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WHO COLLABORATING CENTRE FOR CLIMATE CHANGE AND HEALTH IMPACT ASSESSMENT

WHO Collaborating Centre for Climate Change and Health Impact Assessment

Quantitative HIA for long term air pollution exposure – an example of an end-to-end health burden study

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Curtin University School of Population Health

https://research.curtin.edu.au/whocc-cchia

Masterclass aims and objectives

- Aims:
  - Enhance your understanding of quantitative HIA methods for air pollution,
  - Contribute to the development for future iterations
- Objectives
  - Demonstrate an end-to-end example of health burden
  - A worked example for hands-on "Coached" practice
  - Gather participant feedback using the Slido survey: at Slido.com with #3370 651

Worked example and tools

- To support the masterclass we will use ‘Coached’ practice
- There is a set of our tools we provide from Github
  - https://github.com/cardat/DatSciTrain_HIA_Health_Impact_Functions_explained
- We will start by looking at the 02_Lifetables_with_spreadsheet
  - We will not have time to look at the other tools today
  - We will not have time to troubleshoot your computing environment
  - Feel free to play around with the other tools later, and send any feedback via Github issues or pull requests.

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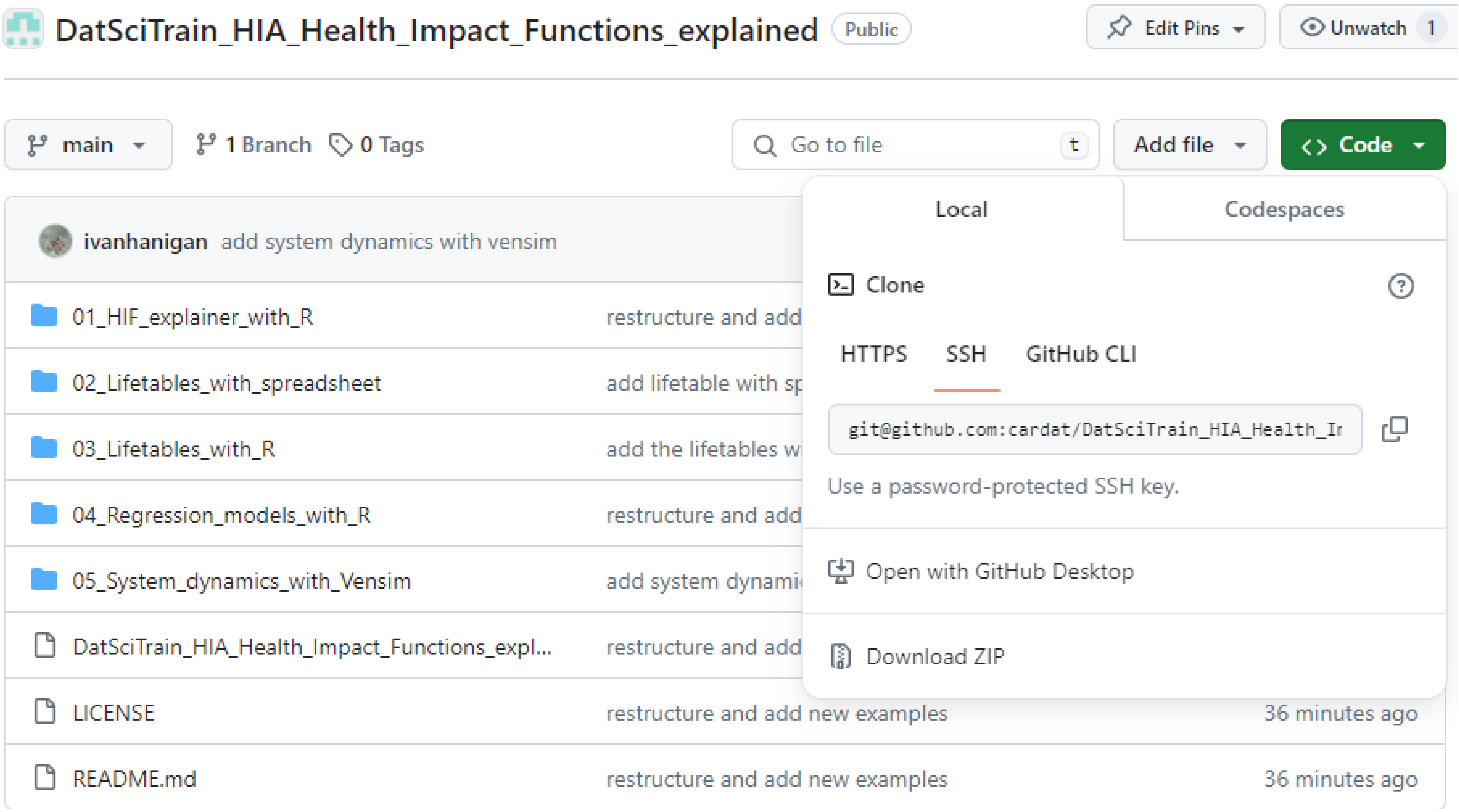
Quickest way is to click ‘Code’ and Download Zip



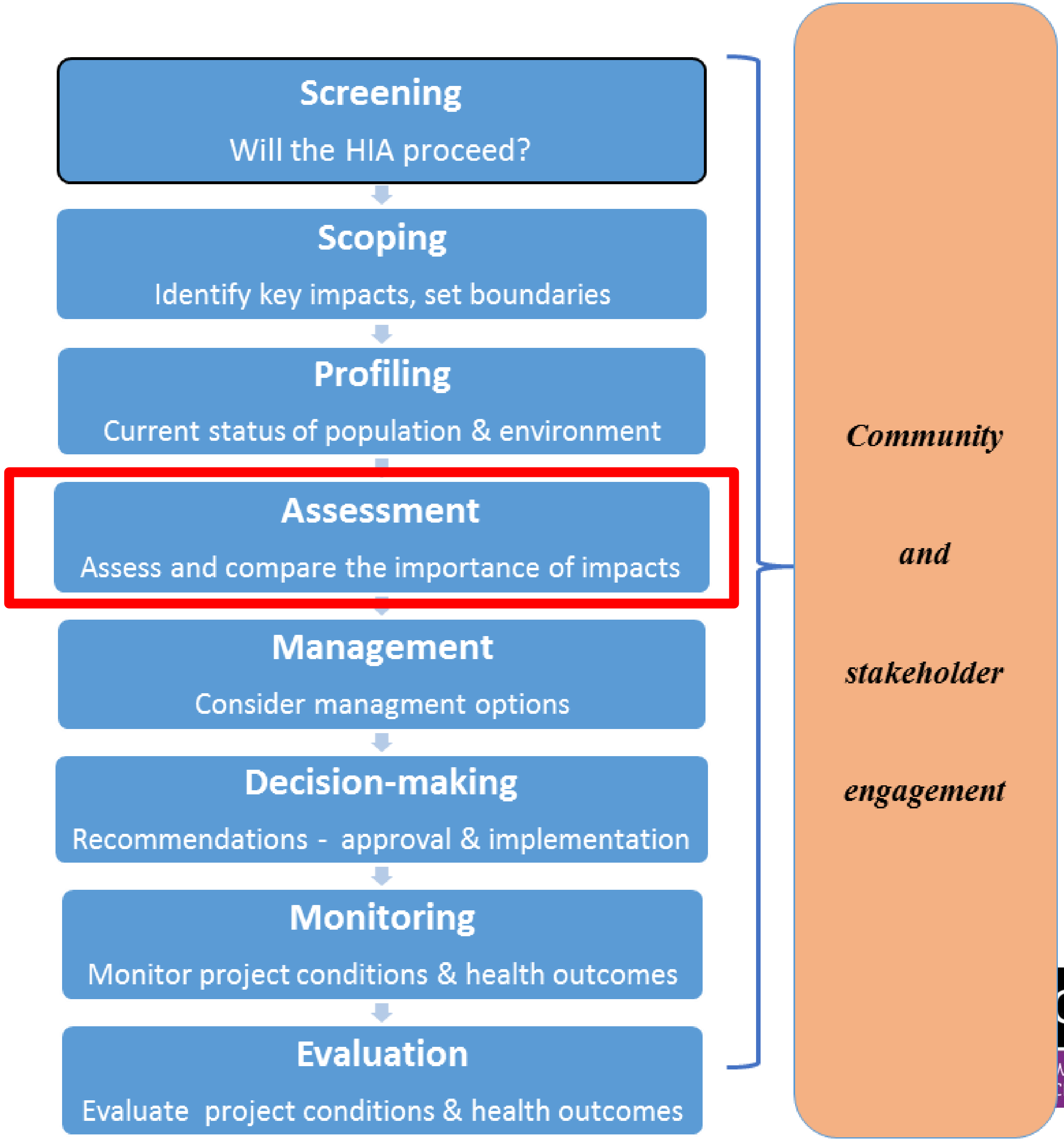
The HIA Process

Aus enHealth 17

- Similar/same in other countries

- Principles:

1. Democracy
2. Equity
3. Sustainable Development
4. Ethical use of evidence
5. Comprehensive approach to health



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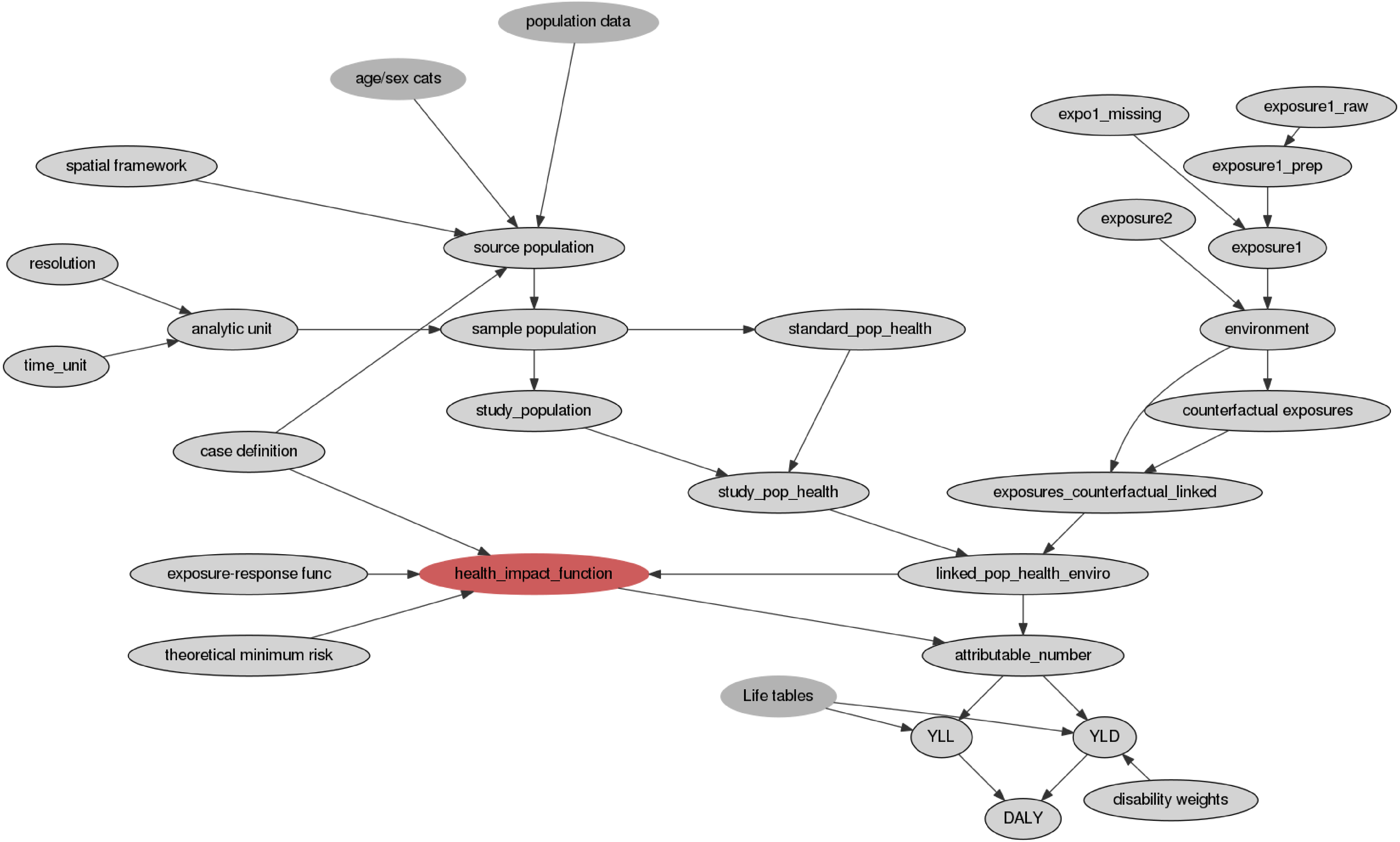
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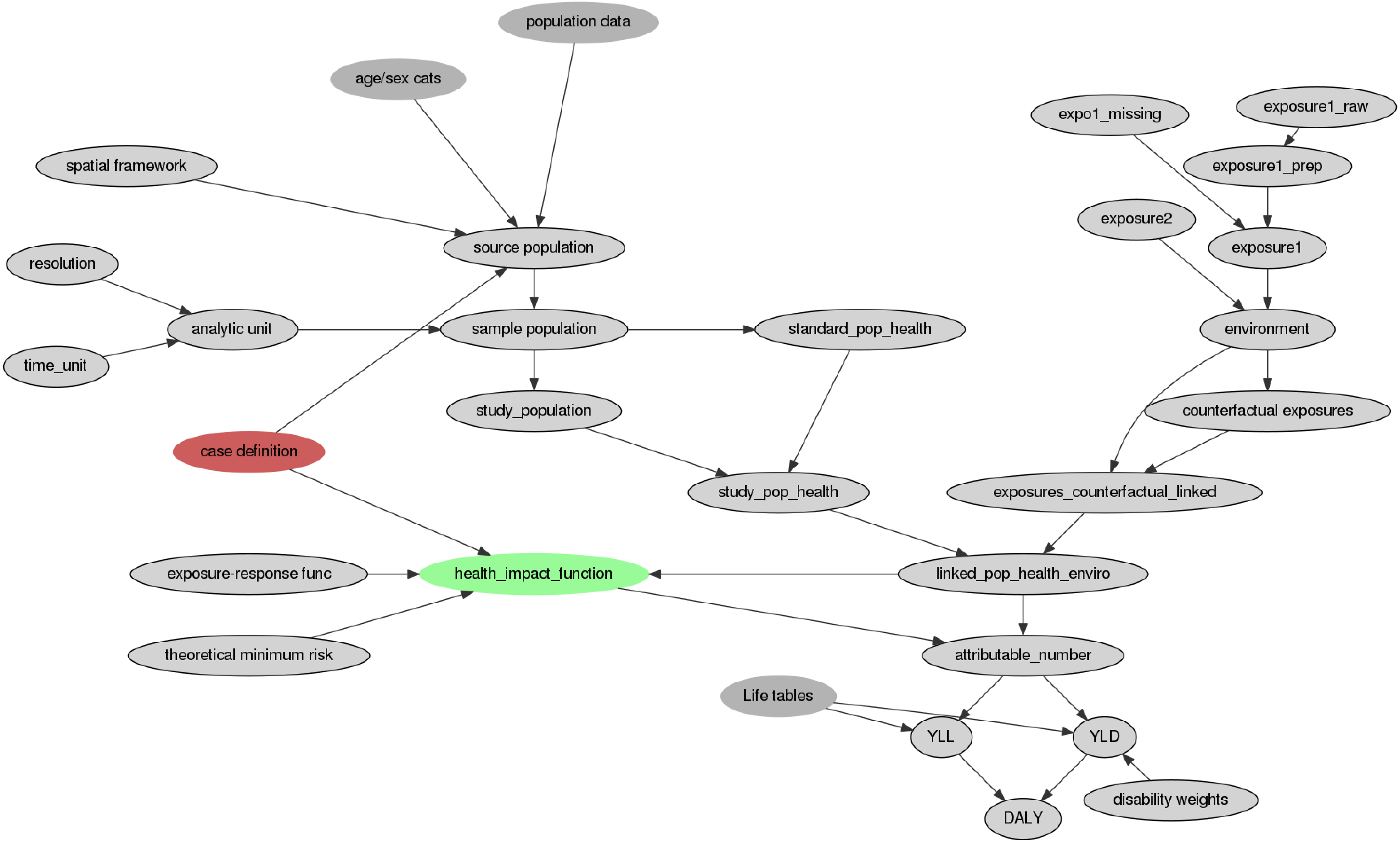
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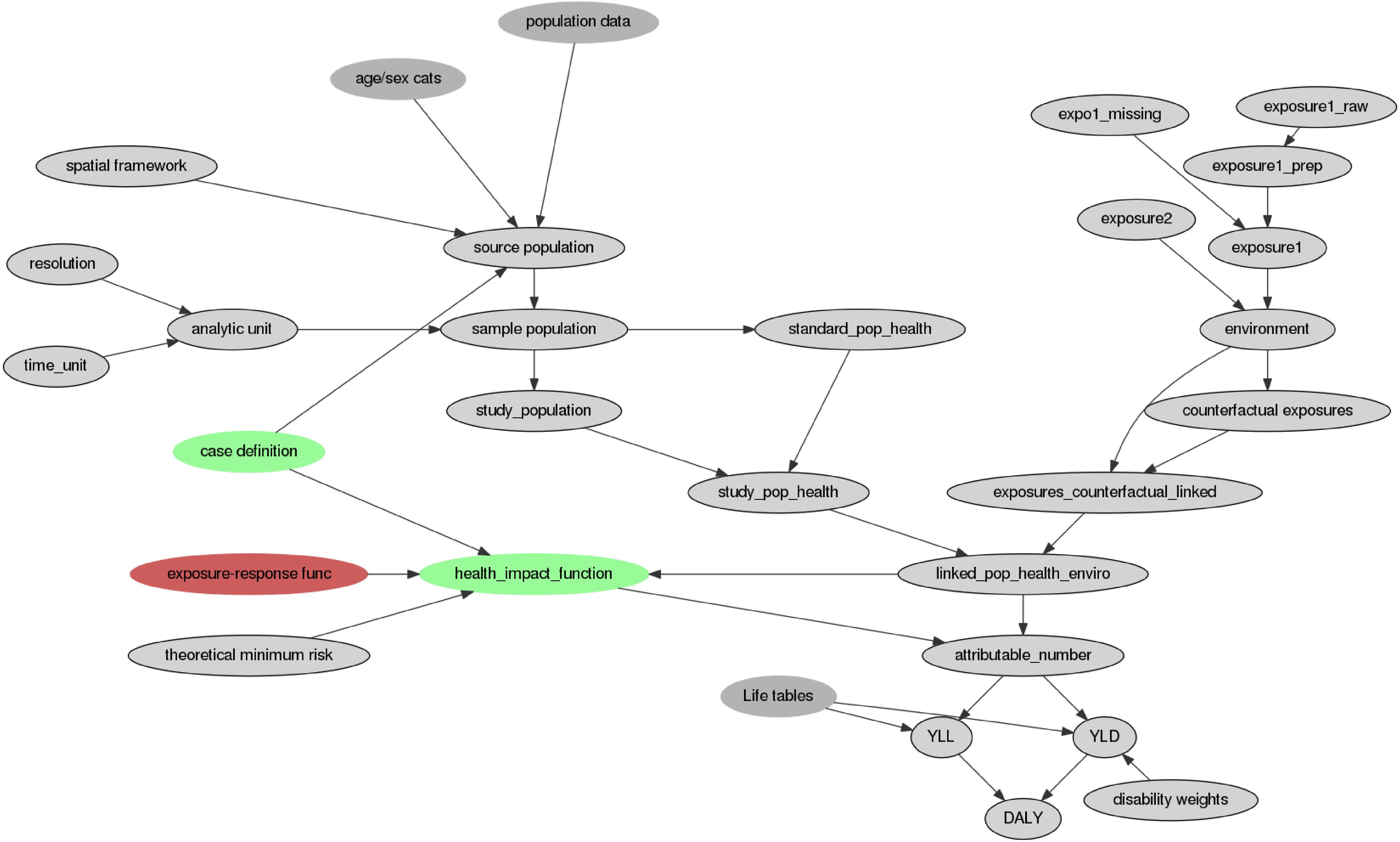

