Supplement 1: Example pseudocode and tables of results

Table A1: System description and AI Generated variable lists

Rising population level, together with population ageing, cause an increase in the chronic disease burden as well as the burden of frailty in Singapore. These two burdens both translate into three types of needs: (i) acute care needs (ii) sub-acute care needs (iii) rehab needs. Acute care needs drive unavoidable Length of Stay (LOS) in Acute Hospitals (AHs), while sub-acute needs drive Avoidable LOS. (Note: LOS is considered avoidable when the stay could have been "decanted" to a site other than an AH). Rehab needs drive both unavoidable and avoidable LOS. Avoidable LOS drives avoidable AH inpatient-days, and unavoidable LOS drives unavoidable AH inpatient-days. Avoidable and unavoidable inpatient-days together affect AH beds required. AH capacity gap is directly driven by AH beds required; on the other hand AH beds required is positively linked to AH capacity increases, which is negatively linked to AH capacity gap. AH capacity gap drives waiting time for AH beds, which drives unmet needs, which increases chronic disease burden and the burden of frailty. Burden of frailty and chronic disease burden drive AH inpatient admissions, which is positively linked to both Avoidable and unavoidable AH inpatient-days.		
ChatGPT 4o	Claude 3.7 Sonnet	DeepSeek R1
01 Population Level 02 Population Ageing 03 Chronic Disease Burden 04 Burden of Frailty 05 Acute Care Needs 06 Sub-Acute Care Needs 07 Rehab Needs 08 Acute Hospital (AH) Inpatient Admissions 09 Unavoidable Length of Stay (LOS) 10 Avoidable Length of Stay (LOS)	Population level Population ageing Chronic disease burden Burden of frailty Acute care needs Sub-acute care needs Rehab needs Unavoidable LOS Avoidable LOS Unavoidable AH inpatient-days Avoidable AH inpatient-days AH beds required AH capacity gap AH capacity increases Waiting time for AH beds Unmet needs	Population level (01) Population ageing (02) Chronic disease burden (03) Burden of frailty (04) Acute care needs (05) Sub-acute care needs (06) Rehab needs (07) Unavoidable Length of Stay (LOS) in AHs (08) Avoidable Length of Stay (LOS) in AHs (09) Avoidable AH inpatient-days (10) Unavoidable AH inpatient-days (11) AH beds required (12) AH capacity gap (13)

11 Unavoidable AH Inpatient-Days 12 Avoidable AH Inpatient-Days 13 AH Beds Required 14 AH Capacity Increases 15 AH Capacity Gap 16 Waiting Time for AH Beds 17 Unmet Needs	AH inpatient admissions	AH capacity increases (14) Waiting time for AH beds (15) Unmet needs (16) AH inpatient admissions (17)

Table A2: Curated node (variable) lists and Edge (relationship) lists. 1 denotes a positive link and -1 a negative link

ChatGPT 4o and Claude 3.7 Sonnet			DeepSeek R1		
Source.Node.ID	Sink.Node.ID	Value	Source.Node.ID	Sink.Node.ID	Value
A01	A03	1	A01	A03	1
A01	A04	1	A02	A03	1
A02	A03	1	A01	A04	1
A02	A04	1	A02	A04	1
A03	A05a	1	A03	A05a	1
A03	A05c	1	A04	A05a	1
A03	A05b	1	A03	A05b	1
A04	A05a	1	A04	A05b	1
A04	A05c	1	A03	A05c	1
A04	A05b	1	A04	A05c	1
A05a	A06a	1	A05a	A06a	1
A05b	A06a	1	A05c	A06b	1
A05b	A06b	1	A05b	A06a	1
A05c	A06b	1	A05b	A06b	1
A06a	A07a	1	A06a	A07a	1
A06b	A07b	1	A06b	A07b	1
A07a	A08	1	A07a	A08	1
A07b	A08	1	A07b	A08	1
A08	A09	1	A08	A10	1
A08	A10	1	A09	A10	-1
A09	A10	-1	A10	A11	1
A10	A11	1	A11	A12	1
A11	A12	1	A12	A03	1
A12	A03	1	A12	A04	1
A12	A04	1	A03	A13	1
A03	A13	1	A04	A13	1
A04	A13	1	A13	A07a	1
A13	A07a	1	A13	A07b	1
A13	A07b	1			

