Worksheet 3.1 – Causal Loop Diagrams – Brainstorming Variables

Purpose: The purpose of this worksheet is to provide a framework that can be used to brainstorm variables within your system to create your systems map.

Objectives:

- Understand the importance of selecting and naming variables when systems mapping
- Create an initial list of variables as part of a systems map

Guidelines:

- *Variables* are components of a system that can change (increase or decrease) over time with potential to affect other parts of the system.
- When selecting variables to include as part of a systems map, aim to use consistent language throughout.
    - Use the positive sense of the word (e.g., profit, growth, increase) rather than the negative (loss, reduction, decrease) for consistency, and to prevent duplication.
    - It may help to use categories to group variables by theme or topic, as shown in the table provided. The categories shown, which may be referred to as the pillars of resilience or categories of infrastructure relevant for resilience, are commonly used in resilience planning and are suggestions as prompts to get started but are not a requirement. It may be just as effective to use categories tailored to a specific project or organization, or a blank sheet of paper.
- Good variables to select are those which are measurable, whether quantitative or qualitative.
    - Remember that things that are changeable are not always things that are measurable. For example, your state of mind is something that can change over time, but which is hard to measure. Using a variable like "Happiness" expressed as a number that can increase or decrease over time is a better variable to use.
- Where possible, avoid using verbs when naming variables. The action aspect is indicated by the arrow used to connect different variables. For example, instead of 'increase in price', simply use 'cost' or 'fee'.

Note: *we use 'variables' at this stage in the process rather than 'infrastructure elements' to ensure that we are comprehensive in developing our systems understanding. As we will demonstrate in later steps of the guidebook, we will follow a process to translate 'variables' to 'infrastructure elements' for use in a climate risk assessment.*

Individually or as a group-workshopping exercise, brainstorm variables for your system and list them in the relevant categories below or develop categories that are more appropriate for your needs.

Categories

Physical	Social	Economic	Environmental	Institutional/ Governance	Other
Number of patient beds	*Patients admitted*	*Staff productivity*	*Air quality*	*Government funding*	*Patient satisfaction*

Worksheet 3.2 – Causal Loop Diagrams – Linking Variables

Purpose: Provide demonstrations and practice on how to connect different variables using causal loop diagrams, which will be the building blocks of your systems map. Demonstrate how to connect different variables

Objectives:

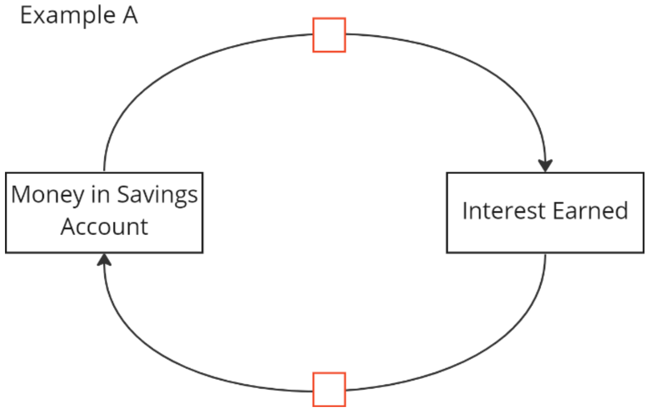
- Understand the purpose of linking variables that affect each other
- Understand the naming conventions used to label the links
- Be able to populate a blank causal loop diagram

Guidelines – Part 1: Practicing with Causal Loop Diagrams

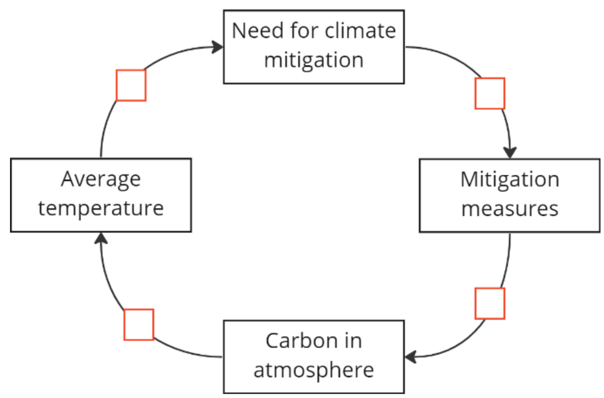
Examples of variables are provided below.

For **Examples A** and **B**, the arrows linking the variables have been provided. Place a "+" in the box on the arrow if the first variable causes the second to move in the same direction, and a "-" if it causes the second to move in the opposite direction. Correct responses can be found on the following page.