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2020 WHO commissioned report

For long-term exposure impacts assessment

Pollutant metric	Health outcome	RR (95% CI) per 10 ug/m3	Range of concentrations
PM2.5, annual mean	Mortality, all-cause (natural) adults.	1.08 (95%CI:1.06, 1.09) per 10 µg/m3 increase in PM2.5	All
PM10, annual mean	Mortality, all-cause (natural) adults.	1.04 (95%CI:1.03, 1.06) per 10 µg/m3 increase in PM10	All

A population consistently exposed to 10 µg/m^3 more $PM_{2.5}$ are expected to have ~1.08 times (or ~8%) more "non-injury" deaths compared to a counterfactual population, in the age 30+ group. RR is the exposure-response function.
Chen & Hoek. (2020) systematic review and meta-analysis. Environment International https://doi.org/10.1016/j.envint.2020.105974

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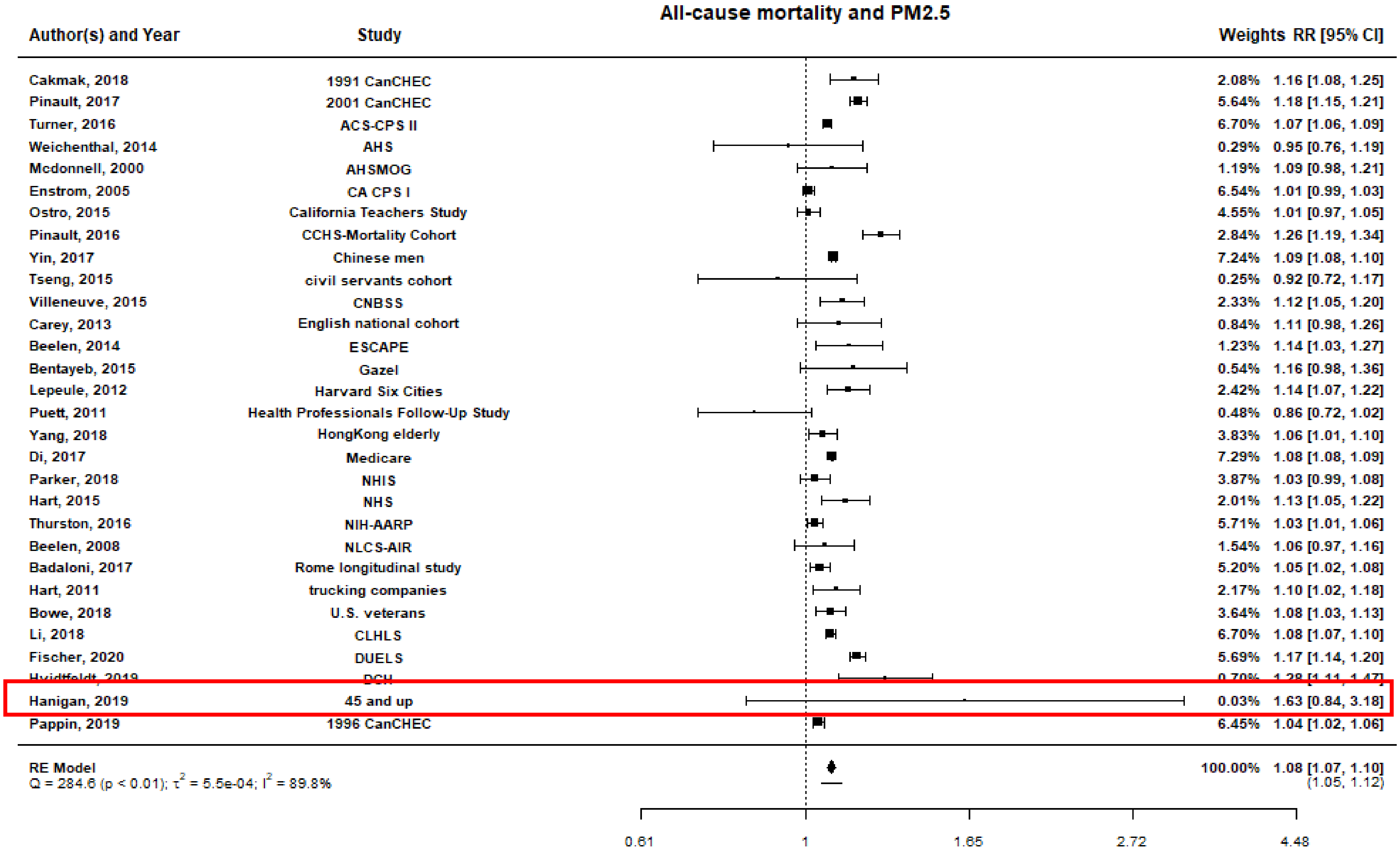
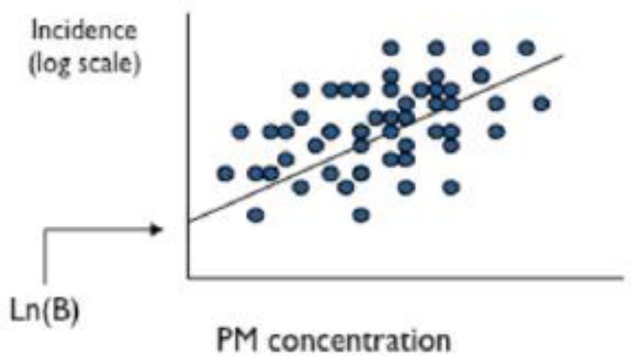
We class Epi studies and meta-analysis as ‘primary’, HIA 2nd’ary



Chen and Hoek, Environ. Int. 2020.

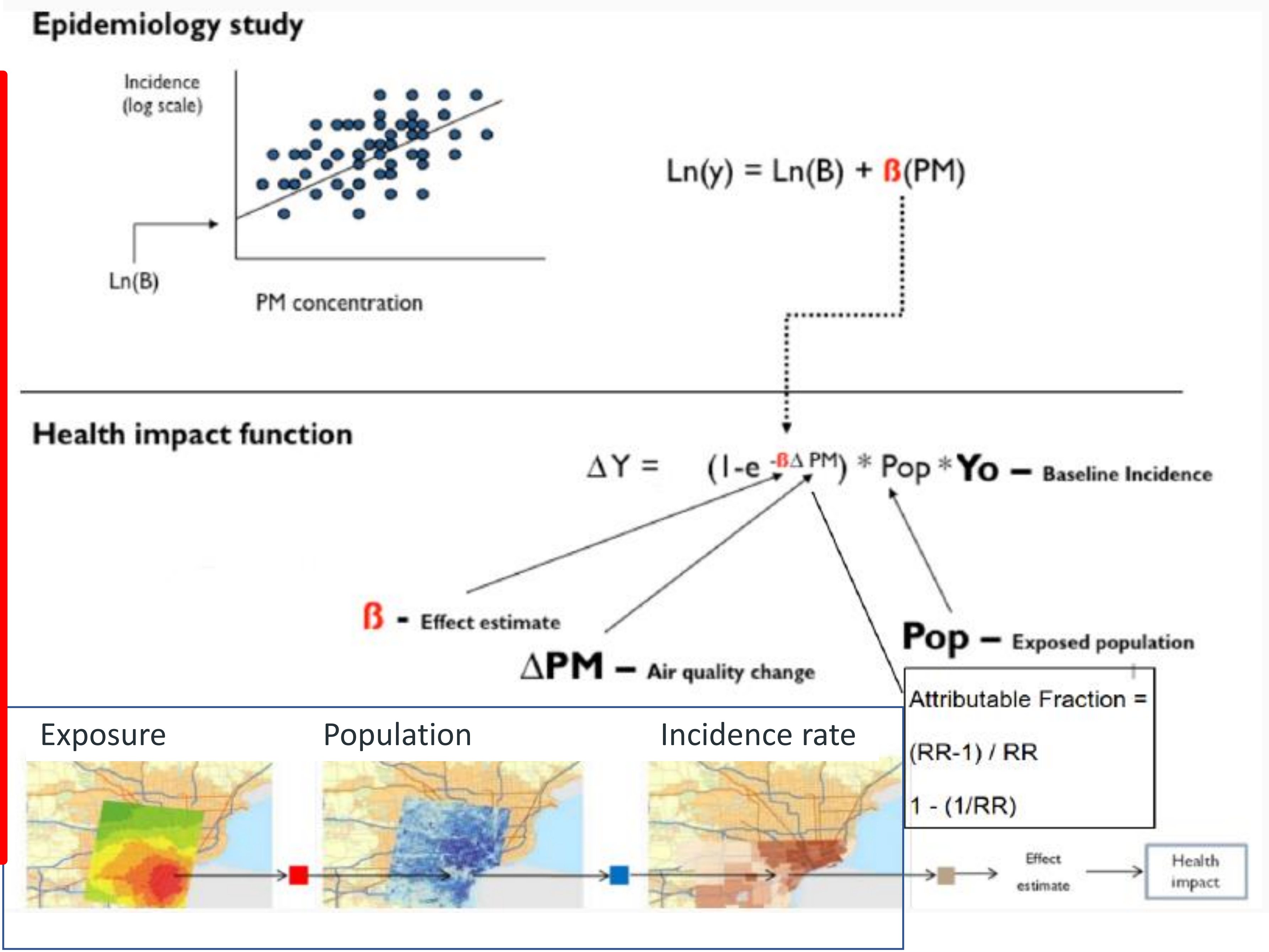
1) Exposure
AND
2) Health impact function
AND
3) Population
AND
4) Incidence rate

Epidemiology study



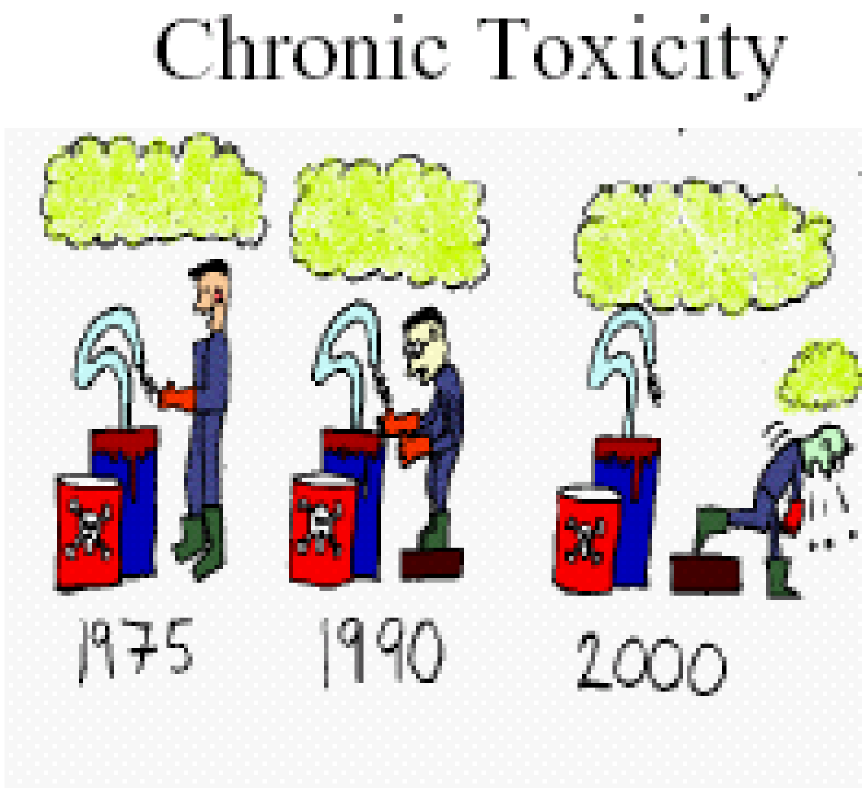
Adapted from BenMap toolkit USA user guide

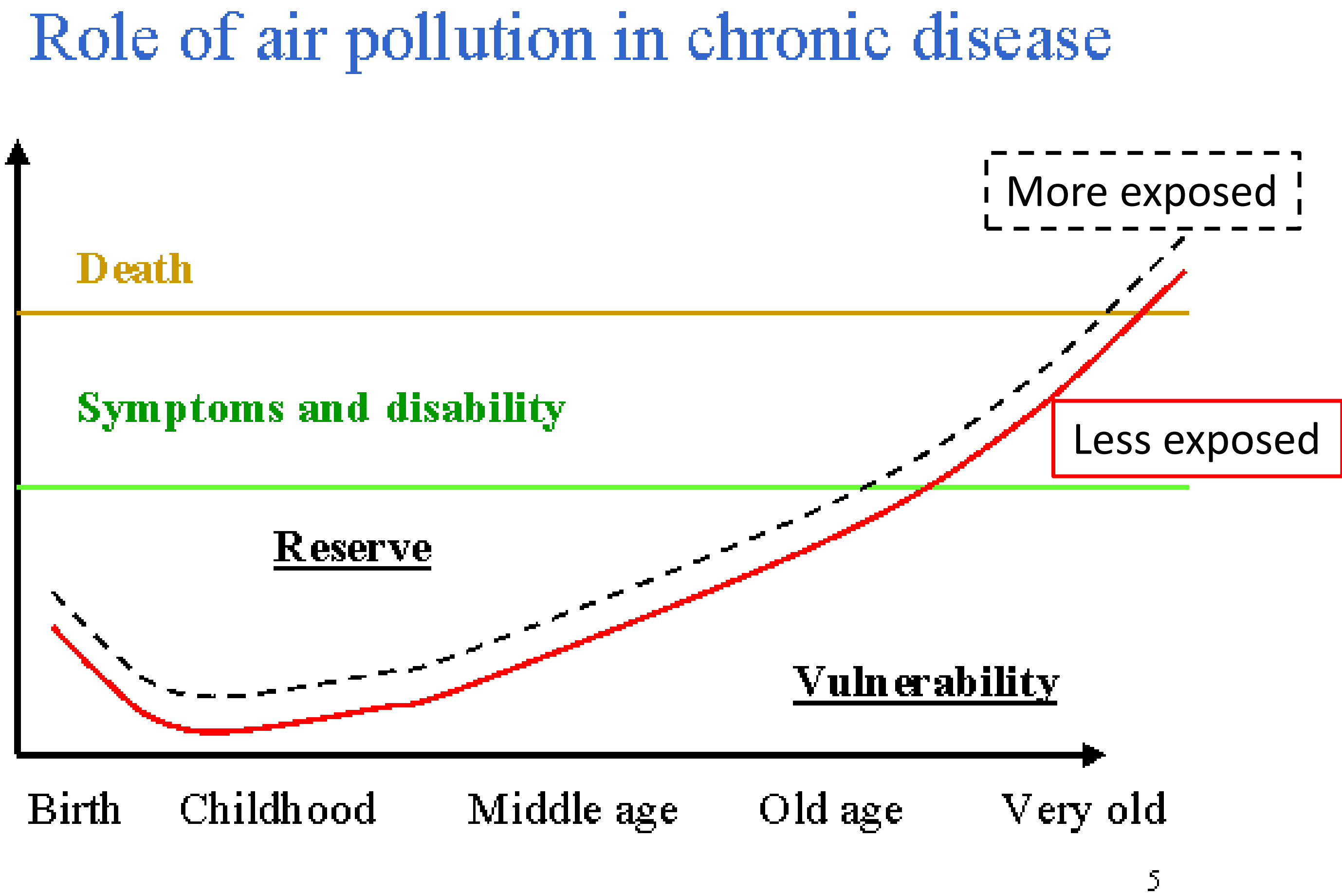
1) Exposure
AND
2) Health impact function
AND
3) Population
AND
4) Incidence rate



Adapted from BenMap toolkit USA user guide

Long-term exposures





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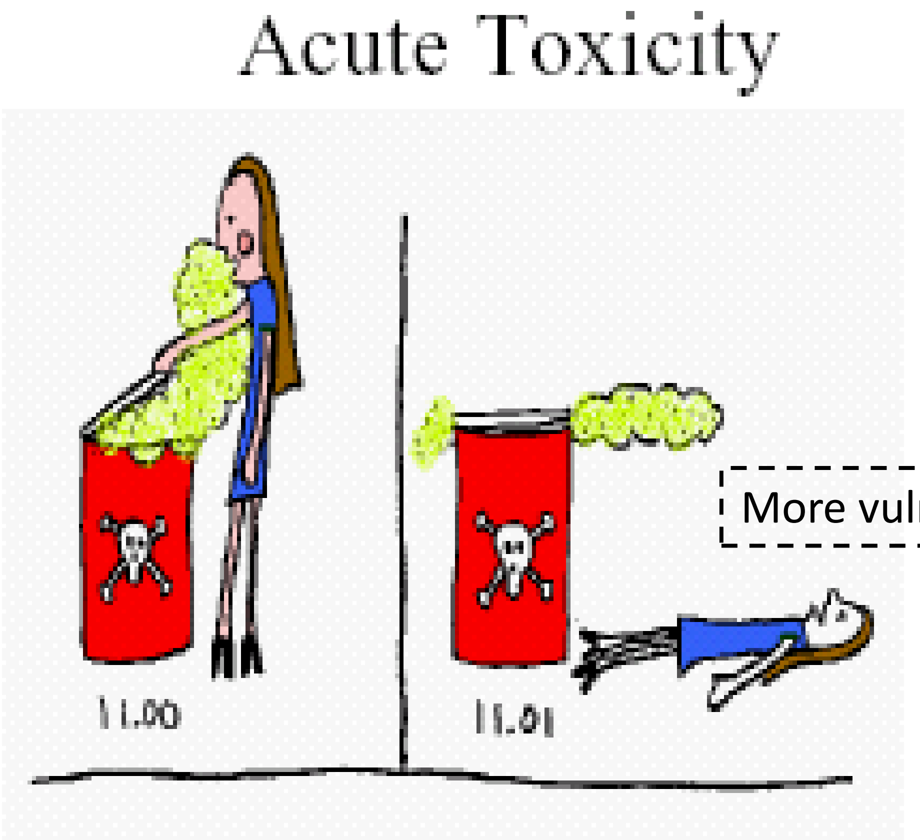
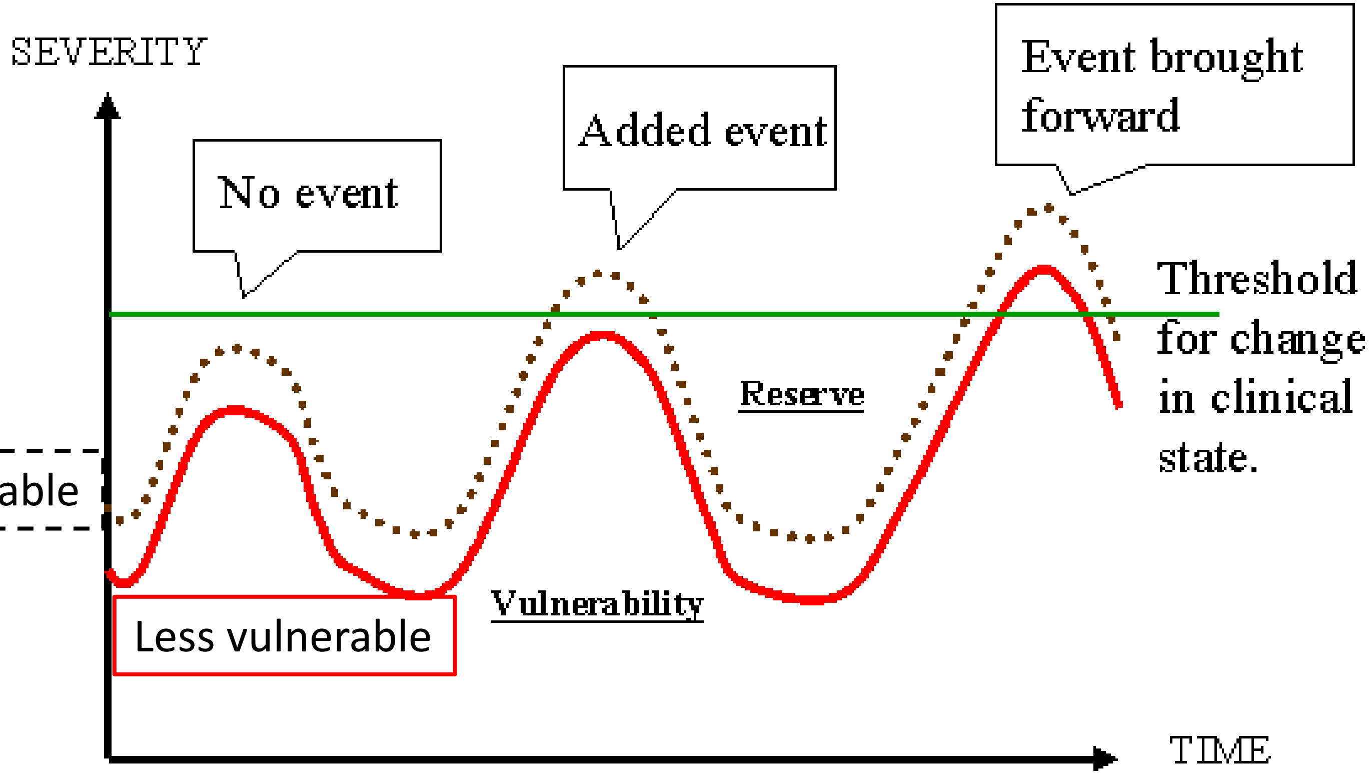
Short-term exposures (and other Stressors – e.g. viruses)





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How are you?