Table A3: Feedback loops identified

ChatGPT 4o and Claude 3.7 Sonnet

Loop #	Edges	Polarity
B1	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05a (1), A05a -> A06a (1), A06a -> A07a (1), A07a -> A08 (1), A08 -> A09 (1)	Balancing
B2	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05c (1), A05c -> A06b (1), A06b -> A07b (1), A07b -> A08 (1), A08 -> A09 (1)	Balancing
B3	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05b (1), A05b -> A06a (1), A06a -> A07a (1), A07a -> A08 (1), A08 -> A09 (1)	Balancing
B4	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05b (1), A05b -> A06b (1), A06b -> A07b (1), A07b -> A08 (1), A08 -> A09 (1)	Balancing
B5	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A13 (1), A13 -> A07a (1), A07a -> A08 (1), A08 -> A09 (1)	Balancing
B6	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A13 (1), A13 -> A07b (1), A07b -> A08 (1), A08 -> A09 (1)	Balancing
B7	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05a (1), A05a -> A06a (1), A06a -> A07a (1), A07a -> A08 (1), A08 -> A09 (1)	Balancing
B8	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05c (1), A05c -> A06b (1), A06b -> A07b (1), A07b -> A08 (1), A08 -> A09 (1)	Balancing
B9	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05b (1), A05b -> A06a (1), A06a -> A07a (1), A07a -> A08 (1), A08 -> A09 (1)	Balancing
B10	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05b (1), A05b -> A06b (1), A06b -> A07b (1), A07b -> A08 (1), A08 -> A09 (1)	Balancing
B11	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A13 (1), A13 -> A07a (1), A07a -> A08 (1), A08 -> A09 (1)	Balancing
B12	A09 -> A10 (-1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A13 (1), A13 -> A07b (1), A07b -> A08 (1), A08 -> A09 (1)	Balancing
R1	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05a (1), A05a -> A06a (1), A06a -> A07a (1), A07a -> A08 (1)	Reinforcing
R2	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05c (1), A05c -> A06b (1), A06b -> A07b (1), A07b -> A08 (1)	Reinforcing
R3	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05b (1), A05b -> A06a (1), A06a -> A07a (1), A07a -> A08 (1)	Reinforcing
R4	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05b (1), A05b -> A06b (1), A06b -> A07b (1), A07b -> A08 (1)	Reinforcing
R5	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A13 (1), A13 -> A07a (1), A07a -> A08 (1)	Reinforcing

	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A13	
R6	(1), A13 -> A07b (1), A07b -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05a	
R7	(1), A05a -> A06a (1), A06a -> A07a (1), A07a -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05c	
R8	(1), A05c -> A06b (1), A06b -> A07b (1), A07b -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05b	
R9	(1), A05b -> A06a (1), A06a -> A07a (1), A07a -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05b	
R10	(1), A05b -> A06b (1), A06b -> A07b (1), A07b -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A13	
R11	(1), A13 -> A07a (1), A07a -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A13	
R12	(1), A13 -> A07b (1), A07b -> A08 (1)	Reinforcing

DeepSeek R1

Loop #	**Edges**	**Polarity**
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05a (1), A05a ->	
R1	A06a (1), A06a -> A07a (1), A07a -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05b (1), A05b ->	
R2	A06a (1), A06a -> A07a (1), A07a -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05b (1), A05b ->	
R3	A06b (1), A06b -> A07b (1), A07b -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A05c (1), A05c ->	
R4	A06b (1), A06b -> A07b (1), A07b -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A13 (1), A13 ->	
R5	A07a (1), A07a -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A03 (1), A03 -> A13 (1), A13 ->	
R6	A07b (1), A07b -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05a (1), A05a ->	
R7	A06a (1), A06a -> A07a (1), A07a -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05b (1), A05b ->	
R8	A06a (1), A06a -> A07a (1), A07a -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05b (1), A05b ->	
R9	A06b (1), A06b -> A07b (1), A07b -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A05c (1), A05c ->	
R10	A06b (1), A06b -> A07b (1), A07b -> A08 (1)	Reinforcing
	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A13 (1), A13 ->	
R11	A07a (1), A07a -> A08 (1)	Reinforcing

R12	A08 -> A10 (1), A10 -> A11 (1), A11 -> A12 (1), A12 -> A04 (1), A04 -> A13 (1), A13 -> A07b (1), A07b -> A08 (1)	Reinforcing

