Centre for Air pollution, energy+ health Research

Comparing estimated years of life lost due to air pollution using system dynamics versus Leslie matrices

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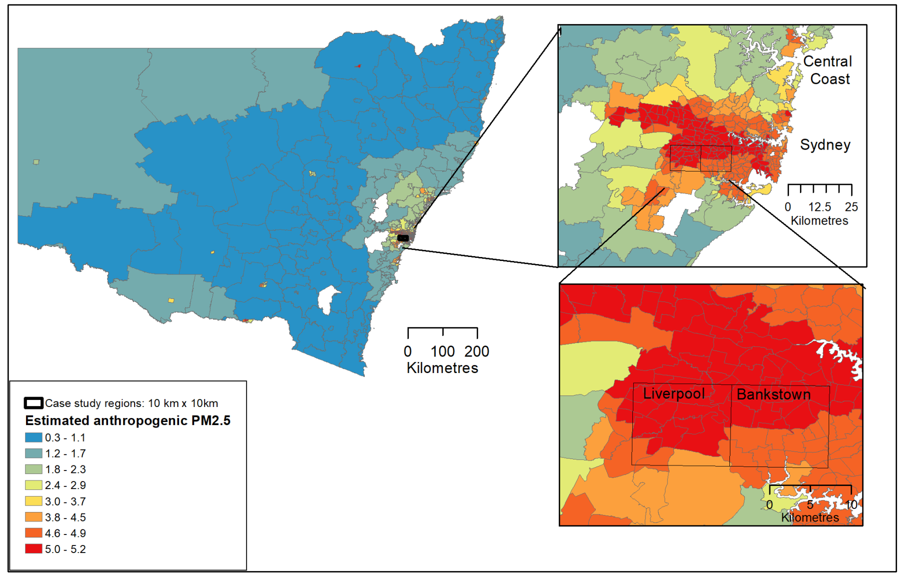
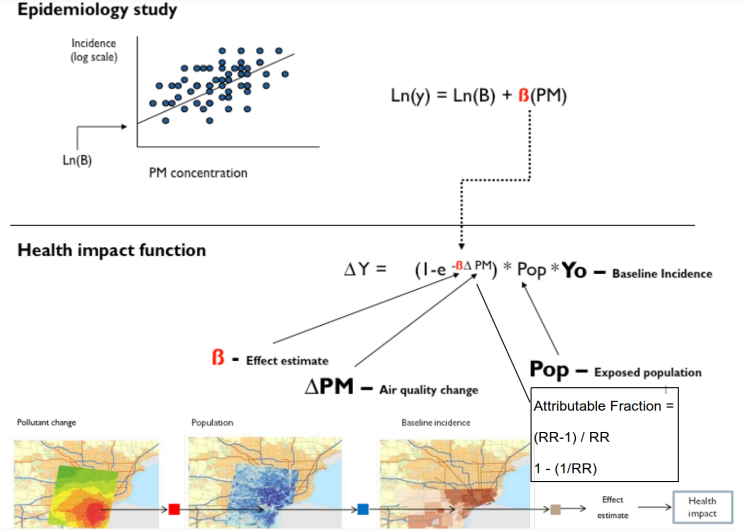
Ivan Hanigan PhD, The University of Sydney

ANNUAL $PM_{2.5}$ USING SATELLITE/LAND USE/DISPERSION: POP-WEIGHTED/ANTHROPOGENIC



DERIVING THE ATTRIBUTABLE NUMBER OF HEALTH OUTCOMES



YEARS OF LIFE LIVED/LOST (YLL) USING LIFE TABLES

A number of ways to estimate potential YLL under different exposure scenarios

Our approach: $YLL = \sum$ Attributable N due to exposure $\times$ Life Expectancy w/o exposure