Compared to what?

Health Impact Function
for 'excess risk' or 'attributable fraction'

Using formulae to describe this we can present the two approaches as below. First the 'excess risk formula' is:

$$\underset{\text{Exposed}}{Observed} = RR \times \underset{\text{Un-exposed}}{Expected}$$

Where the RR is calculated for the level of exposure observed in the study population.

The attributable number (AN) can be calculated as:

$$AN = (RR - 1) \times Expected$$

This is sometimes expanded when the HIF is estimated using log-linear regression models of continuous exposure levels and applied to multiple subpopulations into this equivalent formula:

$$AN_i = \sum(e^{(\beta \times X_i)} - 1) \times Expected_i$$

Where X_i is the exposure for $studypopulation_i$.

The alternative formulation is the 'attributable fraction formula':

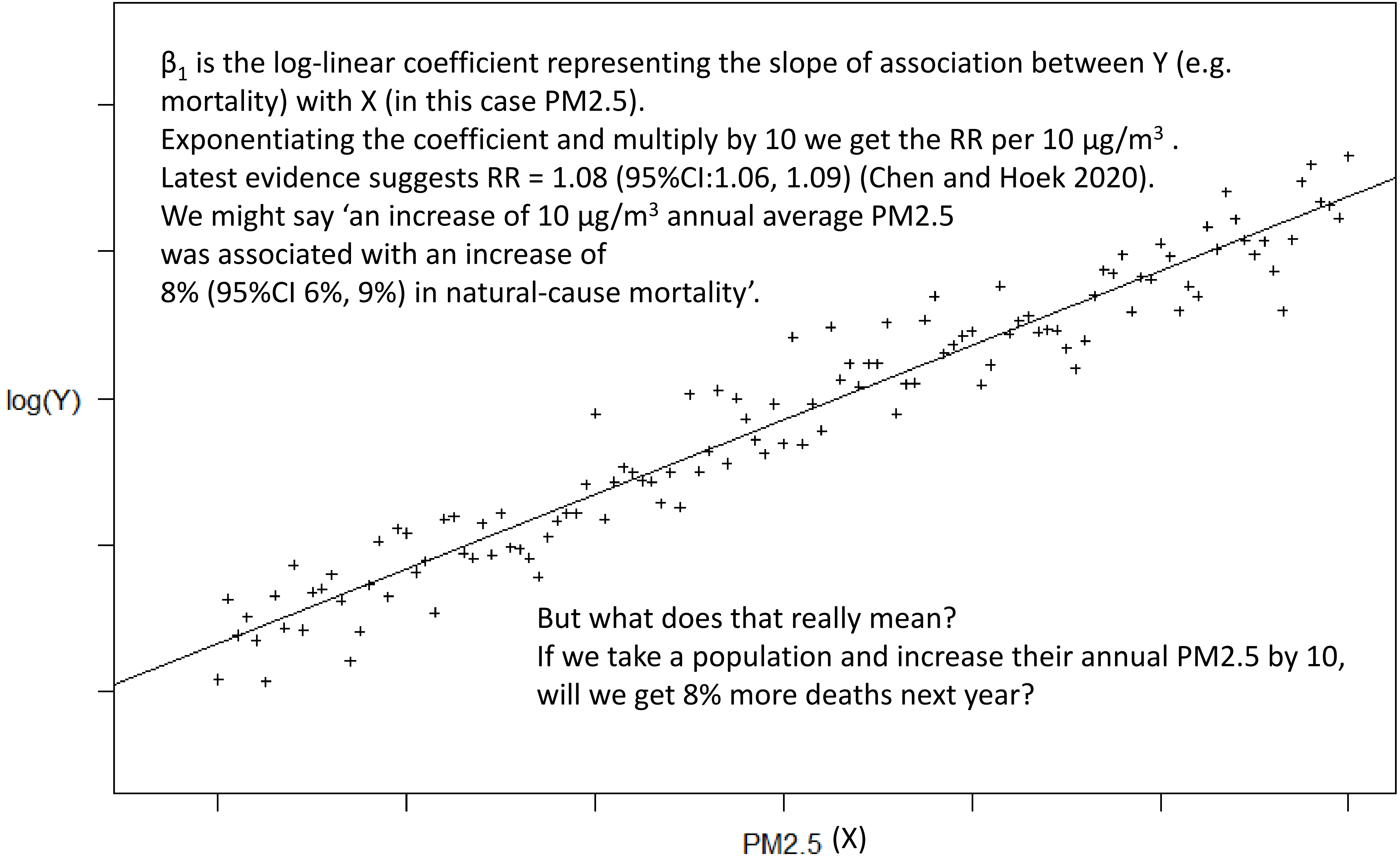
$$AN = (RR - 1)/RR \times Observed$$

Which is often simplified to

$$AN = (1 - (1/RR)) \times Observed$$ Equivalent to $$AN = \sum\left(1 - e^{(-\beta \times X_i)}\right) \times Observed_i$$

FURTHER READING
Appendix 1: Hanigan, et al. (2020). Environmental health indicators. Human Health and Social Impacts (HHSI) Node and the NSW DPIE. DOI:10.17605/OSF.IO/YJ98D

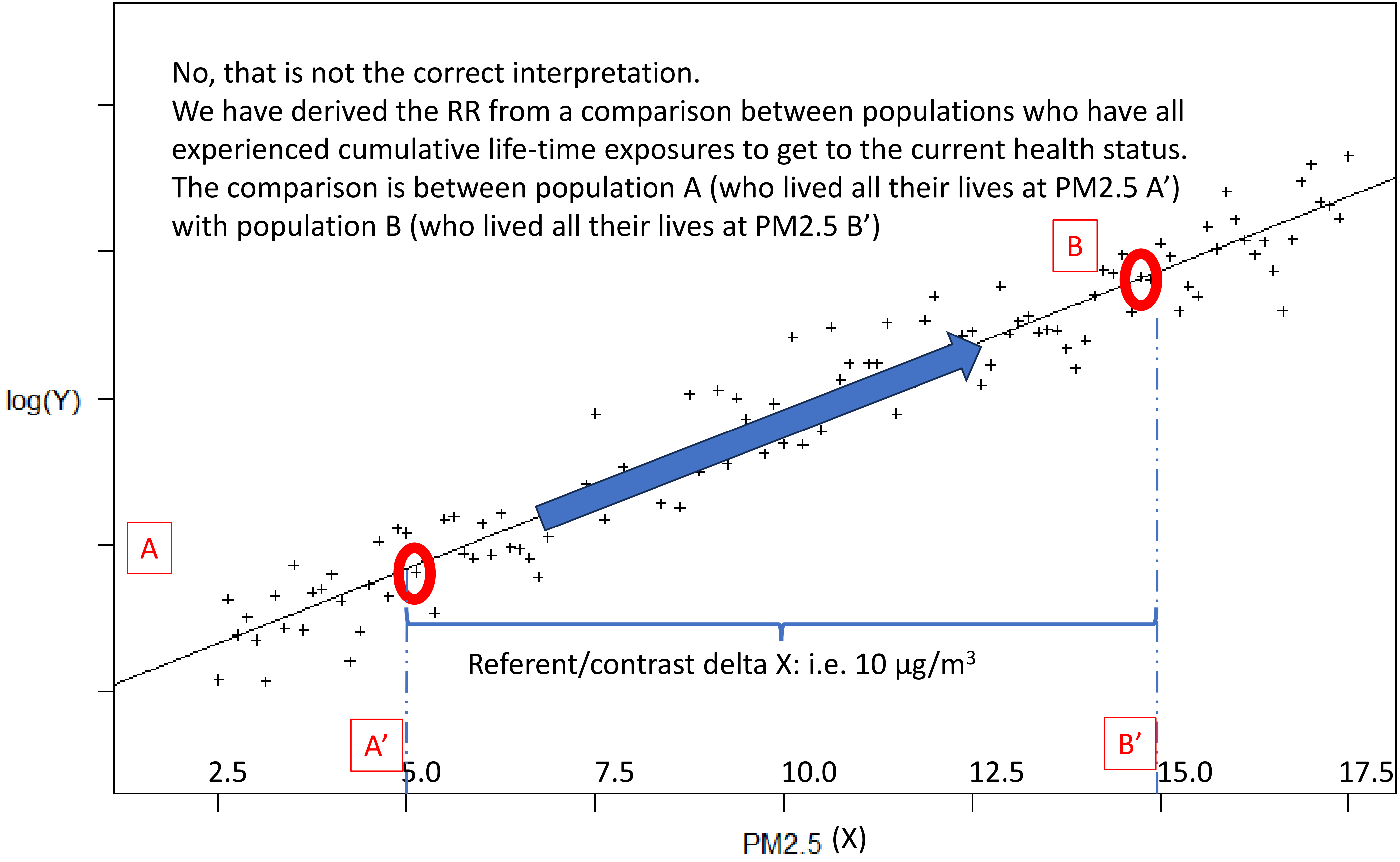
Regression model $Y = \beta_0 + \beta_1 X + \beta_2 Z + [\ldots]$



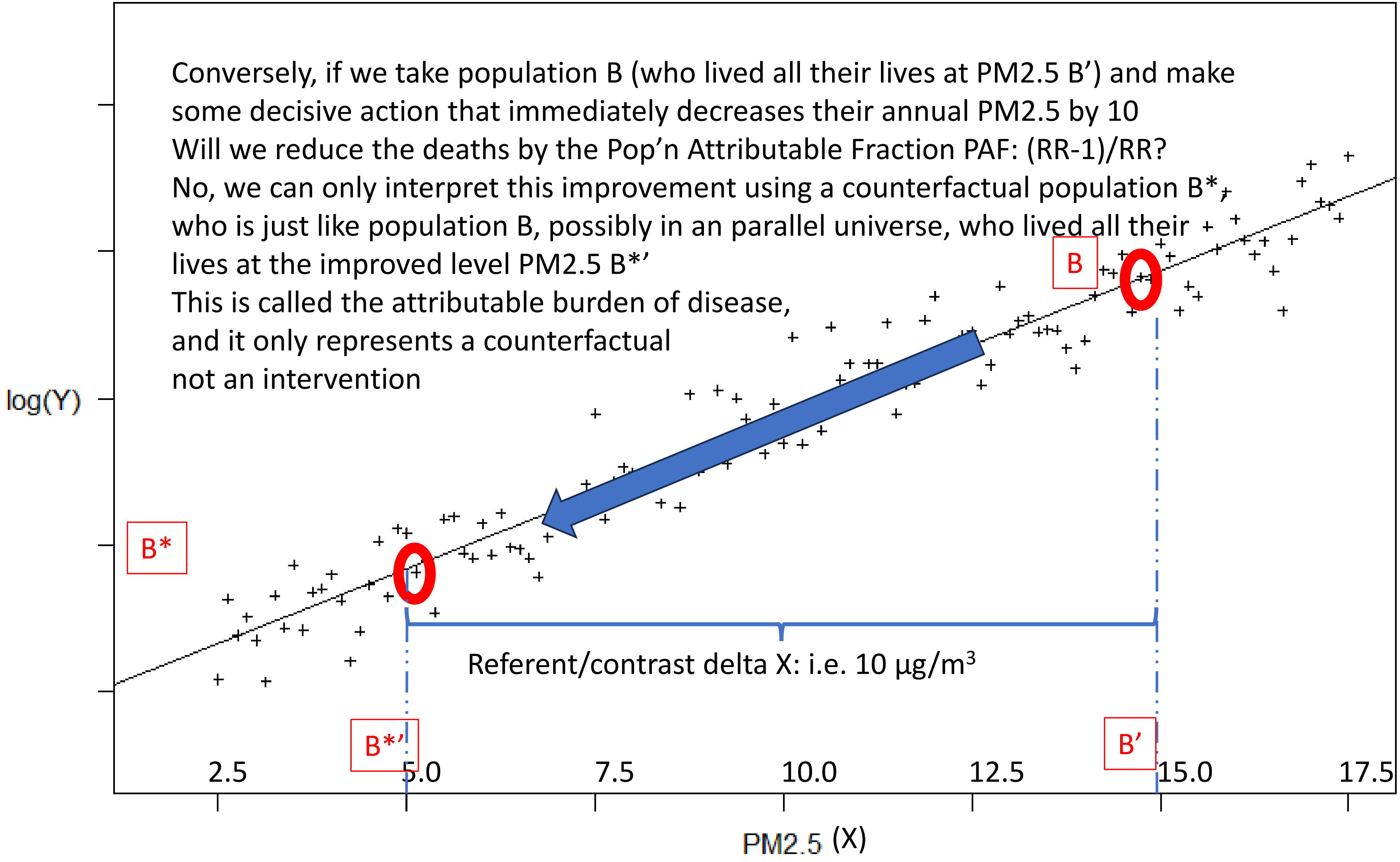
β_1 is the log-linear coefficient representing the slope of association between Y (e.g. mortality) with X (in this case PM2.5).
Exponentiating the coefficient and multiply by 10 we get the RR per 10 μg/m^3 .
Latest evidence suggests RR = 1.08 (95%CI:1.06, 1.09) (Chen and Hoek 2020).
We might say ‘an increase of 10 μg/m^3 annual average PM2.5 was associated with an increase of 8% (95%CI 6%, 9%) in natural-cause mortality’.

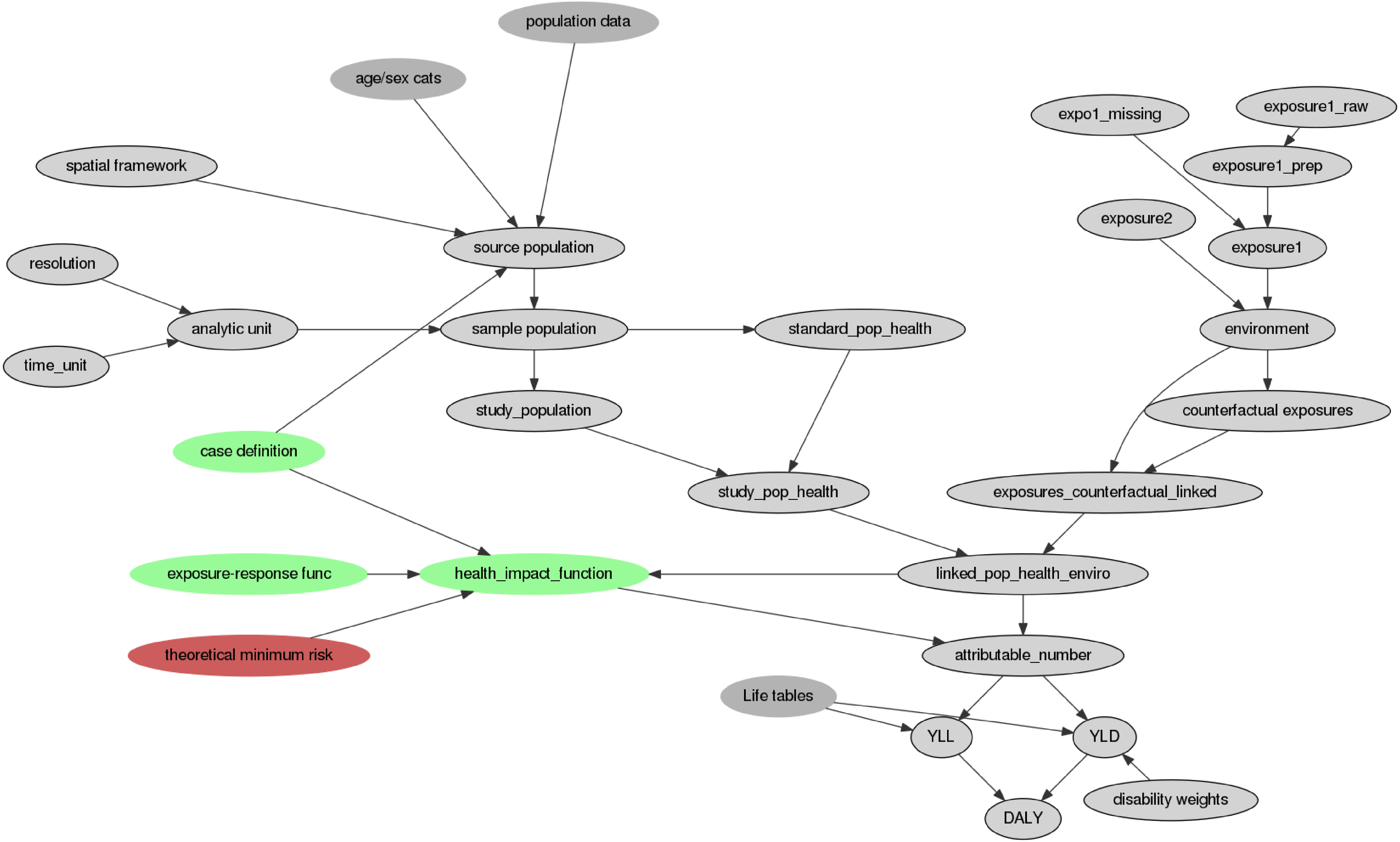
But what does that really mean?
If we take a population and increase their annual PM2.5 by 10, will we get 8% more deaths next year?

Regression model Y = $\beta_0 + \beta_1 X + \beta_2 Z$ + [...]