Table A4: Betweenness Centrality

Node ID	**Node Description**	**Betweenness Centrality**
A03	Chronic Disease Burden	0.214
A04	Burden of frailty	0.214
A08	AH beds required	0.206
A13	AH inpatient admissions	0.178
A12	Unmet needs	0.130
A07a	Unavoidable AH inpatient-days	0.116
A07b	Avoidable AH inpatient-days	0.116
A11	Waiting time for AH beds	0.074
A05b	Rehab care needs	0.073
A06a	Unavoidable AH LOS	0.054
A06b	Avoidable AH LOS	0.054
A10	AH capacity gap	0.053
A05a	Acute care needs	0.029
A05c	Sub-acute care needs	0.029
A01	Population	0.001
A02	Population ageing	0.001
A09	AH capacity increases	0.000

Supplement 2: Prompt document (Stagewise Text to CLD specification using Chain-of-Thought (COT) Prompting)

The series of prompts outlines our proposed approach to learning and applying Causal Loop Diagram Specification (CLDS) generation from Dynamic Hypotheses Input (DHI). The process gradually increases in complexity across three cases. Below, we seek to explain each step in the COT process.

The modeling team establishes the tasks for the LLM to: (a) Extract system variables as a variable (node) list in the CLD. Causal relationships are captured in the edge list. The LLM system starts by observing worked examples which progresses to when it is able to independently generates both the variables(nodes) and the relationships between the variables(edges) of the CLD. This structured approach ensures progressive learning through the COT process.

Step 1: Basic understanding of the task and the overall flow

Prompt (1) for understanding the task at hand:

> Your task is to aid a team of system dynamics modellers by a generating Causal Loop Diagrams Specification (CLDS), which consists of a Node List and an Edge List, from a textual description of a system. The textual description is called the Dynamic Hypotheses Input (DHI). The task of generating a CLDS from a DHI has two parts:
>
> (i) generation of system variables, specified as a Node List, from the DHI.
> Note that the variables are generally nouns, with a sense of direction. A sense of direction means that, for example, “Morale” is better than “Mental Attitude”, because with morale we know that higher generally is better.
>
> (ii) generation of a directed graph (which completes the CLDS), specified by the Node List and an Edge List, from the DHI.
> Note that the Edge List shows relationships between the variables in the Node List. Only two types of relationships exist: positive (shown by 1) and negative links (shown by -1).
> A positive link from variable X to variable Y means that other things being constant, increasing X would change Y to a level above what it would otherwise have been and decreasing X would change Y to a level below what it would otherwise have been.
> A negative link from variable X to variable Y means that other things being constant, increasing X would change Y to a level below what it would otherwise

have been and decreasing X would change Y to a level above what it would otherwise have been.

The steps to follow are the following:

For Case 1 and Case 2,

1. The modelling team will give you the DHI and ask you to confirm that you have understood it.
2. Then the modelling team will give you the Node List.
3. Finally, the modelling team will provide you with the Edge List.

Use Cases 1 and 2 to internalize the generation of the CLDS from the DHI.

For Case 3 and other cases in the future:

1. The modelling team will give you the DHI.
2. You are to generate a proposed Node List.
3. The modelling team will review this list and provide you a corrected Node List.
4. You are to generate the Edge List.
5. The modelling team will provide you with the corrected Edge List.

Case 1, Case 2, and Case 3 have increasing complexity.

Is this overall flow clear?

Step 2: Scaffolding with a simple use case (Prompt 2 and 3)

Prompt 2 establishes the basic mechanism of CLDS construction with a simple use case. By completing Case 1, the LLM should gain some familiarity with the syntax and logic of causal diagrams. Prompt 2 is as follows:

Let's follow the flow and start with Case 1.

Case 1 DHI: Births and deaths

An increase in fertility (births per population) means the birth rate (in people per year) will increase above what it would otherwise have been, and a decrease in fertility means the birth rate will fall below what it would otherwise have been. In short: fertility is positively linked to birth rate.

Average lifetime (years lived per person) is negatively linked to death rate (people per year). Birth rate to population is a positive link; Population to birth rate is a positive link. Population to death rate is a direct relationship; Death rate to population is an inverse relationship.

Prompt 3 provides the LLM with the Node and Edge Lists for Case 1 as follows:

Case 1 Node List

Node.ID	Node.Description
01	Fertility
02	Birth rate
03	Population
04	Death rate
05	Average lifetime

Case 1 Edges List

Source.Node.ID	Sink.Node.ID	Value
01	02	1
02	03	1
03	02	1
03	04	1
04	03	-1
05	04	-1

Is Case 1 clear?

