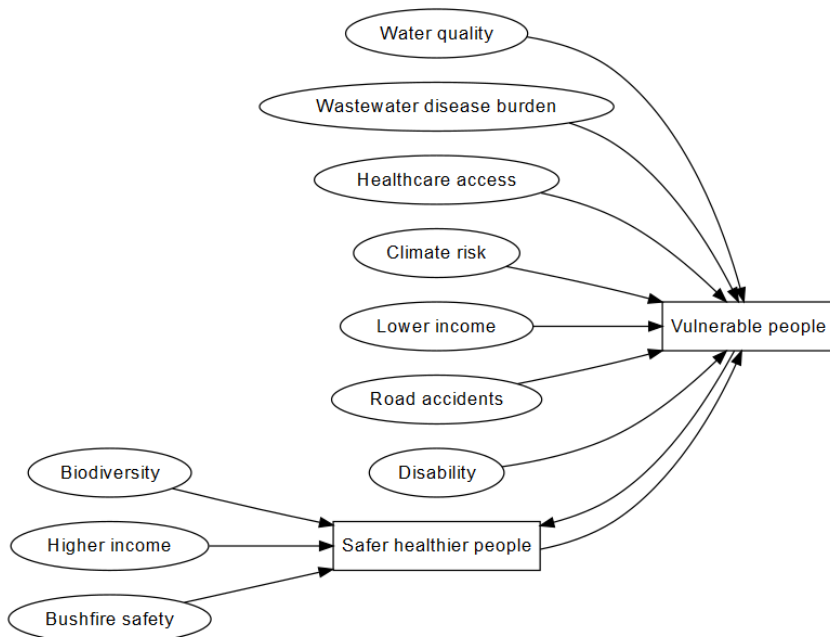


Figure S13: Health and Wellbeing sector of local SDGs systems model

S5. Poster responses from the Group Model Building Workshop

NB: some sectors have two posters, these are labelled “V1” and “V2” here.