Regression model Y = $\beta_0 + \beta_1 X + \beta_2 Z + [\ldots]$

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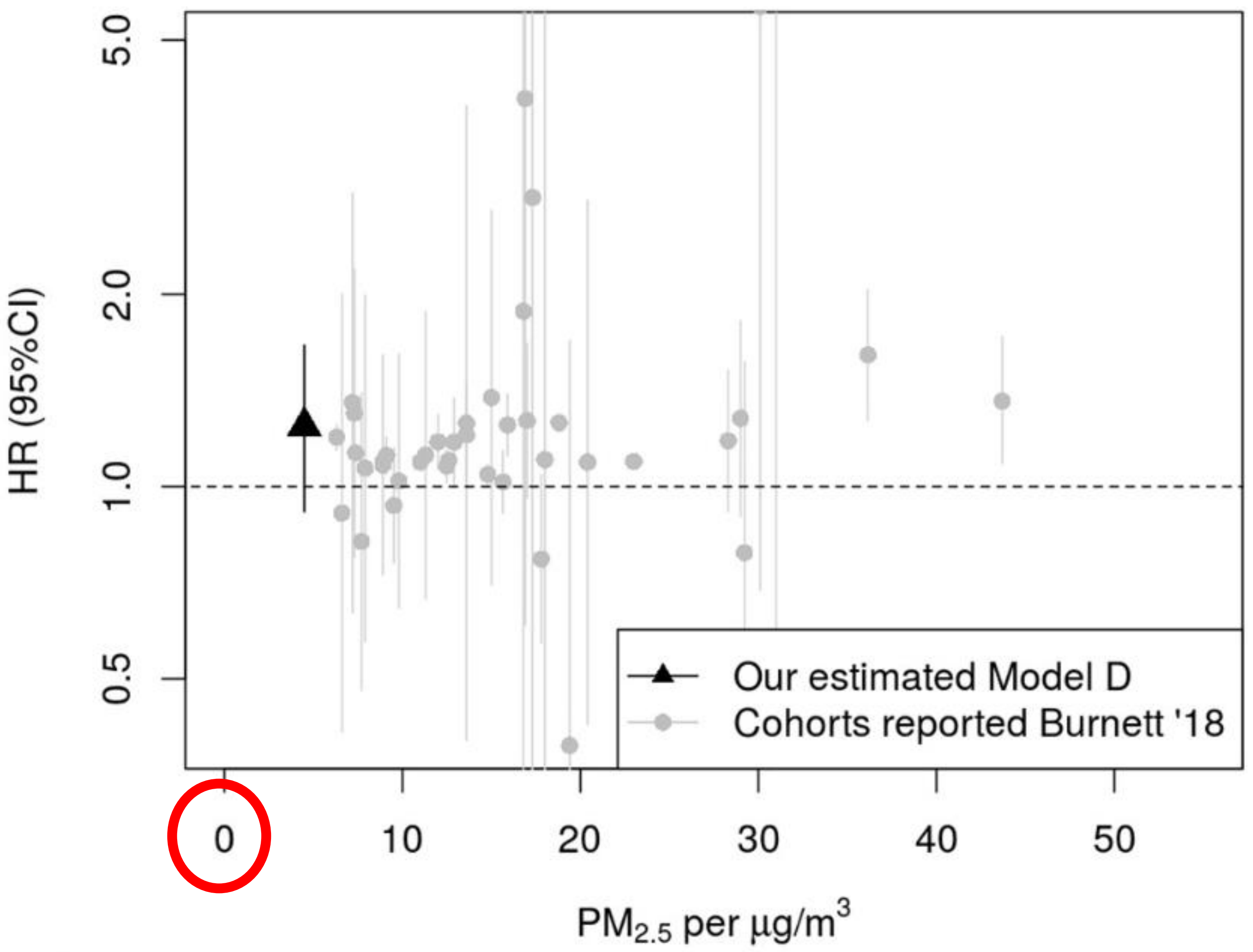
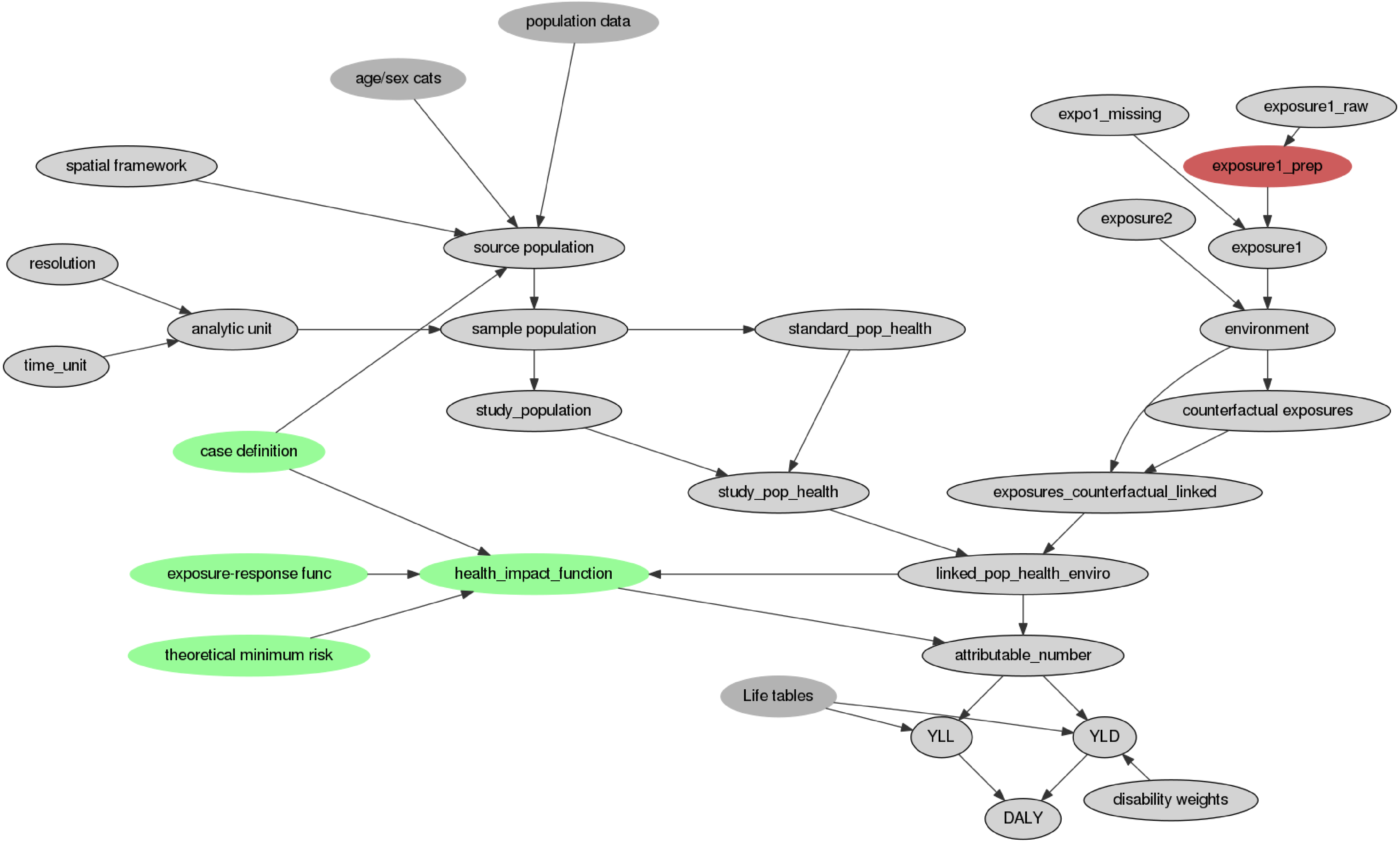
Theoretical minimum risk level (TMREL)?



Hanigan et al 2019. Environment International.
Study population: 45andUp in Sydney (85K)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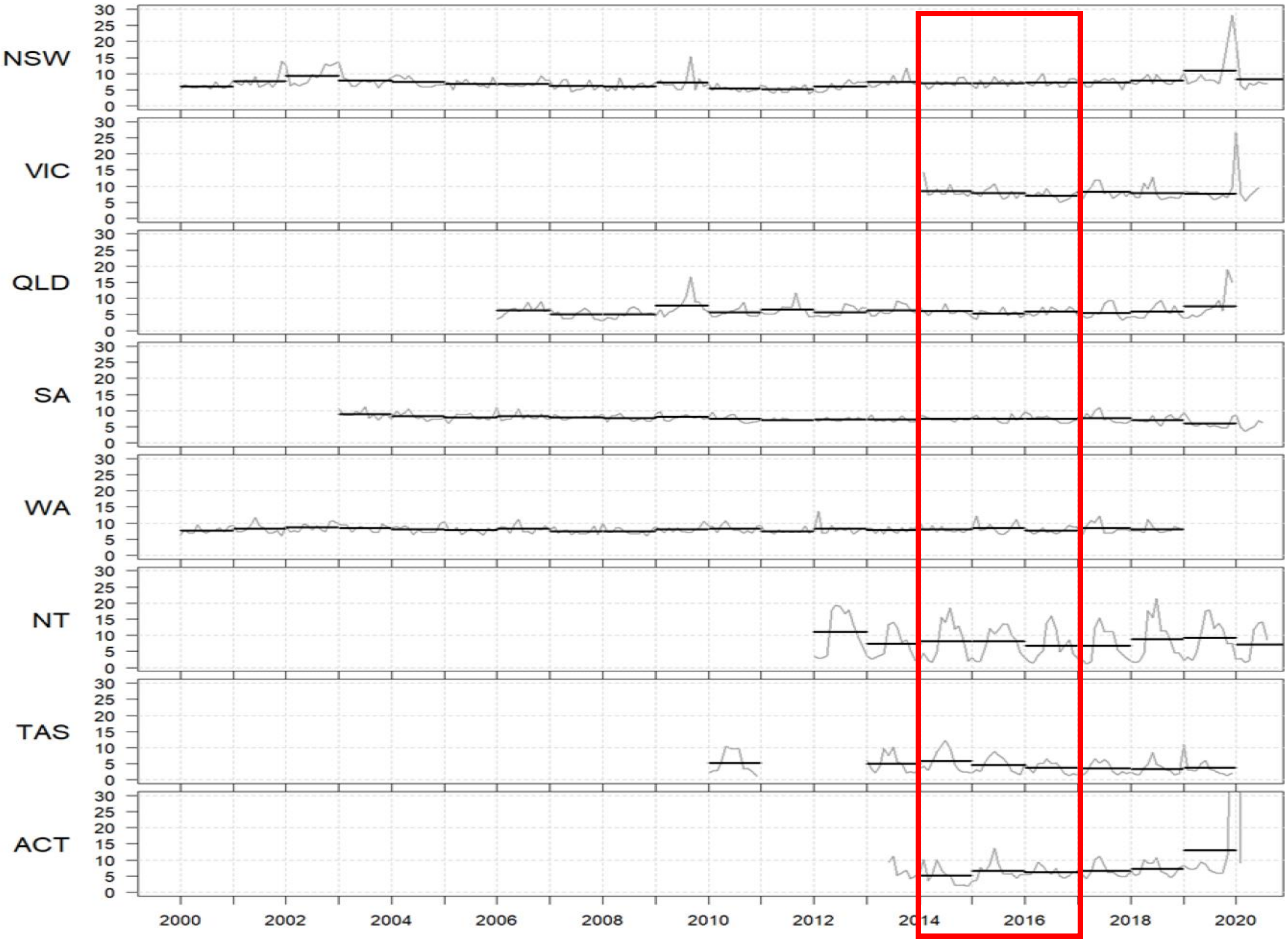
PM2.5 population weighted annual averages



Study period? 2014-2016

National Air Pollution Monitoring Database, derived from regulatory monitor data from NSW DPIE, Vic EPA, Qld DES, SA EPA, WA DEWR, Tas EPA, NT EPA, and ACT Health. Downloaded from the Centre for Air pollution, energy and health Research DOI 10.17605/OSF.IO/JXD98

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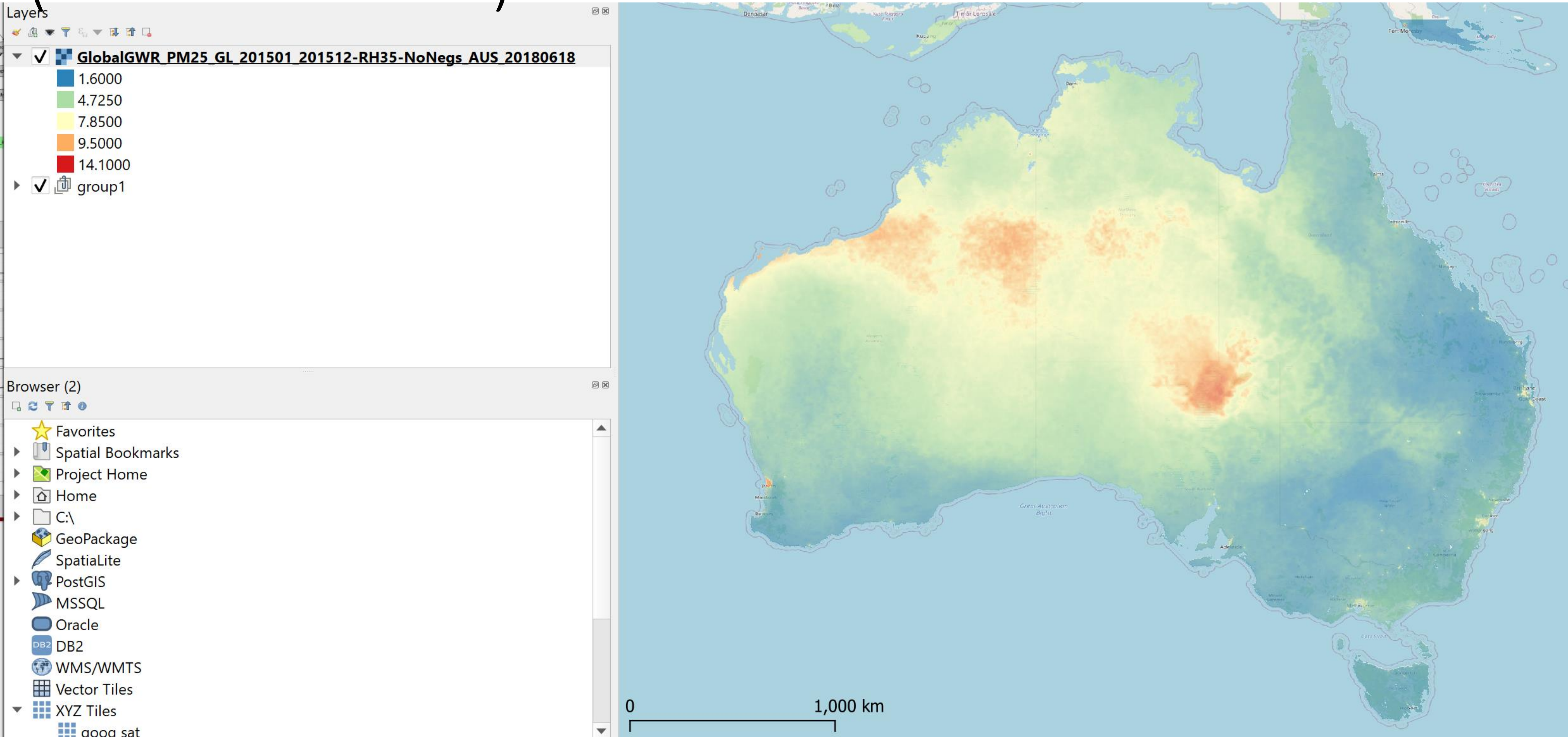
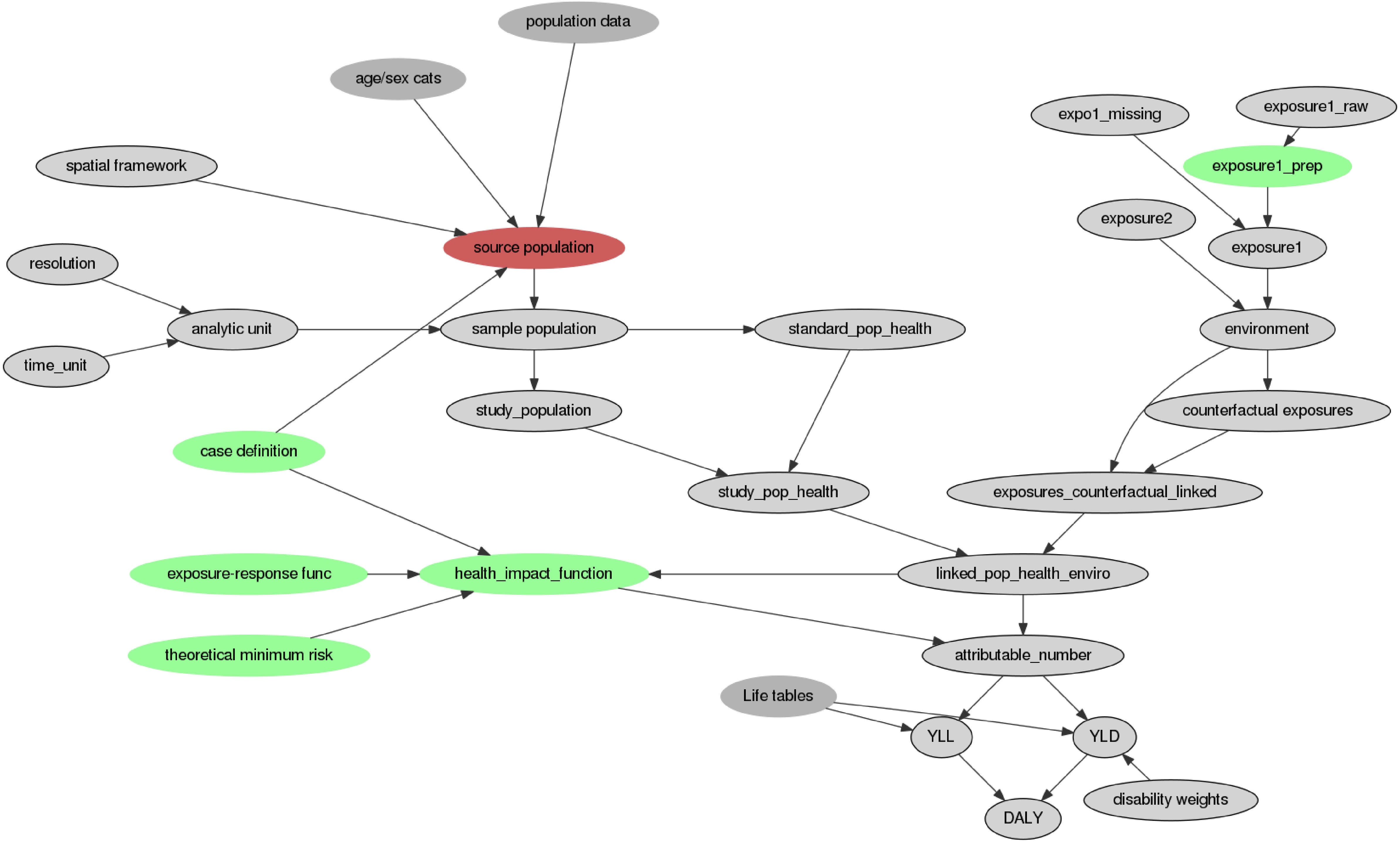
Example of annual PM2.5 2015 from van Donkelaar (Global and free)