Example A

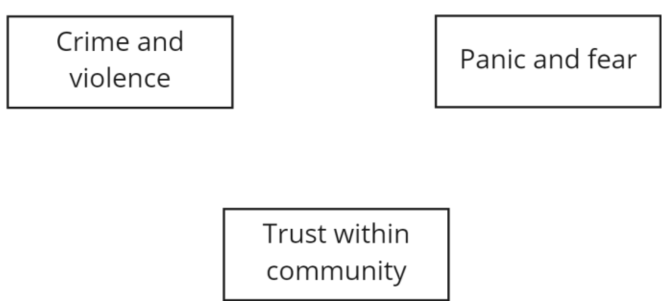


Example B



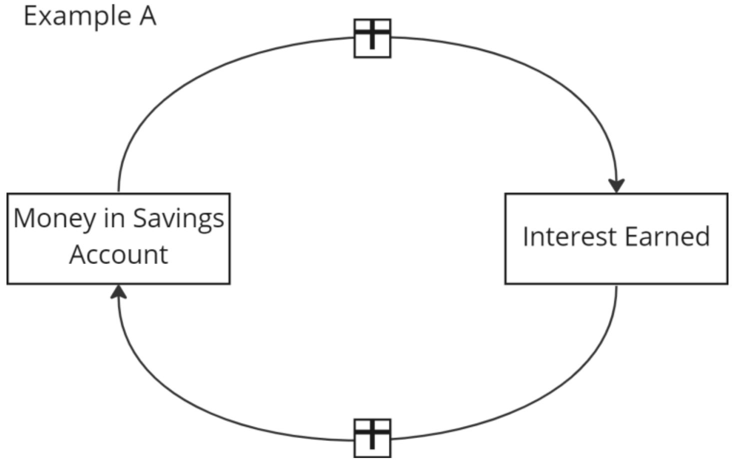
For **Example C**, the arrows have not yet been placed. Place the arrows indicating which variable is influencing which other variable, and label it with a "+" if the two move in the same direction, and a "-" if the two variables move in the opposite direction.