Scenario A with no change in exposure

RR per 10	1.060
beta	0.006
deltaX	0

	x	n	a_x	pop	death	AN	Expected	M_x	e_x	YLL
<1	0	1	0.1	2,533	20		20	0.007896	71.99	0.00
1-4	1	4	0.5	11,130	1		1	0.000090	71.55	0.00
5-9	5	5	0.5	15,519	2		2	0.000129	67.58	0.00
10-14	10	5	0.5	16,409	4		4	0.000244	62.62	0.00
15-19	15	5	0.5	16,133	9		9	0.000558	57.70	0.00
20-24	20	5	0.5	21,482	10		10	0.000466	52.85	0.00
25-29	25	5	0.5	15,997	22		22	0.001375	47.97	0.00
30-34	30	5	0.5	16,026	35	0	35	0.002184	43.28	0.00
35-39	35	5	0.5	19,800	34	0	34	0.001717	38.73	0.00
40-44	40	5	0.5	16,076	39	0	39	0.002426	34.04	0.00
45-49	45	5	0.5	13,404	59	0	59	0.004402	29.43	0.00
50-54	50	5	0.5	13,027	108	0	108	0.008290	25.02	0.00
55-59	55	5	0.5	10,051	136	0	136	0.013531	20.98	0.00
60-64	60	5	0.5	10,220	176	0	176	0.017221	17.27	0.00
65-69	65	5	0.5	9,190	320	0	320	0.034820	13.60	0.00
70-74	70	5	0.5	7,427	445	0	445	0.059917	10.72	0.00
75-79	75	5	0.5	5,231	414	0	414	0.079144	8.61	0.00
80-84	80	5	0.5	2,884	355	0	355	0.123093	6.63	0.00
85+	85	11	0.5	1,840	347	0	347	0.188587	5.30	0.00
										0.00
										TOTAL YLL

Scenario B with reduction of 3 $\mu g/m^3$ $PM_{2.5}$

RR per 10	1.060
beta	0.006
deltaX	3

	x	n	a_x	pop	death	AN	Expected	M_x	e_x	YLL
<1	0	1	0.1	2,533	20		20	0.007896	72.18	0.00
1-4	1	4	0.5	11,130	1		1	0.000090	71.75	0.00
5-9	5	5	0.5	15,519	2		2	0.000129	67.77	0.00
10-14	10	5	0.5	16,409	4		4	0.000244	62.81	0.00
15-19	15	5	0.5	16,133	9		9	0.000558	57.89	0.00
20-24	20	5	0.5	21,482	10		10	0.000466	53.04	0.00
25-29	25	5	0.5	15,997	22		22	0.001375	48.16	0.00
30-34	30	5	0.5	16,026	35	1	34	0.002146	43.47	26.37
35-39	35	5	0.5	19,800	34	1	33	0.001687	38.92	22.93
40-44	40	5	0.5	16,076	39	1	38	0.002384	34.22	23.13
45-49	45	5	0.5	13,404	59	1	58	0.004325	29.60	30.27
50-54	50	5	0.5	13,027	108	2	106	0.008147	25.20	47.16
55-59	55	5	0.5	10,051	136	2	134	0.013297	21.14	49.82
60-64	60	5	0.5	10,220	176	3	173	0.016923	17.42	53.14
65-69	65	5	0.5	9,190	320	6	314	0.034217	13.74	76.20
70-74	70	5	0.5	7,427	445	8	437	0.058878	10.84	83.62
75-79	75	5	0.5	5,231	414	7	407	0.077772	8.72	62.59
80-84	80	5	0.5	2,884	355	6	349	0.120960	6.73	41.40
85+	85	11	0.5	1,840	347	6	341	0.185319	5.40	32.45
										549.06
										TOTAL YLL

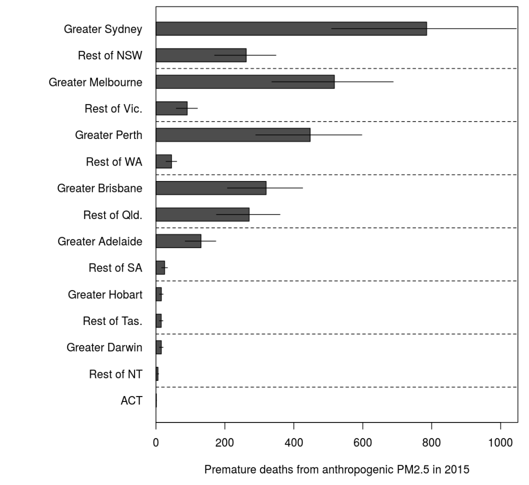
Adjust the death rate (M_x) by the attributable number given RR and exposure change (deltaX)