Step 3: Scaffolding with a more complex use case (Prompts 4 and 5)

Prompt (4) introduces the Susceptible-Infectious-Recovered (SIR) Model to the LLM and expands the complexity by including population compartments (Susceptible, Infectious, Recovered) and additional factors like Contact Rate, Infectivity, Infection Rate, and Recovery Rate as follows:

Now let's move to Case 2. Case 2 DHI: Susceptible Infectious Recovered (SIR) Model:

The total population of an island determines the initial "susceptible population" (i.e., those can be infected). Those contracting the infection become infectious (join "infectious population") for a period of time, but then recover (join "recovered population") and develop permanent immunity. Contact rate is the rate of interaction in the community, or people contacted per person per time. Infectivity is the probability that the disease is transmitted when a susceptible person contacts an infection person. The infection rate, i.e., people infected per day, is directly proportional to susceptible population, (infectious population/total population), infectivity, and contact rate. The infectious population increases as the infection

rate increases; the susceptible population decreases as infection rate increases. Recovery rate (that is, people recovering per unit time), increases with infectious population, but decreases with average duration of infectivity. Recovery rate reduces the infectious population, and increases the recovered population.

Prompt (5) provides provides the nodes and edge lists to the LLM. These are the corrected variables and causal relationship predefined by the modelling team:

Case 2 Node List

Node.ID	Node.Description
01	Susceptible population
02	Infectious population
03	Recovered population
04	Total population
05	Infectivity
06	Contact rate
07	Infection rate
08	Avg duration of infectivity
09	Recovery rate

Case 2 Edges List

Source.Node.ID	Sink.Node.ID	Value
01	07	1
02	07	1
02	09	1
04	01	1
04	07	-1
05	07	1
06	07	1
07	01	-1
07	02	1
08	09	-1
09	02	-1
09	03	1

Step 4: Transfer of tasks to LLM with guidance on the Node List (Prompts 6, 7 and 8)

Prompt 6: The DHI for the test case is transferred to the LLM.

> Now you need to work on Case 3.
>
> Case 3 DHI: Acute Hospital Use
>
> Rising population level, together with population ageing, cause an increase in the chronic disease burden as well as the burden of frailty in Singapore. These two burdens both translate into three types of needs: (i) acute care needs (ii) sub-acute care needs (iii) rehab needs. Acute care needs drive unavoidable Length of Stay (LOS) in Acute Hospitals (AHs), while sub-acute needs drive Avoidable LOS. (Note: LOS is considered avoidable when the stay could have been "decanted" to a site other than an AH). Rehab needs drive both unavoidable and avoidable LOS. Avoidable LOS drives avoidable AH inpatient-days, and unavoidable LOS drives unavoidable AH inpatient-days. Avoidable and unavoidable inpatient-days together affect AH beds required.
>
> AH capacity gap is directly driven by AH beds required; on the other hand AH beds required is positively linked to AH capacity increases, which is negatively linked to AH capacity gap. AH capacity gap drives waiting time for AH beds, which drives unmet needs, which increases chronic disease burden and the burden of frailty.
>
> Burden of frailty and chronic disease burden drive AH inpatient admissions, which is positively linked to both Avoidable and unavoidable AH inpatient-days.
>
> Provide me your Node List

Prompt 7: The guidelines for the corrected node list is provided prior to the generation of the edges in the CLD.

> This is the corrected Case 3 Node List.

Node.ID	Node.Description
A01	Population
A02	Population ageing
A03	Chronic Disease Burden
A04	Burden of frailty

A05a	Acute care needs
A05b	Rehab care needs
A05c	Sub-acute care needs
A06a	Unavoidable AH LOS
A06b	Avoidable AH LOS
A07a	Unavoidable AH inpatient-days
A07b	Avoidable AH inpatient-days
A08	AH beds required
A09	AH capacity increases
A10	AH capacity gap
A11	Waiting time for AH beds
A12	Unmet needs
A13	AH inpatient admissions

Prompt 8: The development of the final Edge List is transferred to the LLM:

> Using the corrected Node List, provide me the Edges List, formatted so that it is easy to copy into a spreadsheet.

Supplement 3

Code and data files can be found in this GitHub link:
https://github.com/seanlam74/ISDC_GenAI_CLD