Example C

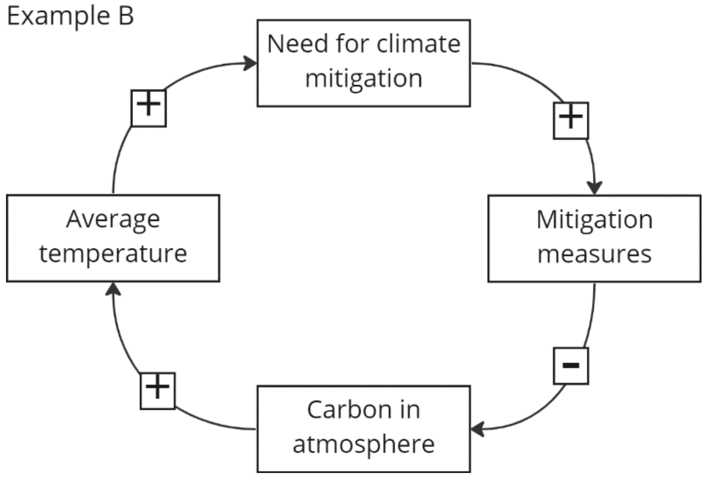


Part 1 Responses

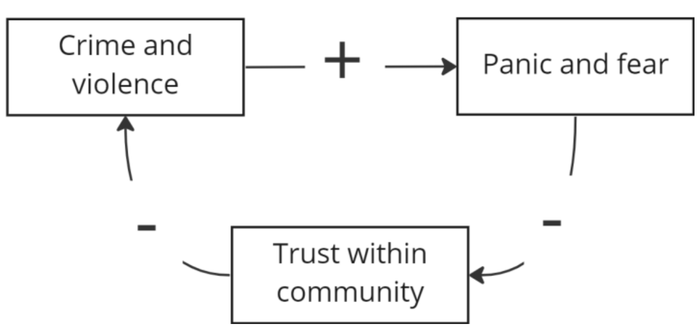
Example A



Example B

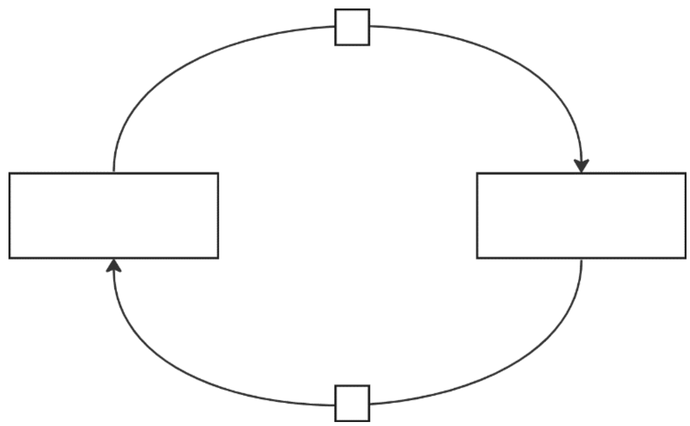


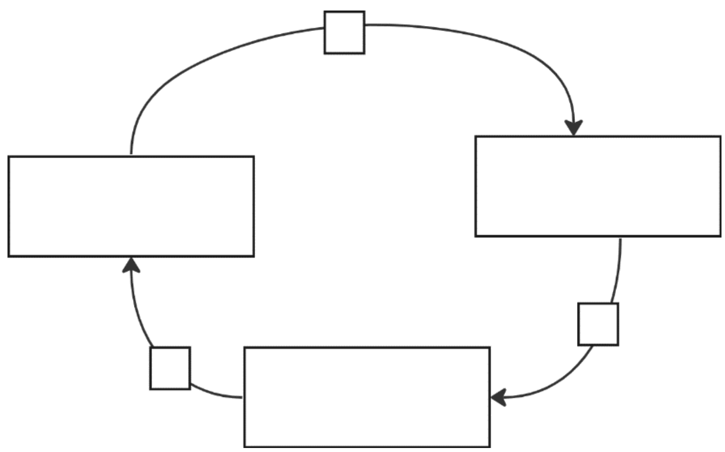
Example C

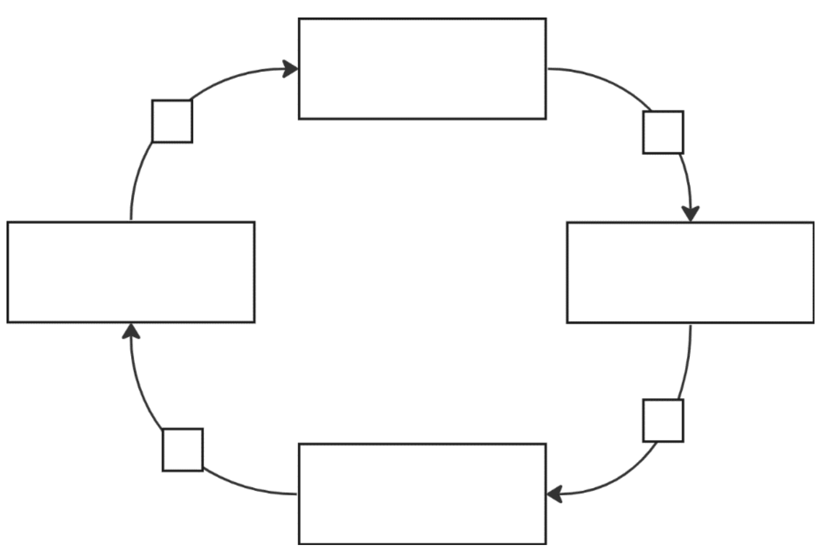


Guidelines – Part 2: Creating Causal Loop Diagrams for Your System
Use this section to practice building and labelling your own causal loops. Some templates have been provided below, but you may use your own space to create other forms or for additional space.

- Start by filling in the variables in the wider boxes. You may want to pull variables from your table in Worksheet 3.1.
- Walk through how one would change along with another, and place a “+” or “-“ as appropriate (see previous page) in the small boxes connecting the variables.
- Ensure that the direction of change works for both an increase and decrease in all variables.







Worksheet 3.3 – Causal Loop Diagrams – Classifying Loops

Purpose: This worksheet is intended to provide practice and blank templates for users to classify feedback loops as balancing or reinforcing, which can help provide insights when developing interventions

Objectives:

- Classify feedback loops as balancing (B) or reinforcing (R)

Guidelines

Examples of simple causal loops are provided below.
Classify the loops as balancing (B) if change in one direction is counteracted with a change in the opposite direction.
Classify the loops as reinforcing (R) loops if they produce compound change in one direction with even more change in that direction.

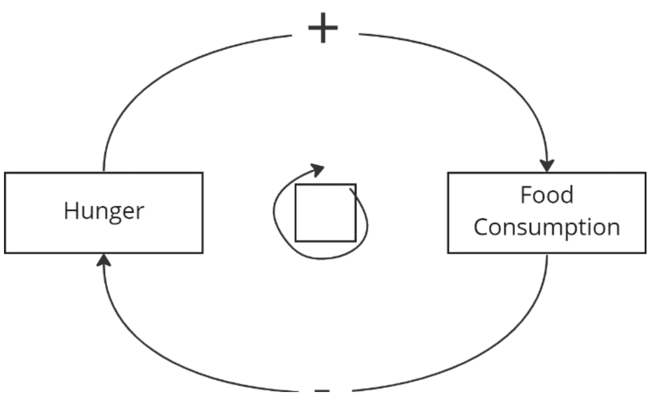
Tip for labelling loops

Sometimes there are multiple elements and links in a loop. If a loop has an even number of negative arrows, the overall loop is a reinforcing loop. If a loop has an odd number of negative arrows, it’s a balancing loop. This is because the two negative arrows cancel each other out and they have the same overall effect as a positive link.

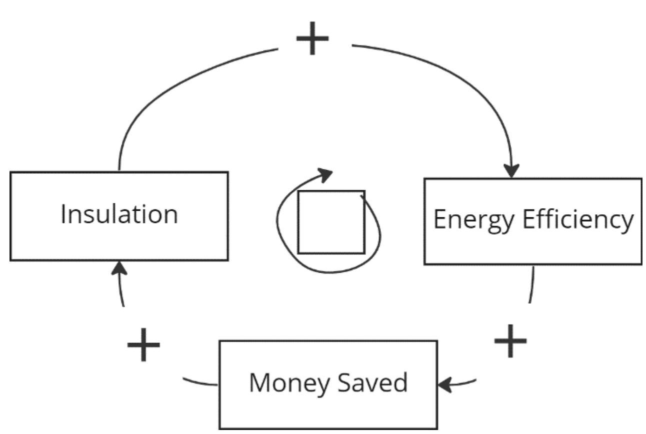
Part 1: Practice labeling feedback loops

For Examples A and B, decide if the feedback loop is a balancing loop or a reinforcing loop. If it is a balancing loop, label the square in the middle with a B, if it is a reinforcing loop, label the square in the middle with an R. Correct responses can be found on the bottom of the following page.[i]