Difference in life expectancy (e_x) at birth = 72.18 − 71.99, about 69 days are lost in scenario A

This is the potential years of life expectancy gained in scenario B

Source: Chiang method (II) https://www.ons.gov.uk

ASSESSMENT OF THE BURDEN OF CURRENT ANTHRO $PM_{2.5}$ ~ 2,900 PREMATURE DEATHS



Hanigan and Morgan Indicator 3.5.2 in MJA-Lancet Countdown 2018

ASSESSMENT OF THE BENEFIT OF $PM_{2.5}$ CONTROL

- Reducing pollution causes people to live longer, increases the size and average age of that population
- Less exposed, but more individuals
- Main effect is not avoidance of deaths (***burden***), but lengthening of life (***impact***)
- Two tables of population in future years:
  - First table: population size assuming that age-specific mortality rates remain constant
  - Second table: age-specific mortality rates are adjusted to account for reduced pollution
- The ***impact*** is measured in terms of the additional YLL by the less-exposed population over 120 years

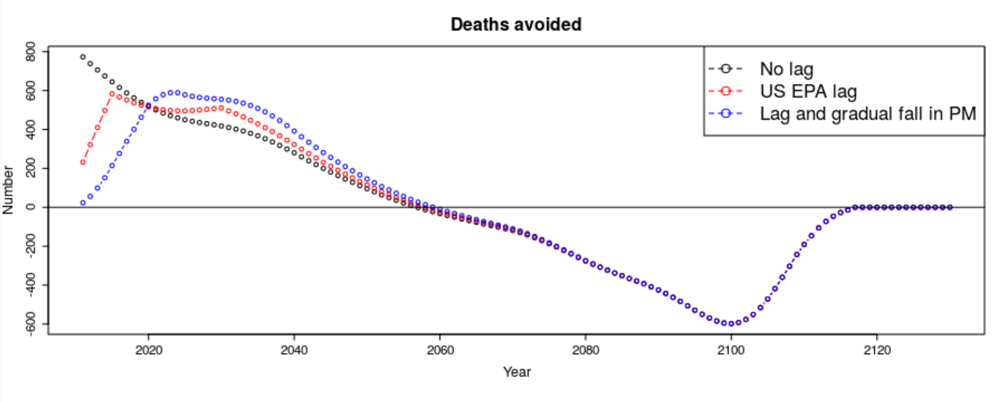
Miller and Hurley (2003). Lags can be incorporated, *but* not great for dynamics and interactions

Age	Entry pop^n	Year												
		1999	2000	- - -	2004	2005	2006	2007	- - - -	j	- - - -	2108	2109	2110
		Births	b_1	- - -	b_5	b_6	b_7	b_8	- - -	b_j	- - -	b_{108}	b_{109}	b_{110}
0	e_0	h_0	h_0		h_0	h_0	h_0	h_0		h_0		h_0	h_0	h_0
1	e_1	h_1	h_1		h_1	h_1	h_1	h_1		h_1		h_1	h_1	h_1
2	e_2	h_2	h_2		h_2	h_2	h_2	h_2		h_2		h_2	h_2	h_2
¦														
I	e_i	h_i	h_i		h_i	h_i	h_i	h_i		$h_{i,j}$		h_i	h_i	h_i
¦														
103	e_{103}	h_{103}	h_{103}		h_{103}	h_{103}	h_{103}	h_{103}		h_{103}		h_{103}	h_{103}	h_{103}
104	e_{104}	h_{104}	h_{104}		h_{104}	h_{104}	h_{104}	h_{104}		h_{104}		h_{104}	h_{104}	h_{104}
105	e_{105}	h_{105}	h_{105}		h_{105}	h_{105}	h_{105}	h_{105}		h_{105}		h_{105}	h_{105}	h_{105}