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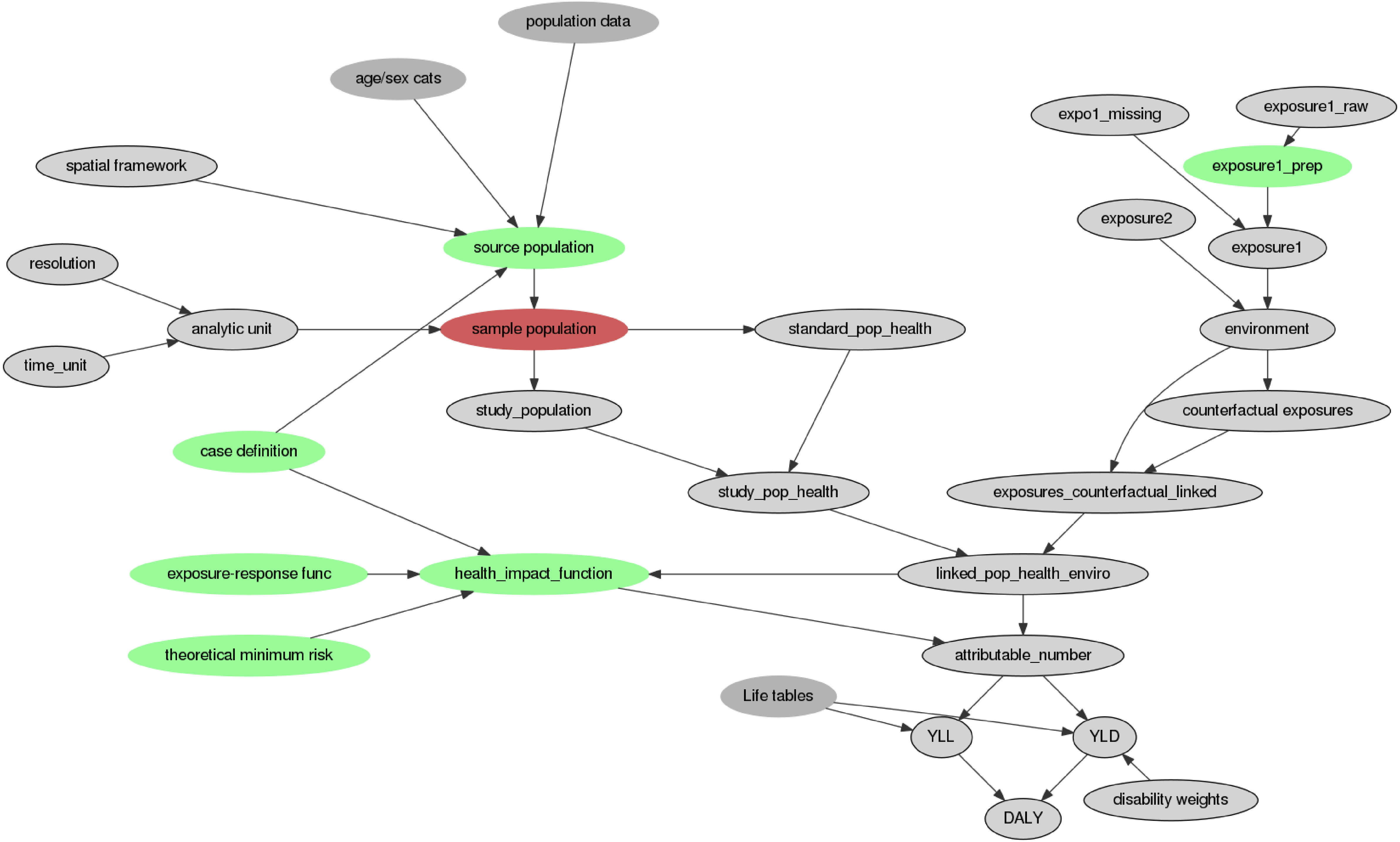
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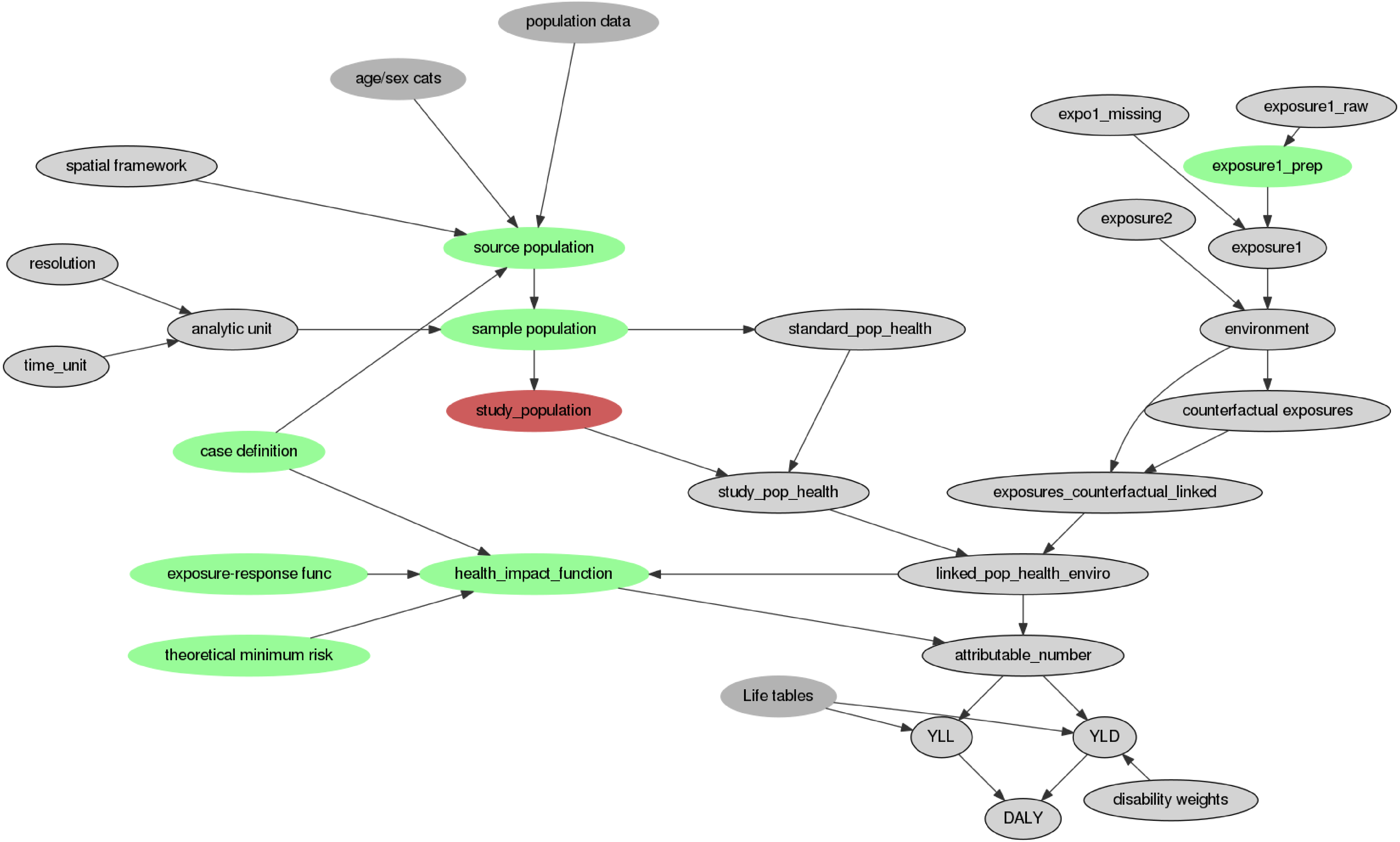
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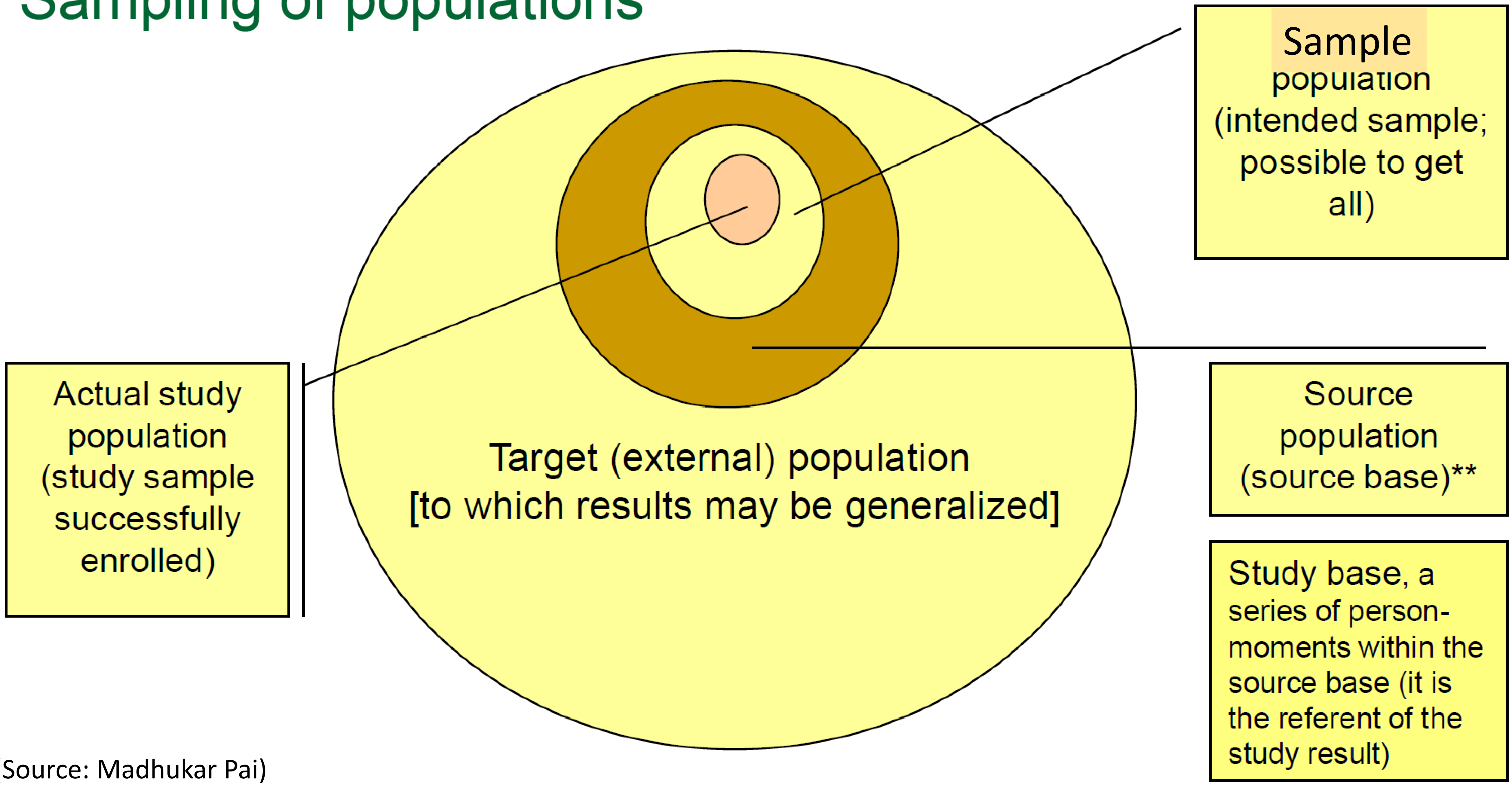
Sampling of populations



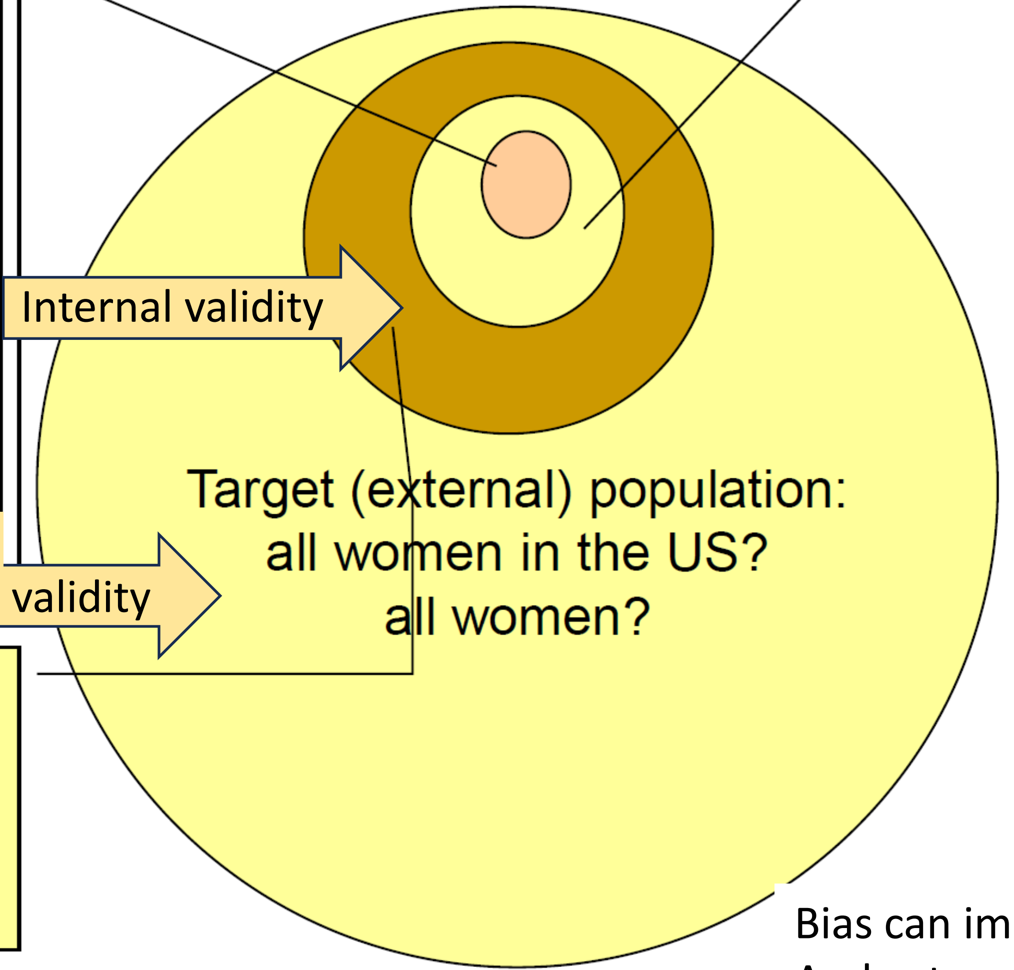
(Source: Madhukar Pai)

Sampling of populations

Example: Nurses Health Study

Study participants: eligible nurses were enrolled in the cohort if they responded to the baseline questionnaire (122,000 out of 170,000 nurses responded)

(minus dropouts, deaths)

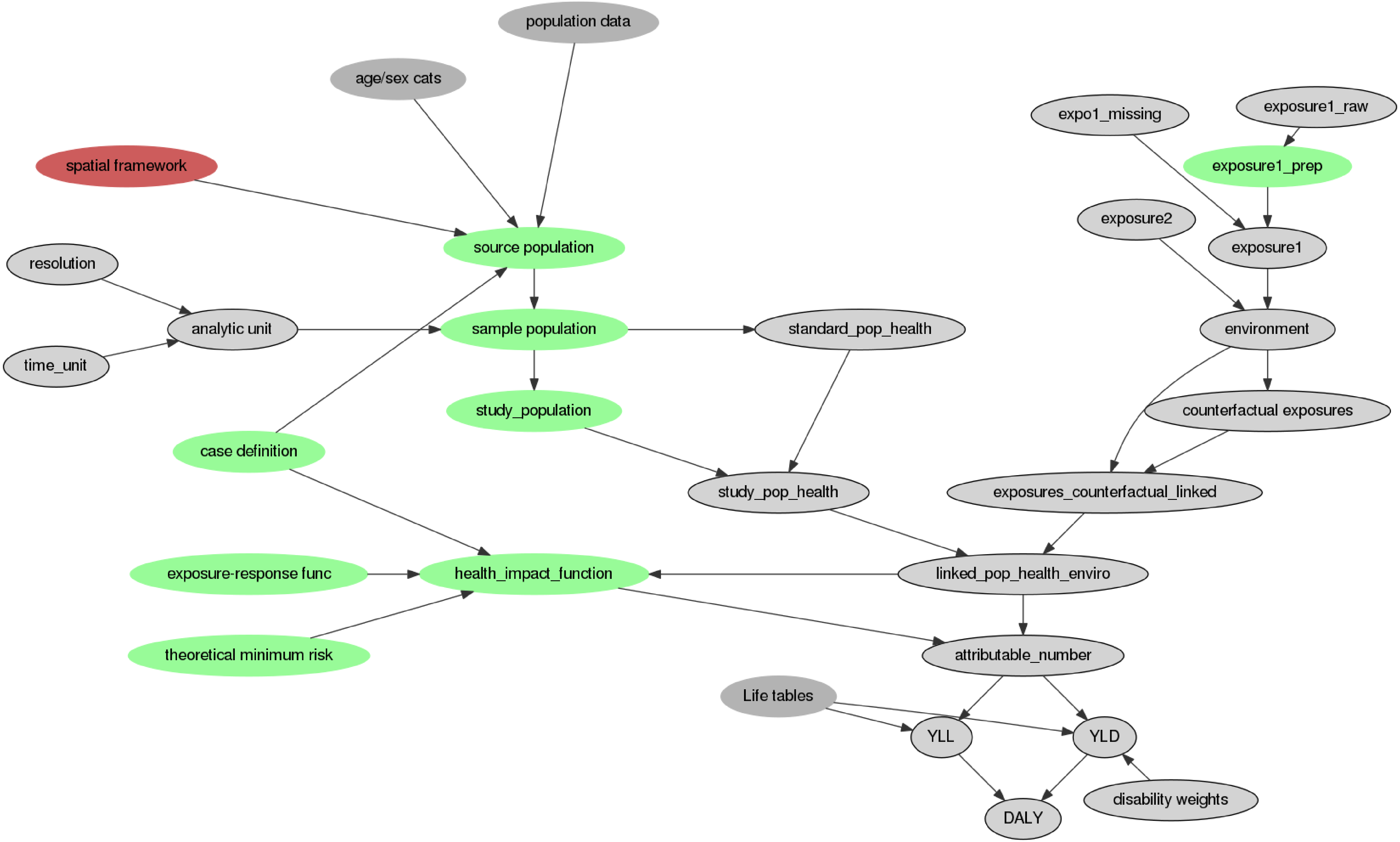


Sample population: Married, registered nurses who were aged 30 to 55 in 1976, who lived in the 11 most populous states and whose nursing boards agreed to supply the study with their members' names and addresses.

Source population: registered nurses in the US?