Example A



Example B

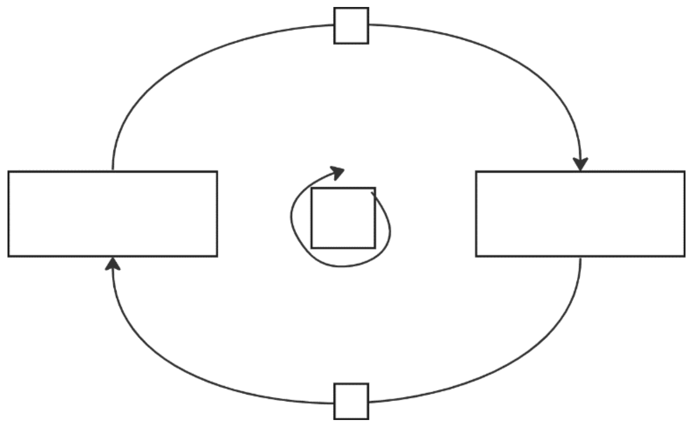


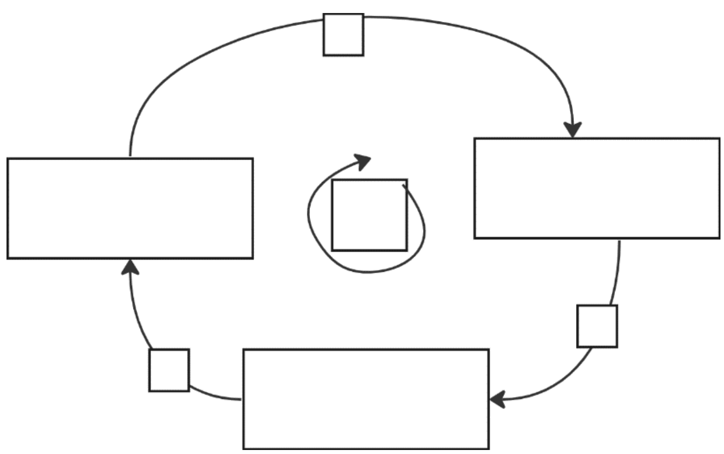
Part 2: Building and labeling feedback loops
Use this section to practice building and classifying your own causal loops. Some templates have been provided below.

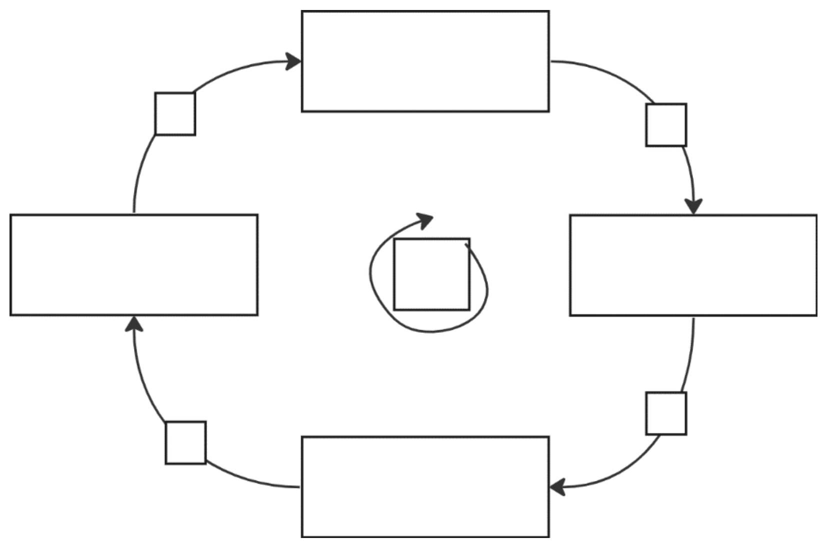
- Start by filling in the variables in the wider boxes.
- Walk through how one would change along with another, and place a "+" or "-" as appropriate in the small boxes connecting the variables.
- Ensure that the change works for both an increase and decrease in all variables.

  Note: you may pull over your causal loop diagrams from Worksheet 3.2 to complete the three bullets above, and then proceed with the next step.

- Classify the loop as balancing (B) or reinforcing (R) according to the type of change produced as you go around the loop.







[i] **Example A** is a balancing loop and should be labelled with a 'B'. **Example B** is a reinforcing loop and should be labelled with an 'R'.

Worksheet 3.4 – High-level Climate Profile

Purpose: Provide users with guidance on how to create a high-level climate profile that can inform the systems map and be enhanced in later stages of the climate risk assessment.

Objectives:

- Have a climatic context within which to create the systems map
- Create a climate profile and resources to create one

Guidance: The climate profile should be filled in by someone who has an understanding of the project area and has the ability to answer general questions about the climate.

Begin by listing past climate disasters. These will give users an idea of some of the climate hazards that the area will be at risk from. For example, recent and historical heat waves could be noted.

These climate disasters and hazards could then be classified under their corresponding climate elements:

- Temperature
- Precipitation
- Wind
- Sea Level Rise
- Other

Begin by filling in as much of Table 1 as possible based on historical climate events that are known to affect the area. Then move to Table 2.

Table 1. Past Climate Events

Past Climate Event	Climate Parameter	Climate Hazard	Year	Notes, including any summary information on damages experienced
Example: Heat dome	*Temperature*	*Heat wave*	*2021*	
Flooding due to heavy rainfall	*Precipitation*	*Flooding*	*2012*	*Major flooding*

If limited data is available, users can access websites such as Climate Atlas of Canada (https://climateatlas.ca/find-local-data) entering the location to get additional information to fill in the Table 2.