Source: Richard Broome

R PACKAGE IN DEVELOPMENT TO EXTEND THE IOMLIFET SPREADSHEET SYSTEM

- Calculations using the life tables approach in the IOMLIFETR software by Broome, Hanigan and Horsley (2019) (https://github.com/richardbroome2002/iomlifetR)
- Either assume the reduction occurs instantaneously or over time; also if effect has delay (cessation lag)



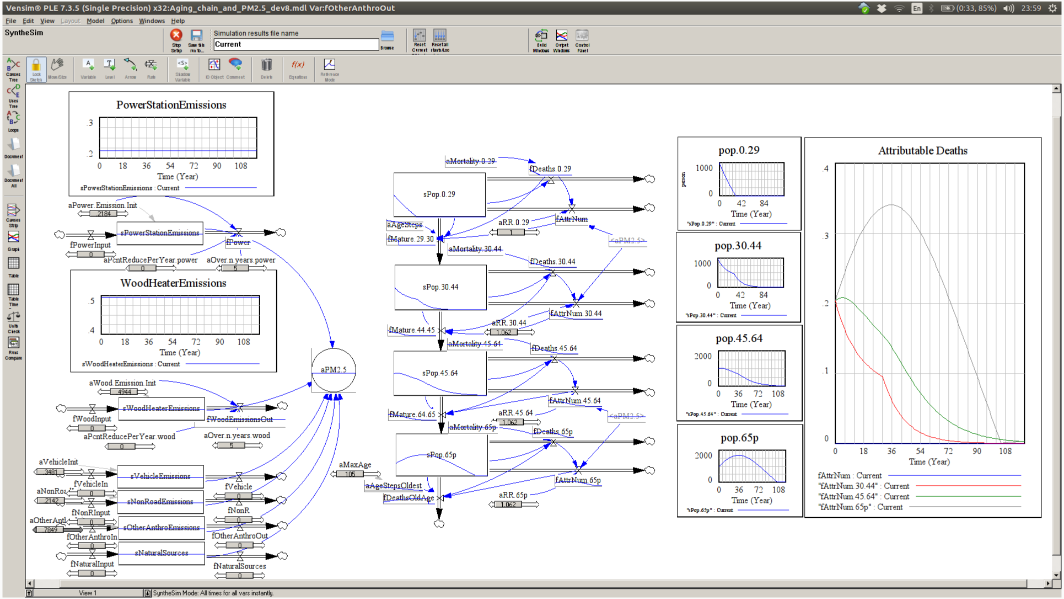
SCENARIO FOR REDUCTION OF ANTHROPOGENIC SOURCES

Based on CSIRO data from paper by Richard Broome, Jennifer Powell, Martin Cope, Geoffrey Morgan (under review)

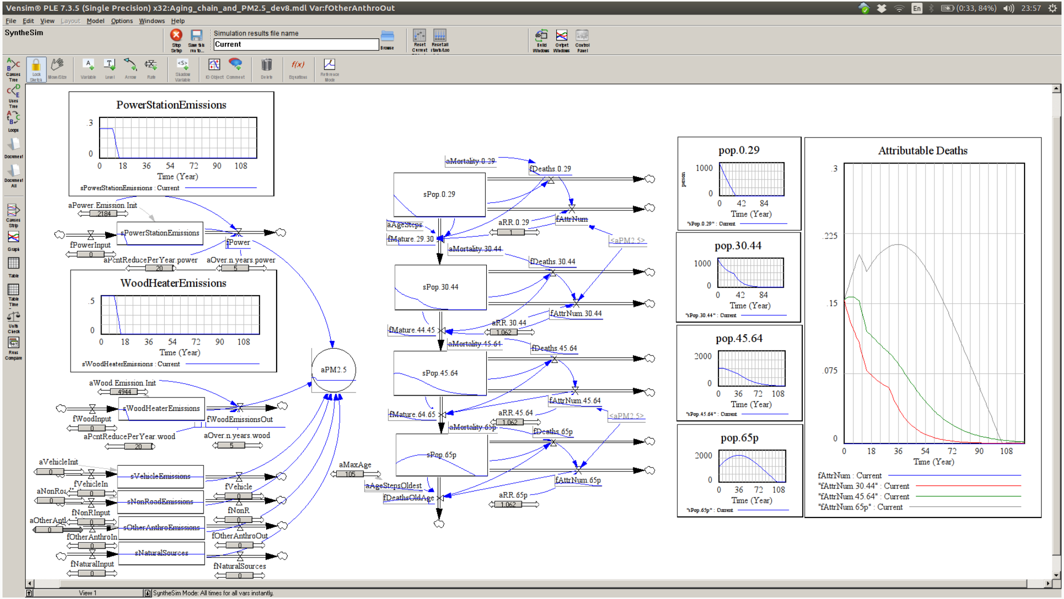
Pop weighted average $PM_{2.5}$ = 5.54 $\mu g/m^3$, anthropogenic = 2.06 $\mu g/m^3$