Bias can impact both internal
And external validity

(Source: Madhukar Pai)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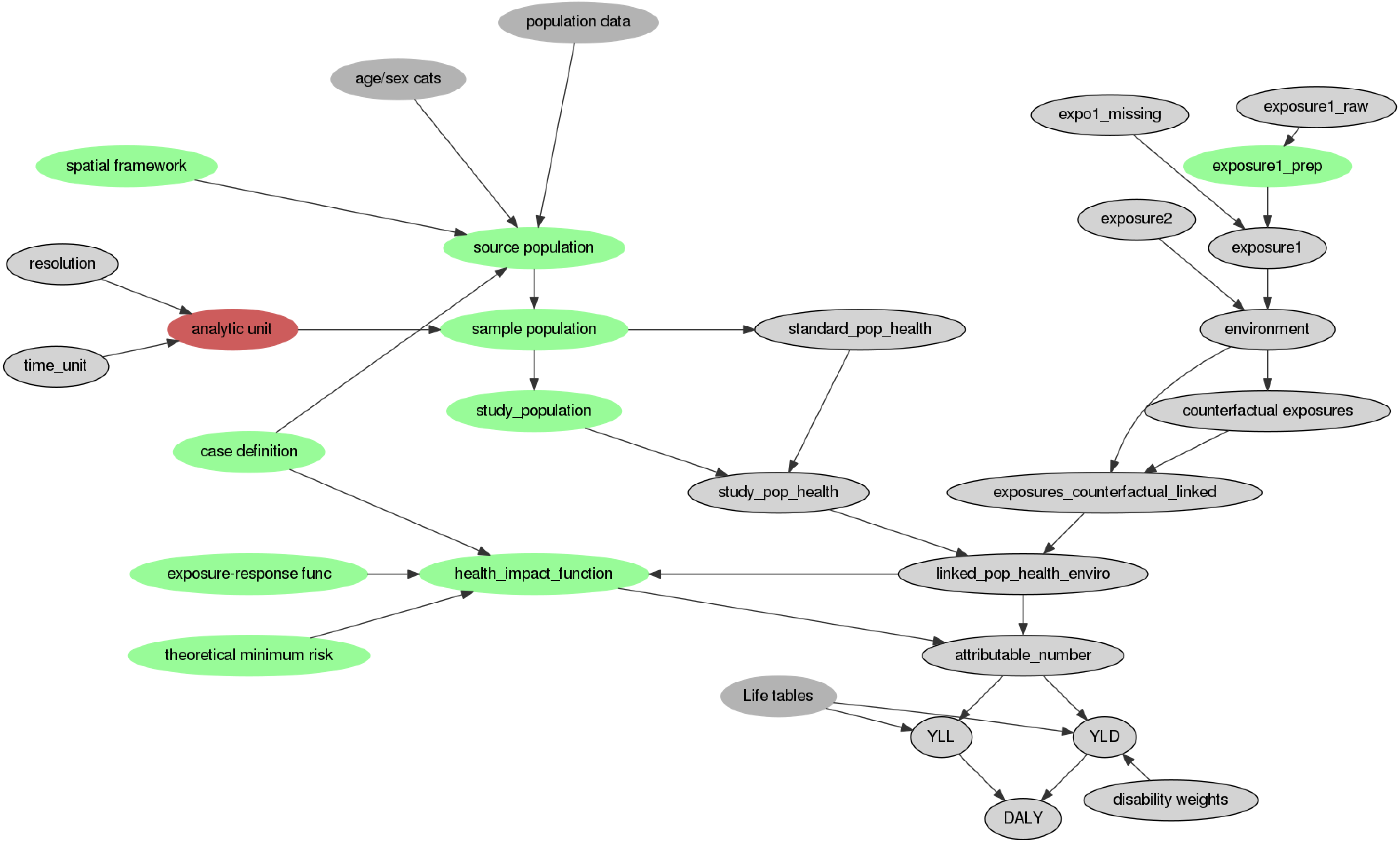
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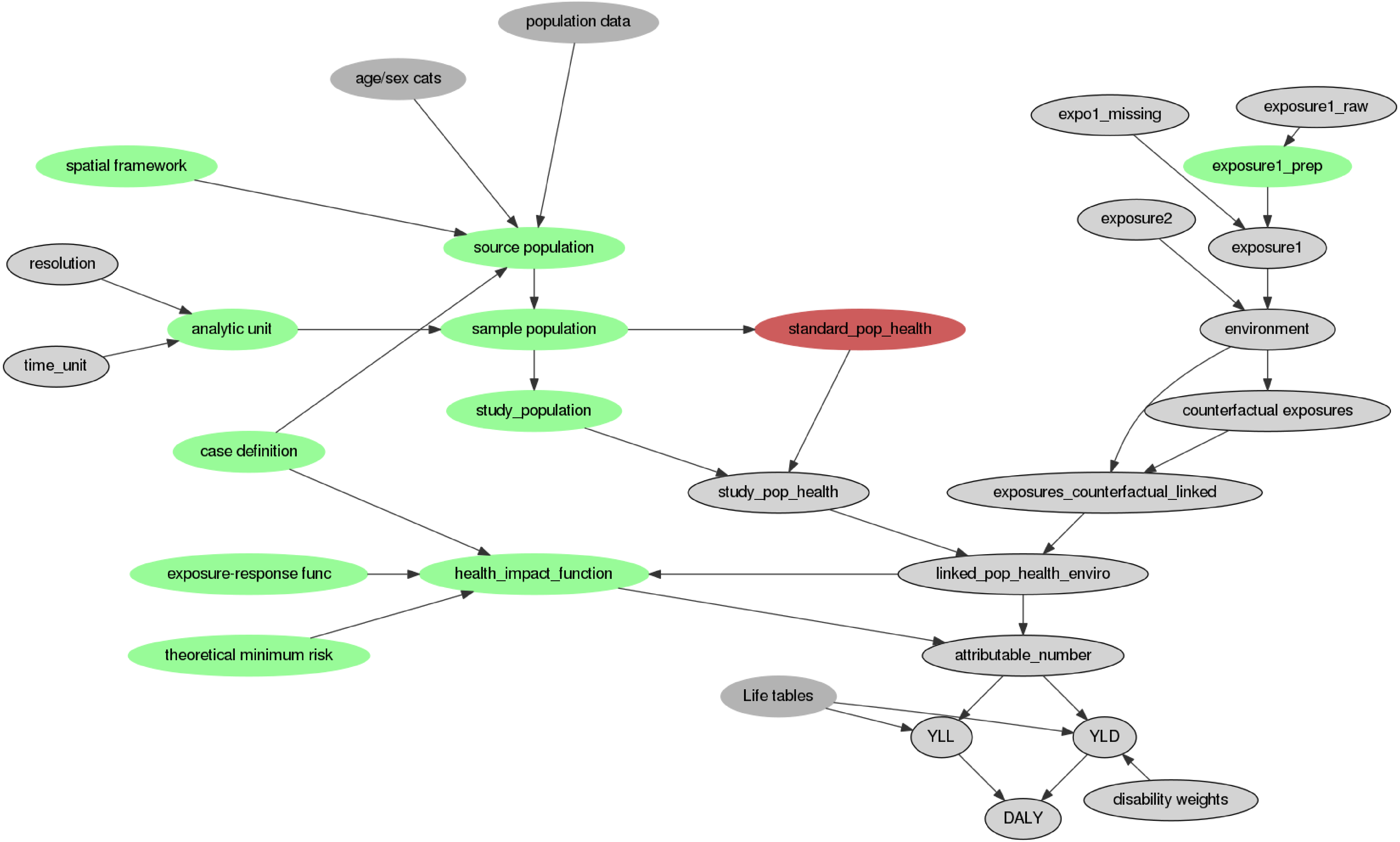
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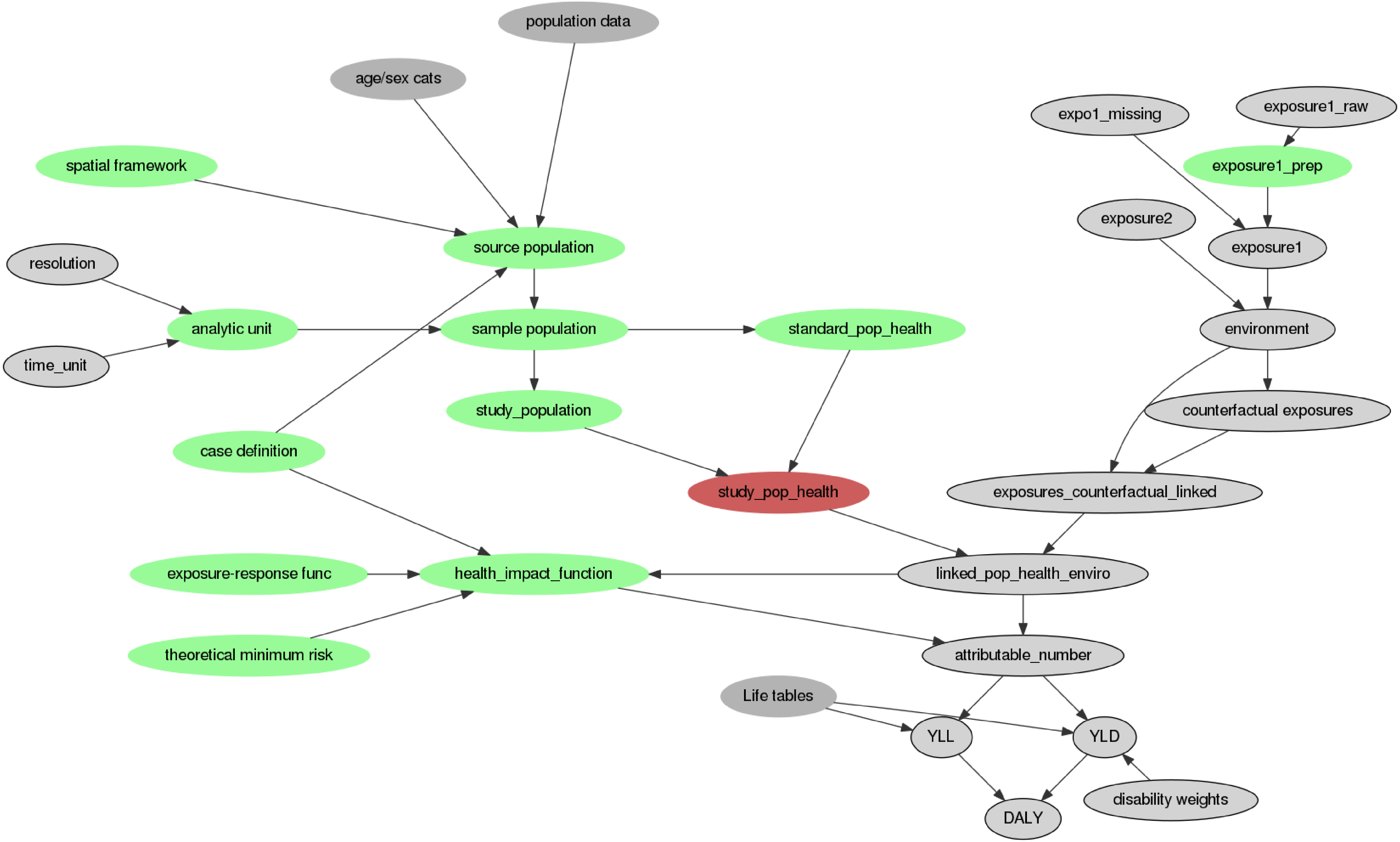
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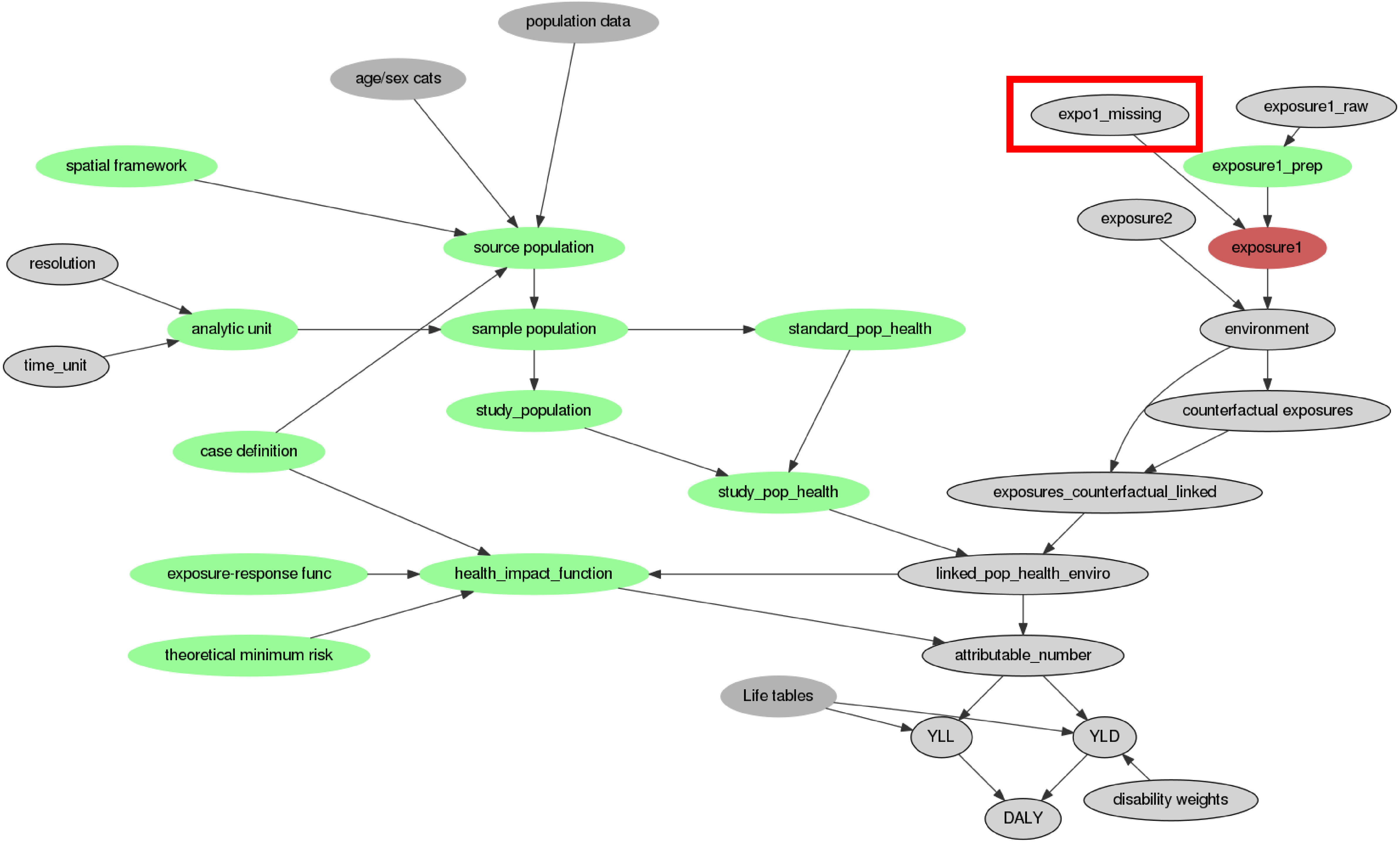
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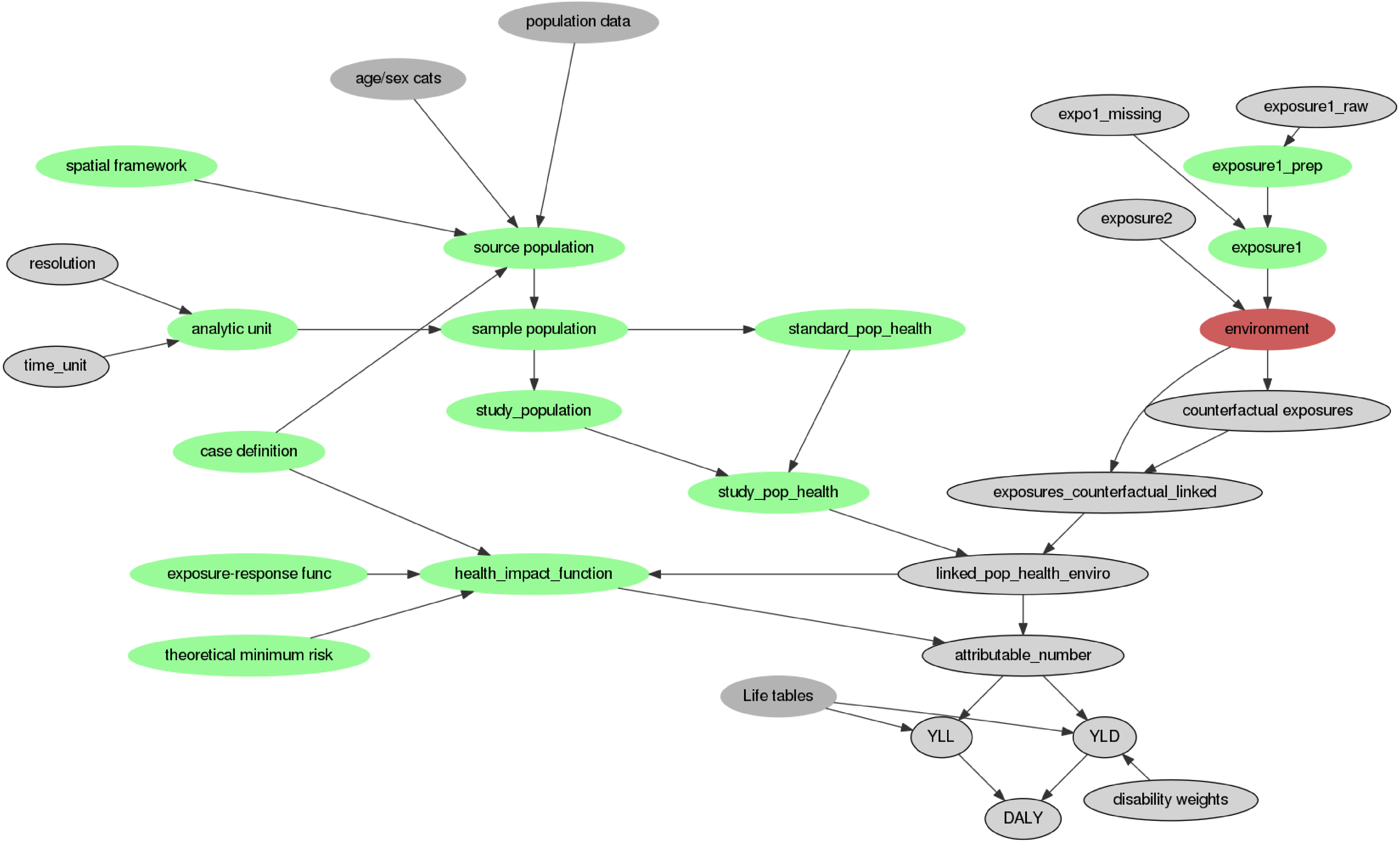
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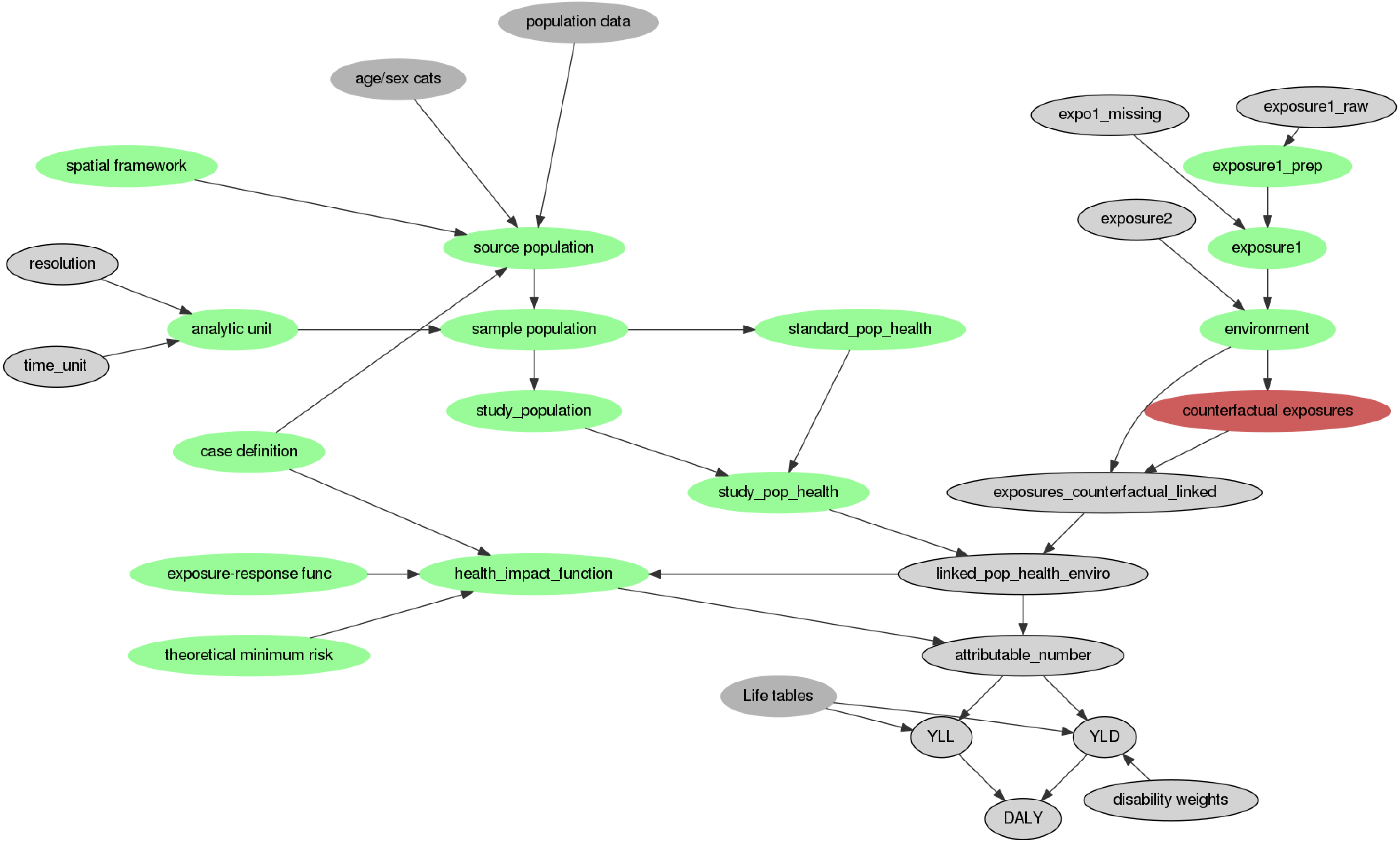
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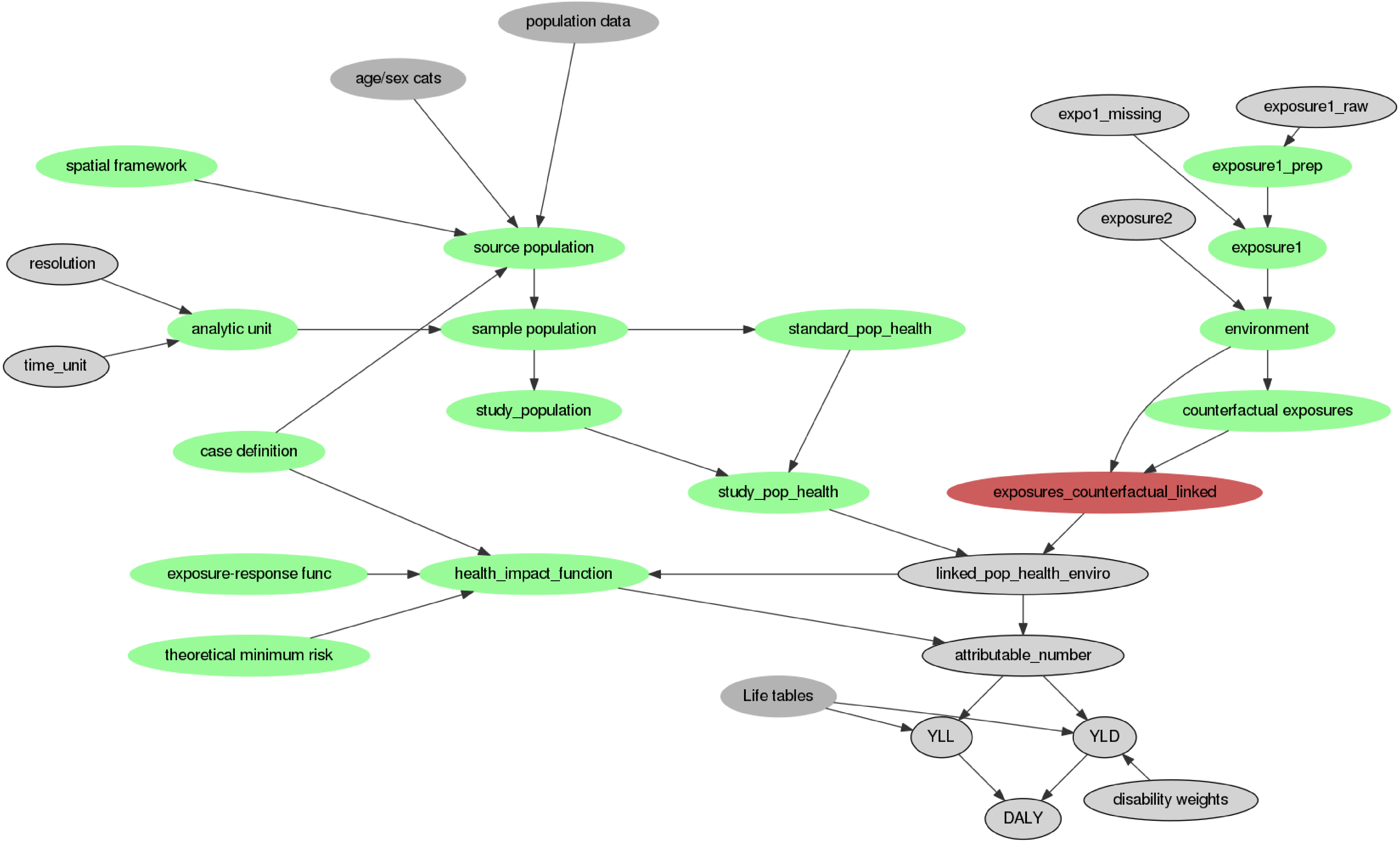
The counterfactual exposure scenario