Table 2

Climate Parameter	Climate Hazard	Change in Hazard from Present	Notes
Example: Temperature	*Frost-free season*	*Shorter*	*Shorter ice-road season*

Worksheet 3.5 – Boundary Matrix Worksheet

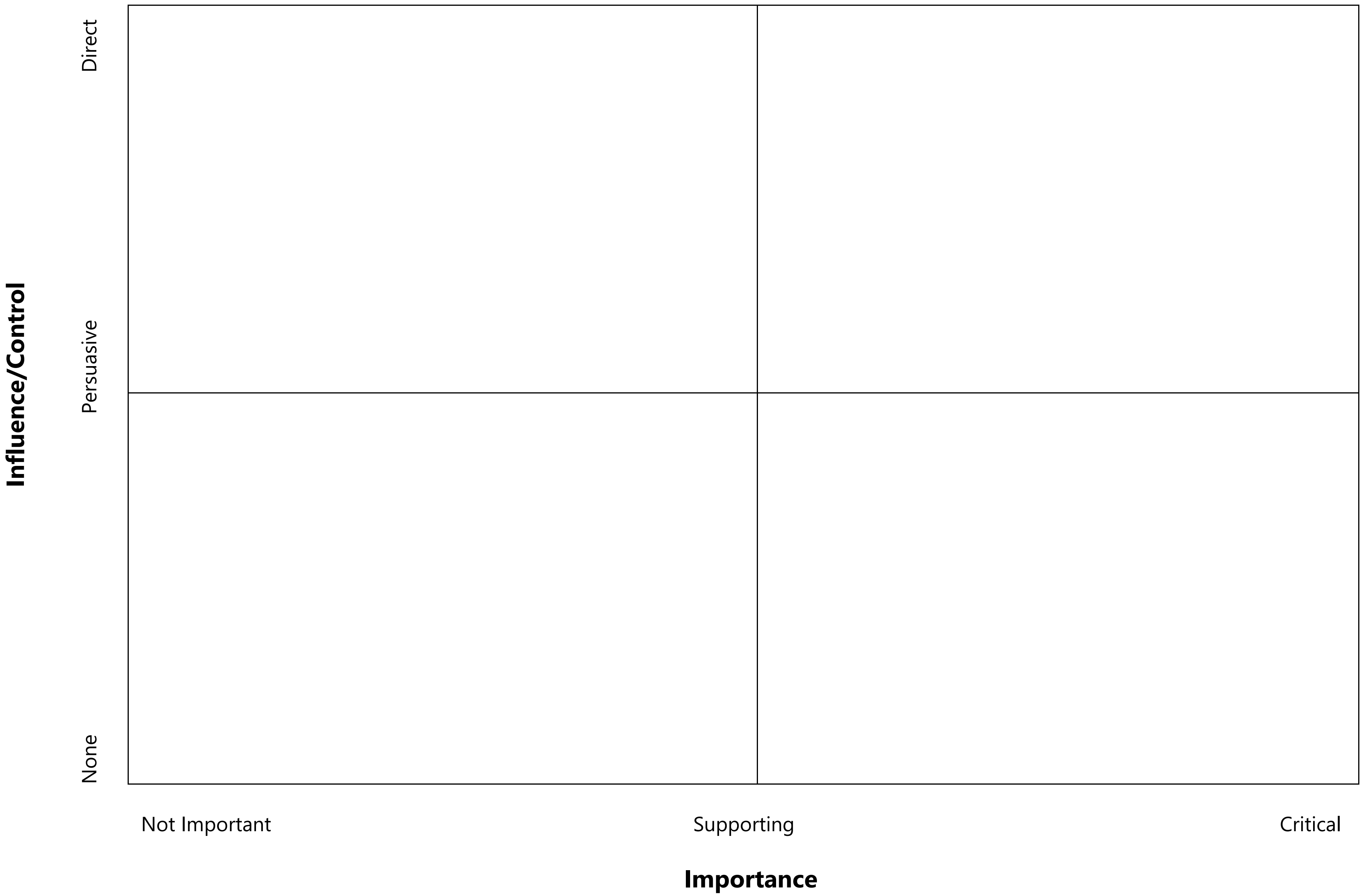
Purpose: The purpose of the boundary matrix is threefold: it helps the project team decide as a whole what is most important and what they have control over giving them a chance to create a shared vision; it allows them set boundaries for what they will include in their systems map; and it gives the team a reference point for where to start building their systems map.

Guidance: This boundary matrix can be used to formulate the context of any system. Using your list of variables from Worksheet 3.1, place variables in the boundaries matrix on the next page. You may find it useful to establish standard classifications for Influence and Importance that make sense for your project before filling out the matrix.
The y-axis corresponds to the level of influence the project team has over that variable, while the x-axis corresponds to how important that variable is to the project team.

Reflect on your boundary matrix: After filling out the matrix, it may be helpful to discuss the following questions:

- For variables that are important and you have control over, what are the biggest challenges that you are currently facing (may or may not be directly related to climate resilience)?
- For variables that are important that you do not control, what other stakeholders would you need to engage to make changes (Depending on the circumstances, it may make sense to engage these other stakeholders during some portion of this process)?
- For variables that are not important, but you have control over, are there any opportunities to make connections to other variables that are more important so that you can make changes?