Source	$PM_{2.5}$ concentration	
	$\mu g/m^3$	%
Wood heaters	0.49	24.0
Power stations	0.22	10.6
On-road mobile sources	0.35	16.9
Exhaust from petrol vehicle	0.08	4.1
Exhaust from diesel vehicles	0.16	7.6
Non-exhaust emissions	0.11	5.3
Off-road mobile sources	0.22	10.4
Industrial vehicles and equipment	0.06	3.0
Ships	0.12	5.7
Aircraft (flight and ground operations	0.03	1.7
Other anthropogenic sources		

ALTERNATIVE: SYSTEM DYNAMICS AGING CHAIN



REDUCED ALL ANTHROPOGENIC SOURCES



ALTERNATIVE TOOLS FOR HEALTH IMPACT ASSESSMENT

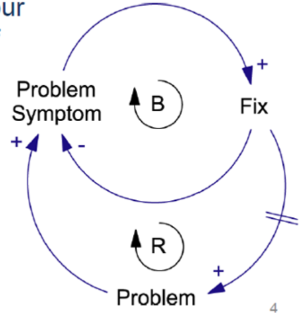
- IOMLIFET (and iomlifetR)
- BenMap and reduced form BenMap
- AirQ
- DYNAMO-HIA (DYNAmic MOdel for Health Impact Assessment)
- HEIMTSA (Health and Environment Integrated Methodology and Toolbox for Scenario Assessment) within INTARESE
- The impact calculation tool (ICT), developed in the context of INTARESE
- PREVENT
- Vivarium
- Health Economic Assessment Tool (HEAT)
- Integrated Transport and Health Impact Model (ITHIM)
- Towards an Integrated Global Transport and Health Assessment Tool (TIGTHAT)
- Health Forecasting / University of California
- MicMac (micro-macro forecasting)
- Health Impact Assessment of Outdoor Air Pollution (HIAIR)
- The Hotspots Analysis Reporting Program (HARP)
- **VENSIM???**

Definition: Complex behaviour that is generated by feedback. Occurs even in very simple systems.

Discovery: System behaviour often reflects dominance of simple, generic feedback structures.