- "What If"?
  - Could PM2.5 in all the areas across a region be reduced to the minimum observed anywhere in the region?
  - Assuming the minimum observed PM2.5 is achievable everywhere then that could be the counterfactual

Terminology Issue!

- Burden:
  - What is the current attributable number in population X
  - Due to the accumulated exposure over life course until now
- Impact:
  - What would be in a counterfactual (future) population X′
  - Due to the changed exposure over life course from now on
  - Accounting for demographic change (aging)
  - And (potentially) population ‘churn’ or ‘turnover’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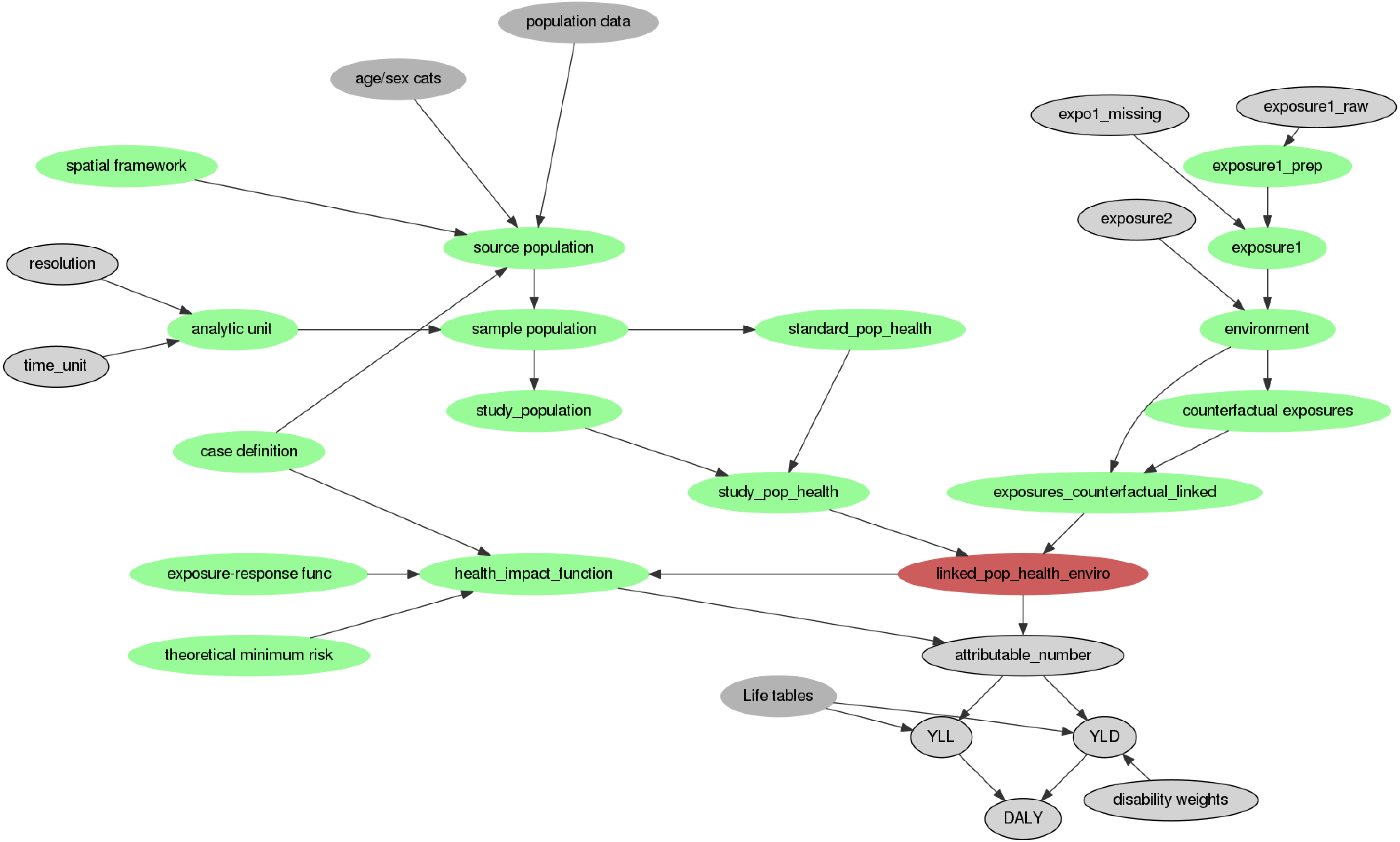

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theoretical minimum risk
attributable_number
Life tables
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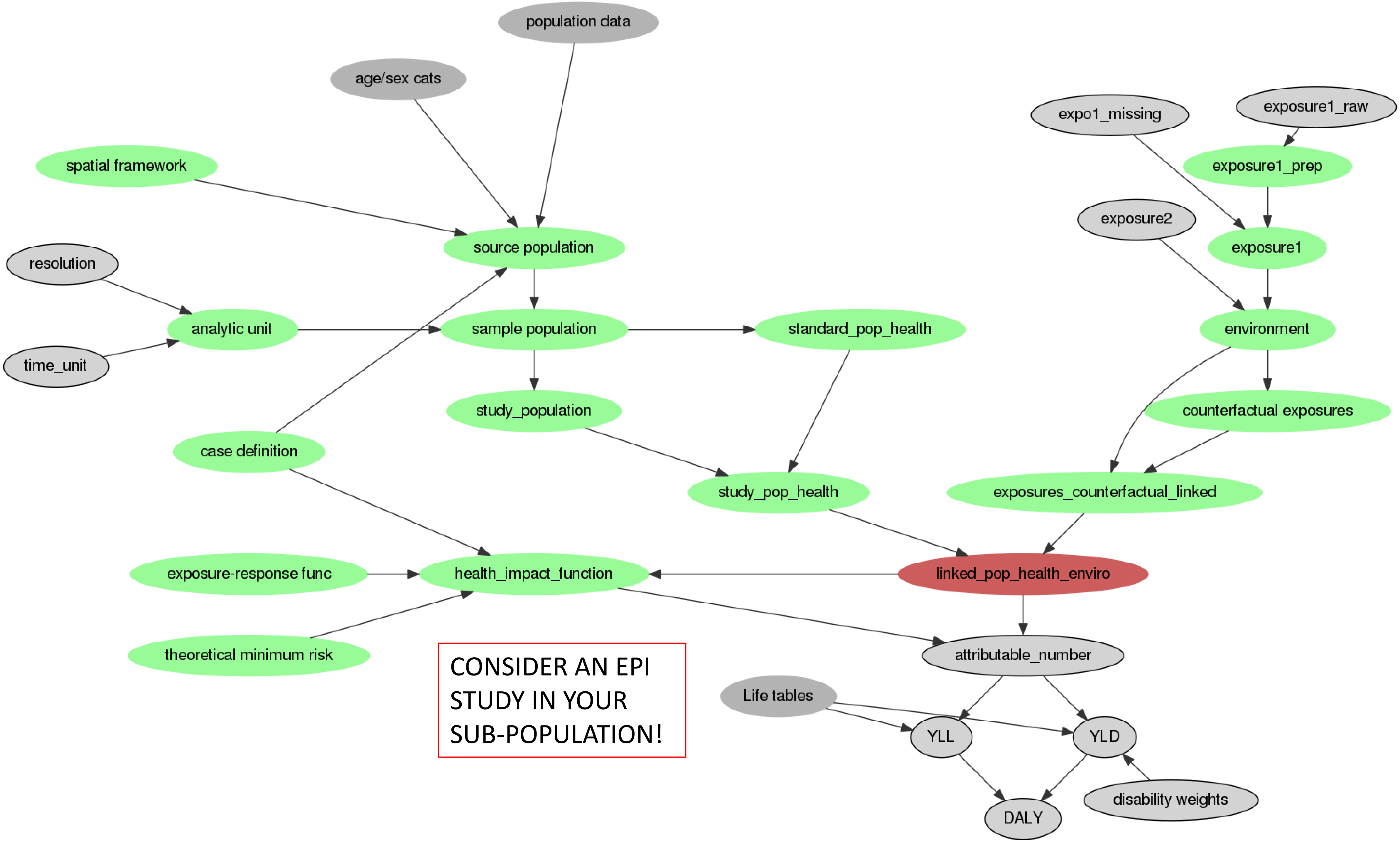
YLD
disability weights
DALY



CONSIDER AN EPI STUDY IN YOUR SUB-POPULATION!

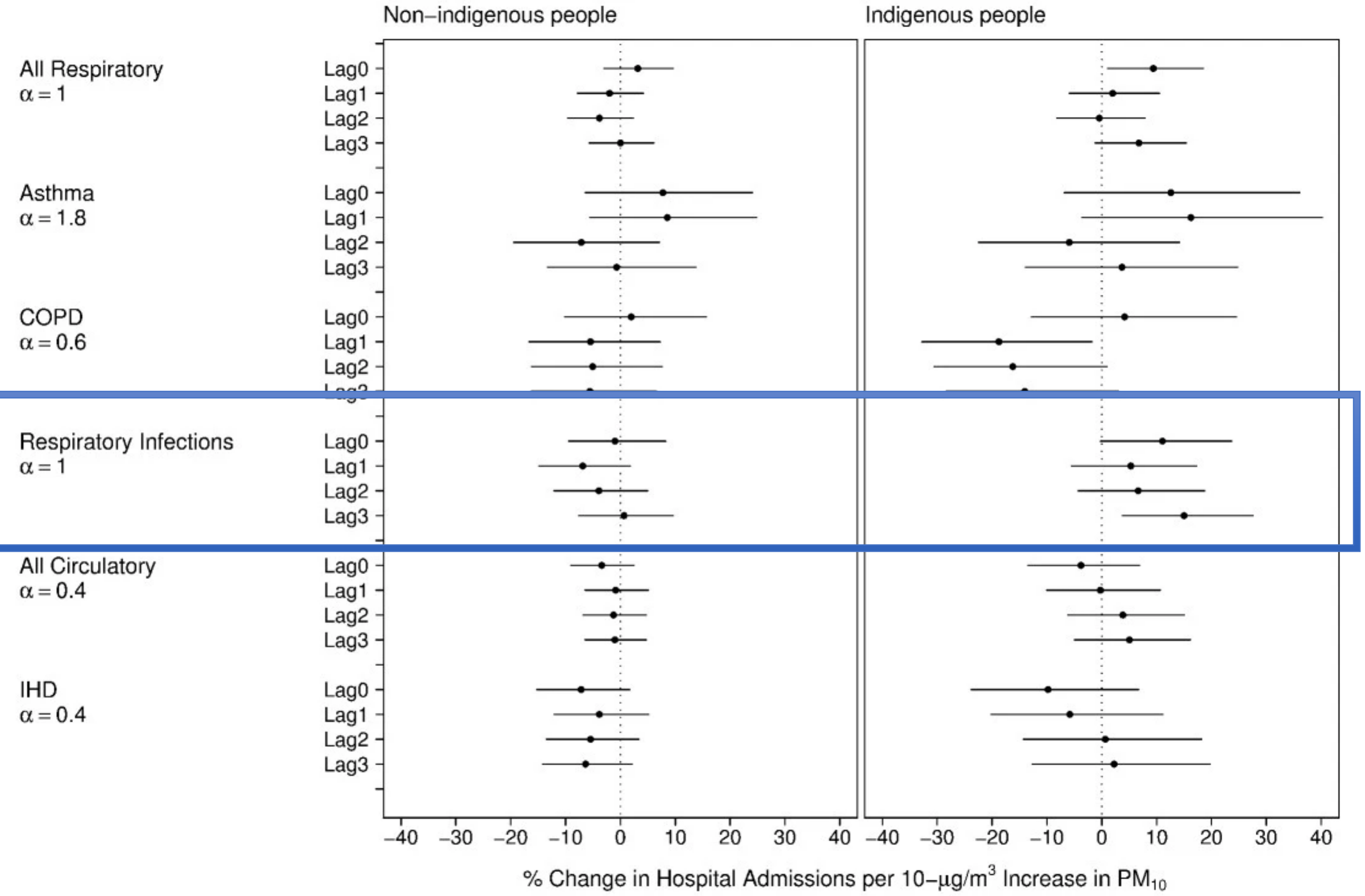
The principles of HIA (from enHealth 2017)