After completing the boundary matrix, users should then begin mapping their system with a variable in the top right quadrant – something that is important and that they have control over. Starting with variables in the top right quadrant is not required but is recommended to focus attention.


Influence/Control
Direct
Persuasive
None
Not Important
Supporting
Critical
Importance

Worksheet 3.6 – Critical Variable Worksheet

Purpose: Help users identify and track critical variables from their systems map to provide a reference for use during the climate risk assessment.

Objectives:

- Determine variables that have a high number of interdependencies.
- Establish whether those variables are influential, vulnerable, or central

Guidance:

Looking at the systems map, visually determine which variables have a high number of connections to other variables.

- If there are multiple connections going outward, this may indicate an **influencing variable**
- If there are multiple connections going into the variable, this may indicate the variable is **vulnerable**
- If there are multiple connection going both to and from the variable, this may indicate the variable plays a **central**, or bridging role in the system

List the variables in the table below, along with the number of inbound and outbound connections to help determine the type of critical variable.

Variable Name	No. Incoming Connections	No. Outgoing Connections	Type of Variable (Influential, Vulnerable, Central/Bridging)
Example: Access to healthcare	*4*	*1*	*Vulnerable*
Quality of flood protection system	*3*	*0*	*Influential*

Worksheet 4.1 - Climate Risk Assessment Components

Purpose: Help users identify, categorize, and track risk assessment components from the systems map

Objectives:

- Separate each type of component needed for the climate risk assessment into various components into one of the tables below.
- Identify a subject matter expert, if applicable.
- Track variables that may drive consequences and make other variables more vulnerable further along into the process

Guidance – Infrastructure Elements: Refer to the systems map and look for variables that represent the physical and functional dimensions of the system. These may be physical but could also be operational or social components of the infrastructure element category.

An example of variables that may be included in the Roads infrastructure element category is included on the top line of the table below.

Category: Infrastructure Elements

Element Name	Variable Names	Subject Matter Expert (If applicable)
Example: Roads	*Access to roads; Quality of asphalt; Road access in and out of community; Maintenance workers available*	*Transportation Engineering*

Guidance – Climate Hazards: Refer to the systems map and look for variables that represent climate hazards in your system. Variables in the map may be related to one or more climate hazard; and the climate hazards may be mapped to one or more variables in the system map.

An example of variables that may be included in the Precipitation and Floods climate hazard category is included on the top line of the table below.

Category: Climate Hazards

Climate Hazard Name	Variable Names	Subject Matter Expert (If applicable)
Example: Precipitation and Floods	River level; Severity of riverine flooding; Length of rainfall; Severity of rainfall;	

Guidance – Vulnerability Drivers: Refer to the systems map and look for variables in the system that influence the vulnerability of other variables or elements, and the consequences of any risks arising as a result. These variables are not grouped into categories in this step because they are able to drive consequences on their own. They may have already been categorized into a previous category, but they will be listed and tracked in the table below.

Some examples of vulnerability drivers are: clearcutting; inflation; and permafrost melt.

Category: Vulnerability Drivers

Vulnerability Driver Name	Subject Matter Expert (If applicable)
Example: Inflation	N/A

Worksheet 4.2 - Identifying Subject Matter Experts

Purpose: To help users identify additional Subject Matter Experts (SMEs)

Objectives:

- To identify and track missing SMEs that may be needed to bring additional knowledge to the table

Guidance: Refer to Worksheet 3.1 to help fill in the categories of infrastructure elements and climate hazards for your systems. If these categories can be broken down into subcategories, this will be helpful for subsequent steps.

List the title of the SMEs in the space provided. The first table is intended for SMEs of infrastructure elements. The table on the following page is for climate hazard SMEs.

Infrastructure Element	Required SME
Category *Example: Building*	Title of SME who can assess vulnerability
Subcategory *Example: Mechanical System*	
Element name Example: *Outdoor Cooling Unit*	*Example: Mechanical Engineer*
Subcategory	
Category	
Subcategory	
Subcategory	
Category	
Subcategory	
Subcategory	

Climate Hazard	Required SME
Category *Example: Drought*	Title of SME who can assess vulnerability
Subcategory *Example: Drought*	
Element name Example: *Reservoirs*	*Example: Civil Engineer*
Subcategory	
Category	
Subcategory	
Subcategory	
Category	
Subcategory	
Subcategory	

Worksheet 5.1 Assessment Objectives, Boundaries, Timescales and Elements Definition

Purpose: help users identify the following components necessary to begin the climate risk assessment.

- **Objectives.** Determines what the intended outcomes from the assessment are, which shape the scope of work and level of effort.
- **Boundaries.** Determines what elements are included or excluded from the assessment.
- **Timescale.** Selects the historical and future time horizons to be included.
- **Elements.** Final list of infrastructure elements (asset components, activities, personnel) to be included in the assessment.
- **Workshop participants.** Subject matter experts who can assess vulnerability of the elements.