System Archetypes:
Peter Senge (1990)
The Fifth Discipline

Example: *Fixes That Fail*



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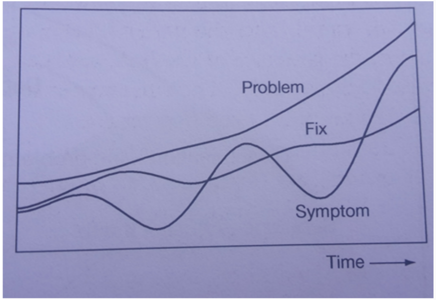
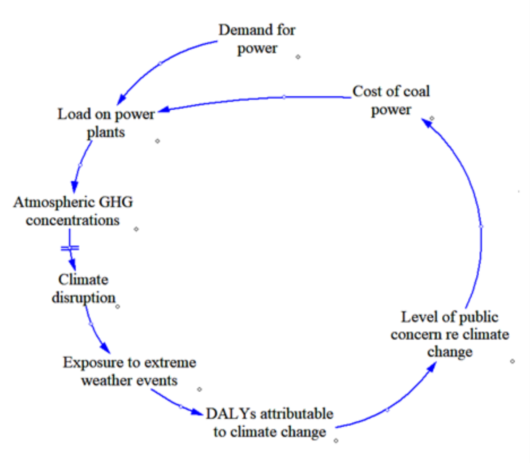
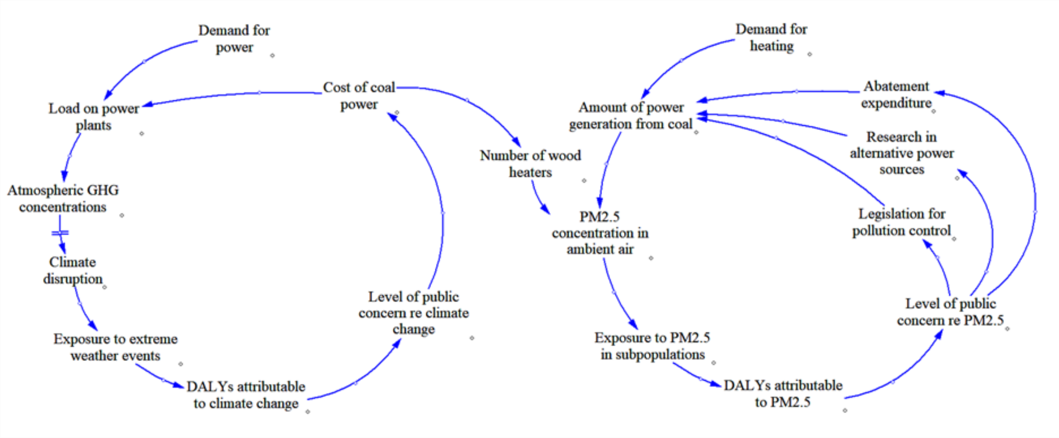


Newell, B., and Proust, K., 2012, *Introduction to Collaborative Conceptual Modelling*, Working Paper, ANU

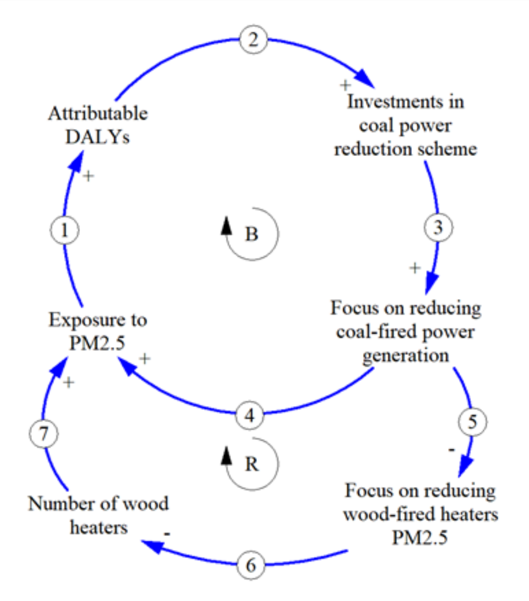
COLLABORATIVE CONCEPTUAL MODEL BUILT IDENTIFIED FEEDBACK



COMPETING DRIVERS MAY LEAD TO UNINTENDED CONSEQUENCES



SYSTEM DYNAMICS MODELLING HAS RICH THEORETICAL FRAMEWORK FOR THIS



CONCLUSIONS

- Leslie matrices are simpler, but
- System dynamics models may provide greater flexibility to explore interactions and lags
- SD well suited to collaborative conceptual modelling: drivers and feedbacks
  - What-If? scenarios
  - Policy intervention experiments *in silico*
  - Escaping the complexity dilemma (Newell and Proust 2017)
- SD also well suited to quantifying sensitivities based on many simulation runs
- BUT many other tools available: CAR workshop on HIA methods and tools planned for mid 2020!

CO-AUTHORS

- Richard Broome
- Martin Cope
- Jane Heyworth
- Josh Horsley
- Bin Jalaludin
- Ed Jegasothy
- Luke Knibbs
- Gavin Pereira
- Steven vander Hoorn
- Barry Newell
- Geoff Morgan

CAR

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MODSIM 2019