1. Democracy
2. Equity
3. Sustainable Development
4. Ethical use of evidence
5. Comprehensive approach to health

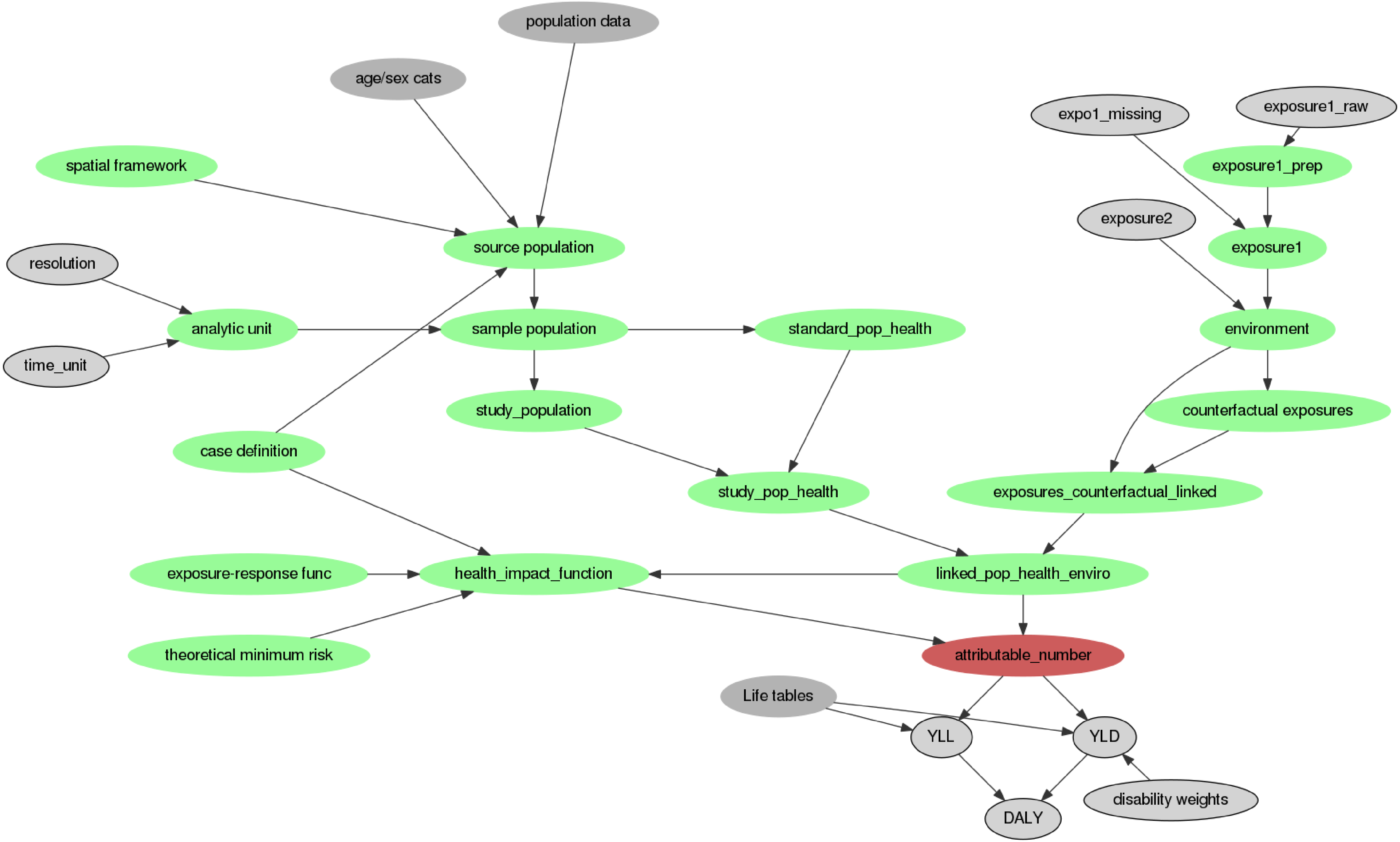
Differential effect estimates

- Exposure-response estimates often assumed to be the same for all areas/subpopulations
  - Using effect-estimates specific to subpopulations would likely show an exacerbation in socio-economically disadvantaged groups
  - Local and international studies have found differential effects between subgroups
- Krewski, D. (2009). *Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality*.
  - Less than high school 1.13 (0.9-1.42) for 10μg/m^3 $PM_{2.5}$
  - High school or more 0.97 (0.9-1.05) for 10 μg/m^3 $PM_{2.5}$

Disadvantage and differential effect estimates



Hanigan, I.C., Johnston, F.H. & Morgan, G.G. Vegetation fire smoke, indigenous status and cardio-respiratory hospital admissions in Darwin, Australia, 1996–2005: a time-series study. *Environ Health* **7,** 42 (2008). https://doi.org/10.1186/1476-069X-7-42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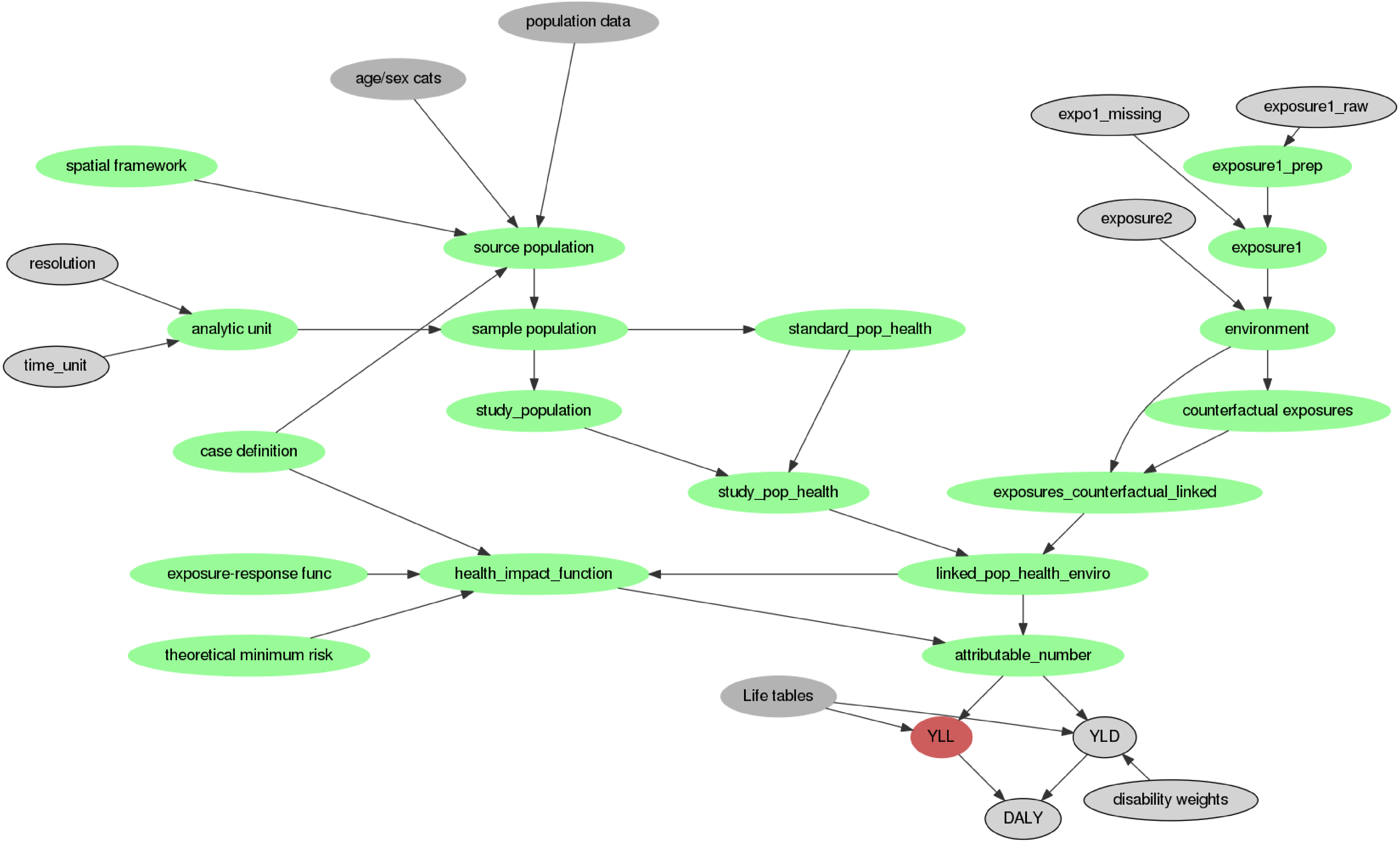
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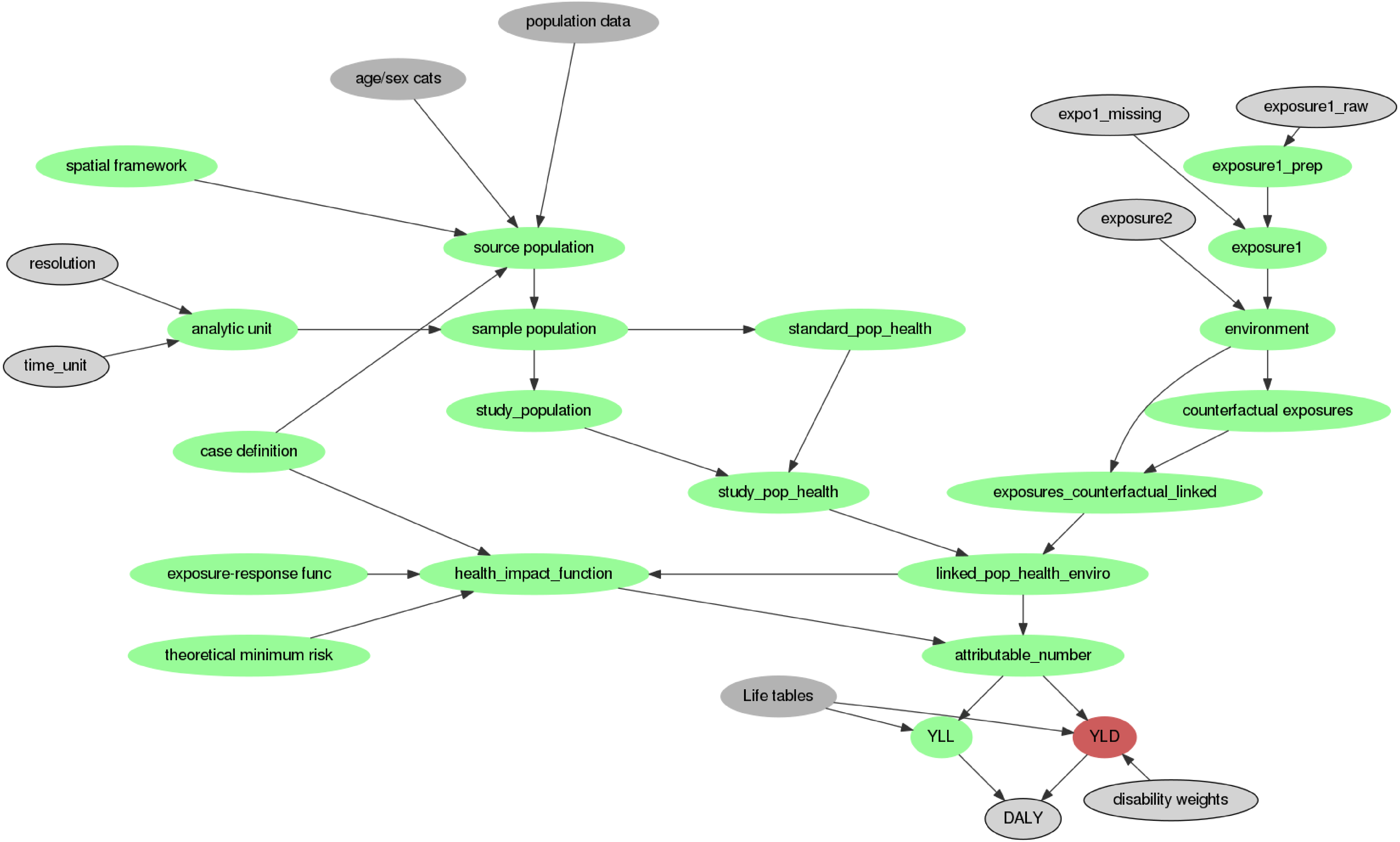
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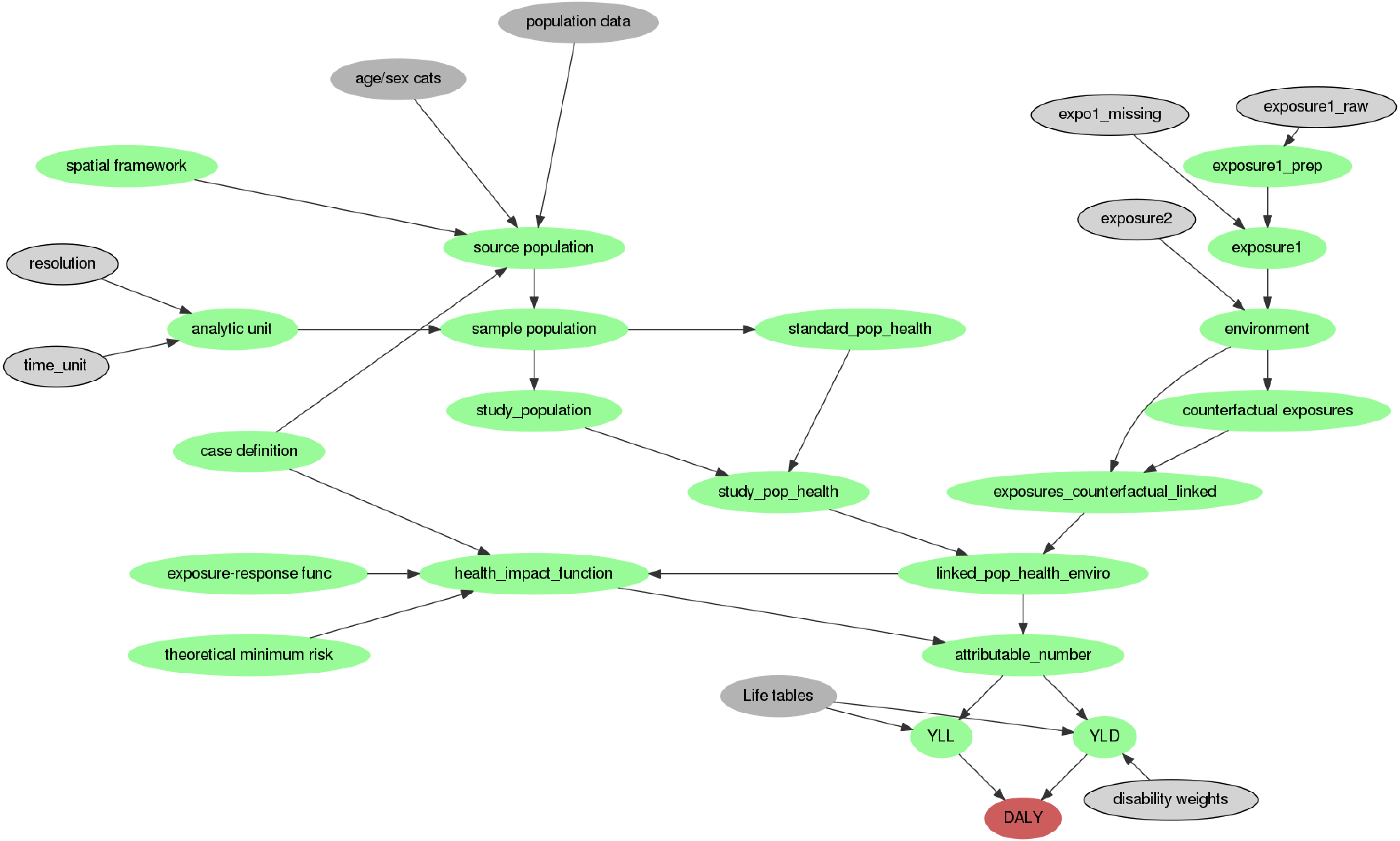

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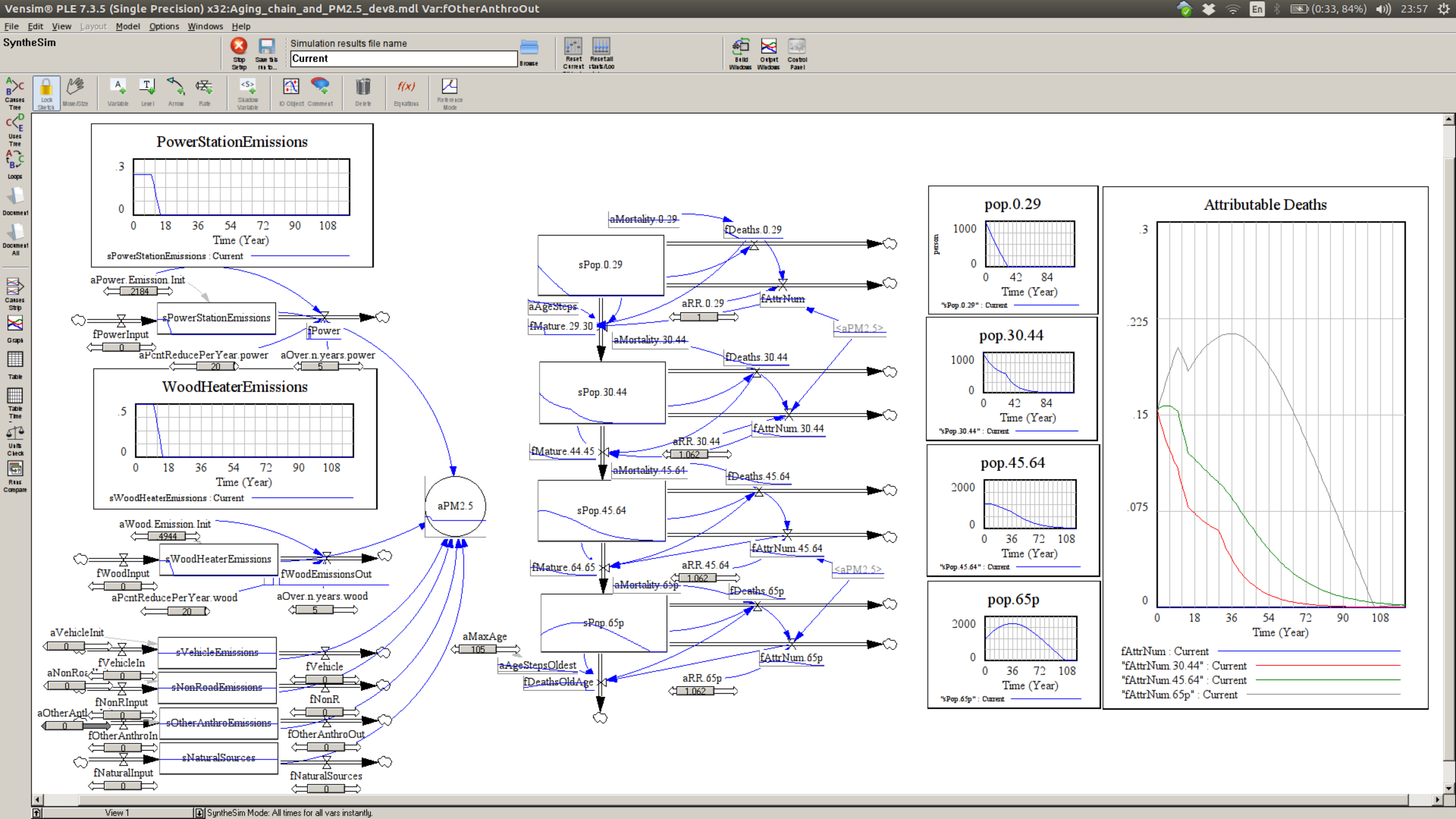
Part two: Impact

- Now we move on to the more desirable question
  - ‘What-If?’
- But we need to be careful about the interpretation
  - Burden is useful for many questions but the limits are clear and caveats required
  - Impact is based on scenarios, assumptions and calculations that move beyond the quantification of the epidemiological relations, into modelling of system dynamics.

Curtin University
WHO COLLABORATING CENTRE FOR CLIMATE CHANGE AND HEALTH IMPACT ASSESSMENT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fDeaths.65p
sPop.65p
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pop.30.44
pop.45.64
pop.65p
Attributable Deaths
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"fAttrNum.45.64" : Current
"fAttrNum.65p" : Current
View 1
SyntheSim Mode: All times for all vars instantly.

“Coached” practice time

- For those of you who have downloaded the tools from Github
  - https://github.com/cardat/DatSciTrain_HIA_Health_Impact_Functions_explained
- We will start by looking at the 02_Lifetables_with_spreadsheet
  - We will not have time to look at the other tools today
  - Feel free to play around with these later, and send any feedback via Github issues or pull requests.

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

Summary, Conclusions and Feedback

- Demonstrated an end-to-end example of health burden analysis, discussed moving from burden to impact
- Discussed key points for interpretation
- Access a worked example for hands-on "Coached" practice

- Now: please provide feedback using the survey at Slido.com with #3370 651