Objectives

The following table can be used to record the key considerations to determine the objectives of the assessment

Consideration	Response
Is the CRA required for a funding application (e.g., as part of an INFC Climate Lens submission)?	☐ YES ☐ NO
If responded Yes to the previous question, provide further details	
Is the CRA part of the development a community climate change adaptation plan?	☐ YES ☐ NO
If responded Yes to the previous question, provide further details	
Is the CRA required under an environmental impacts assessment?	☐ YES ☐ NO
If responded Yes to the previous question, provide further details	
Is the CRA performed to assess the adequacy of design criteria for infrastructure (existing or planned) that will have a long service life during which climate changes are expected?	☐ YES ☐ NO

Consideration	Response
If responded Yes to the previous question, provide further details	
Will the CRA results be used in financial disclosures of climate-related risks (as per the Task-Force on Climate related Financial Disclosures)?	☐ YES ☐ NO
If responded Yes to the previous question, provide further details	
Please use this space to list any other considerations that should be accounted for in the assessment	

Using the information in the table above, describe below the **Objectives** that the CRA intends to complete, preferably in the form of sentences such as “The assessment shall align with Infrastructure Canada’s Climate Lens guidance”.

Boundaries

In the following space, insert a plan view of the area under assessment and highlight the area(s) included in the study. Depending on the scale, consider labelling the infrastructure assets (i.e. hospital building, elementary school, pumping station) for clarity.

Elements and Subject Matter experts.

The assessment timescale and required subject matter experts (SMEs) will depend on the final list of elements under study. Use following template to record the final list of elements, associated lifecycle and required SMEs to assess vulnerability. The breakdown of categories and subcategories will depend on the scope of the study and level of detail required.

This template can be circulated for feedback with the CRA team when finalizing the list of elements, and SMEs may wish to add more elements or break down some rows further.

Element	Lifecycle	Required SME
Category *(i.e. Building)*		
Subcategory (*i.e. Mechanical System)*		
Element name (*i.e. Outdoor Cooling Unit)*	Typical lifespan in years (i.e. 25 years)	Tittle of SME who can assess vulnerability (i.e. *Mechanical Engineer*)
Subcategory		
Category		
Subcategory		

Assessment Timescale

Based on the information on the elements' lifecycle, identify in the table below the time horizons that will be used for the assessment. Typically, 30 year periods are used for each time horizon.

Time horizon	Years included	Justification for selection
Baseline	*(i.e. 1981-2010)*	
Future horizon 1 (*i.e. 2050s*)	*(i.e. 2041-2070)*	
Future horizon 2 (*i.e. 2080s*)	*(2071-2100)*	

Worksheet 5.2 Climate Hazards Summary

Purpose: Summarize the climate hazards, expected projections, and likelihood scores.

Use the table below to summarize the climate parameters, hazards and indicators used in the study. An example is provided in the top rows.

Climate Parameter	Climate Hazard	Climate Hazard Indicator & Threshold	Rationale for selection, Include references to past events if available.
Temperature	*Extreme Heat*	*Number of days with Tmax > 31°C*	*Can exceed HVACs design load.*
		Number of days with Tmax > 31°C and Tmin>20°C	*Prolonged heat with little overnight cooling results in increased risk of thermal stress*

Use the table below to summarize the climate parameters likelihood score scale selected for this project.

Score	Description
1	
2	
3	
4	
5	

Use the table below to summarize the climate data and likelihood scores for all the climate hazard indicators.

Climate Parameter	**Climate Hazard**	**Climate Hazard Indicator & Threshold**	**Unit**	**Base line**	**Change from Baseline under [climate scenario] (%) – Median (90th, 10th percentile)**			**Projected Value– under [climate scenario] Median (90th, 10th percentile)**			**Likelihood Scores**			
					[Time Horizon 1]	**[Time Horizon 2]**	**[Time Horizon 3]**	**[Time Horizon 1]**	**[Time Horizon 2]**	**[Time Horizon 3]**	**Base-line**	**[Time Horizon 1]**	**[Time Horizon 2]**	**[Time Horizon 3]**
Temperature	*Extreme Heat*	*Number of days with Tmax > 31°C*	*days/ year*	*3.4*	*132.8 [38.5, 193.8]*	*355.9 [257.2, 481.5]*	*778.2 [473.9, 1031.2]*	*7.9 [4.7, 10.0]*	*15.5 [12.1, 19.8]*	*29.9 [19.5, 38.5]*	*3*	*5*	*5*	*5*
		Number of days with Tmax > 31°C and Tmin>20°C	*days/ year*	*1.4*	*163.6 [53.9, 284.5]*	*592.8 [452.8, 872.4]*	*1306.8 [903.8, 2033.0]*	*3.7 [2.2,5.4]*	*9.7 [7.7, 13.6]*	*19.7 [14.1, 29.9]*	*3*	*5*	*5*	*5*

Worksheet 5.3 Exposure Summary

Purpose: Summarize the exposure assessment to climate hazards for each element.

Use the table below to record the exposure assessment, with the following on a binary scale:

- **Yes -** If an element exposed to a climate hazard is likely to result in a material impact, then further assessment is needed to determine the extent of that impact.
- **No -** If an element exposed to a climate hazard is unlikely to result in a material impact, no detailed assessment is needed at this stage. If necessary, the element-hazard pair can be re-assessed later.

Element	**Climate Hazards**			
	(i.e. Extreme heat)	**[Hazard 2]**	**[Hazard 3]**	**[Hazard 4]**
Category *(i.e. Building)*				
Subcategory (*i.e. Mechanical System)*				
Element name (*i.e. Outdoor Cooling Unit)*	[YES / NO]			
Subcategory				
Category				
Subcategory				
Total Exposed (YES)				
Total Not Exposed (NO)				

Worksheet 5.4 Vulnerability Assessment

Purpose: Guide users through the completion of an individual and compound vulnerability assessment. .

Use the table below to summarize the individual vulnerability score scale selected for this project. Columns can be added or subtracted as needed based on the impact criteria used to define the scale.

Score	[Criteria 1]	[Criteria 2]	[Criteria 3]
1	[Descriptions]		
2			
3			
4			
5			

Individual Vulnerabilities

Use the following table to record individual vulnerabilities with respect to each climate hazard.

Element		Climate Hazards			
		(i.e. Extreme heat)	[Hazard 2]	[Hazard 3]	[Hazard 4]
		Category *(i.e. Building)*			
		Subcategory (*i.e. Mechanical System)*			
Element name (*i.e. Outdoor Cooling Unit)*	**Score**	*(i.e. 3)*			
	Comments	*(i.e. unit performance affected by extreme heat)*			
	Score				
	Comments				
Subcategory					
	Score				
	Comments				
	Score				
	Comments				
Category					
Subcategory					
	Score				
	Comments				
	Score				
	Comments				
	Score				
	Comments				

Compound Vulnerabilities

In the table below, define a threshold value for individual vulnerability to be considered “high vulnerability” and thus carried forward to the compound vulnerability assessment. The threshold can be different based on the criteria selected for impact scoring.

Threshold	[Criteria 1]	[Criteria 2]	[Criteria 3]
[value]	[Descriptions]		

Use the table below to list the elements whose individual vulnerability exceeds the thresholds noted in the earlier table and document the associated hazard driving the vulnerability.

Element	Vulnerability Score	Climate Hazard

In the following space, draw the portion of the system map that relates to each of the elements noted in the earlier table and label them with their individual vulnerability score. Also label the relationships with the relationship magnitude (0-1) score.

For each element shortlisted in the earlier table, use the following table to calculate the impact on compound vulnerability scores, based on the individual vulnerability of the upstream elements.

Element: Climate			
Upstream elements	**Individual vulnerability**	**Relationship magnitude**	**Impact on compound vulnerability**
Total	**-**	**-**	

Worksheet 5.5 Risk Assessment and Adaptation Strategies

Purpose: Document the risk scores and selected adaptation strategies developed by the CRA team

Use the following table to document the risk scores and adaptation strategies developed in the CRA process.

Element	Climate Hazard	Risk Scores [Individual Vulnerabilities]			Risk Scores [Compound Vulnerabilities]			Adaptation Strategies			
		[Time Horizon 1]	[Time Horizon 2]	[Time Horizon 3]	[Time Horizon 1]	[Time Horizon 2]	[Time Horizon 3]	[Category 1]	[Category 2]	[Category 1]	[Category 1]

Worksheet 7.1 Business Case Problem Definition

Purpose: Help users summarize the results of the CRA into a framework that can be used to define the problem of a Business Case.

Use the tables below to summarize the critical and material element-hazard interactions, both for individual and compound vulnerabilities, with the infromation from the CRA.

Critical Individual Vulnerabilities

Element	Hazard	Individual Vulnerability Description	Adaptation Strategies	Collaborating Agencies, if applicable

Critical Compound Vulnerabilities

Element	Hazard	Compound Vulnerability (Upstream) Description	Adaptation Strategies	Collaborating Agencies, if applicable

Worksheet 7.2 Multicriteria Assessment Resilience Analysis

Purpose: Help users evaluate the resilience of each option to generate a single score that can be fed into the MCA

Use the following table to interact the critical and material elements with the various options. In each cell, document the impact of each option on vulnerability. The cells can be color coded, for example: green – risk mitigated, orange – additional investigation is required, red – risk is maintained.

Critical Individual Vulnerabilities (worksheet 7.1)		Option 1	Option 2	Option 3	Option 4
Element	Hazard				
		Impact description:	**Impact description:**	**Impact description:**	**Impact description:**
		Impact description:	**Impact description:**	**Impact description:**	**Impact description:**
		Impact description:	**Impact description:**	**Impact description:**	**Impact description:**
		Impact description:	**Impact description:**	**Impact description:**	**Impact description:**
		Impact description:	**Impact description:**	**Impact description:**	**Impact description:**
		Impact description:	**Impact description:**	**Impact description:**	**Impact description:**
		Impact description:	**Impact description:**	**Impact description:**	**Impact description:**
		Impact description:	**Impact description:**	**Impact description:**	**Impact description:**
		Impact description:	**Impact description:**	**Impact description:**	**Impact description:**

Worksheet 7.3 Multiple Account Evaluation (MAE)

Purpose: Help users integrate resilience considerations into the MAE process

Step 1: Establish failure thresholds.
Use the following table to document failure threshold for each critical vulnerability.

Critical Individual Vulnerabilities (worksheet 7.1)		Hazard Indicator Failure threshold	Notes
Element	Hazard		

Step 2: Calculate probability of exceeding thresholds.
Use the following table to document probability of exceeding thresholds.

Event	Probability of occurring [Time horizon 1]	Probability of occurring [Time horizon 2]	Probability of occurring [Time horizon 3]

Step 3: Calculate probability of failure.
Use the following table to calculate the probability of failure in any given year

Element: ___________

Hazard: _________

Hazard indicator & threshold: ___________

Year	p Annual probability of failure	q Probability of element surviving to year n	k Probability of failure in year n