A Brief Introduction to System Dynamics

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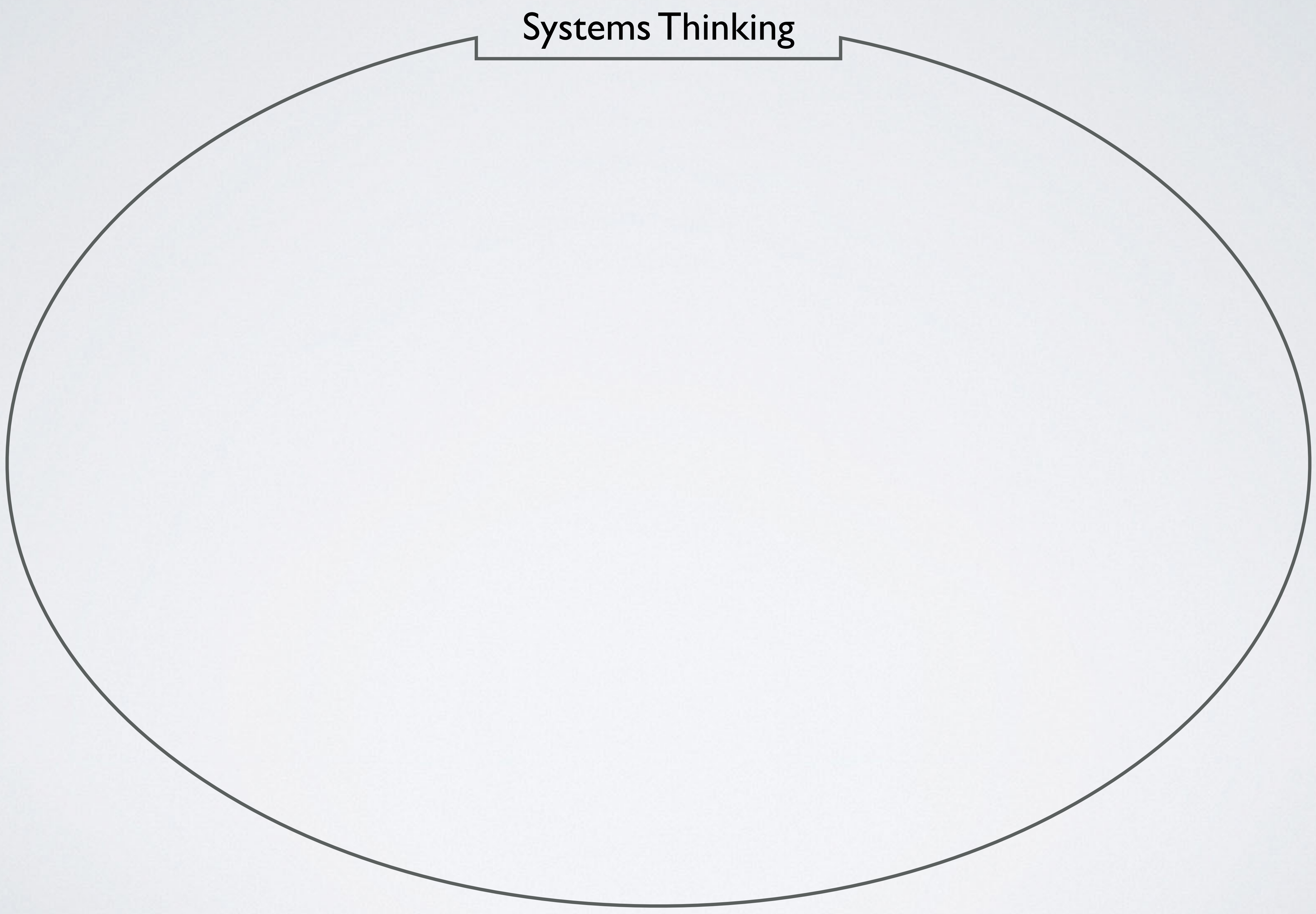
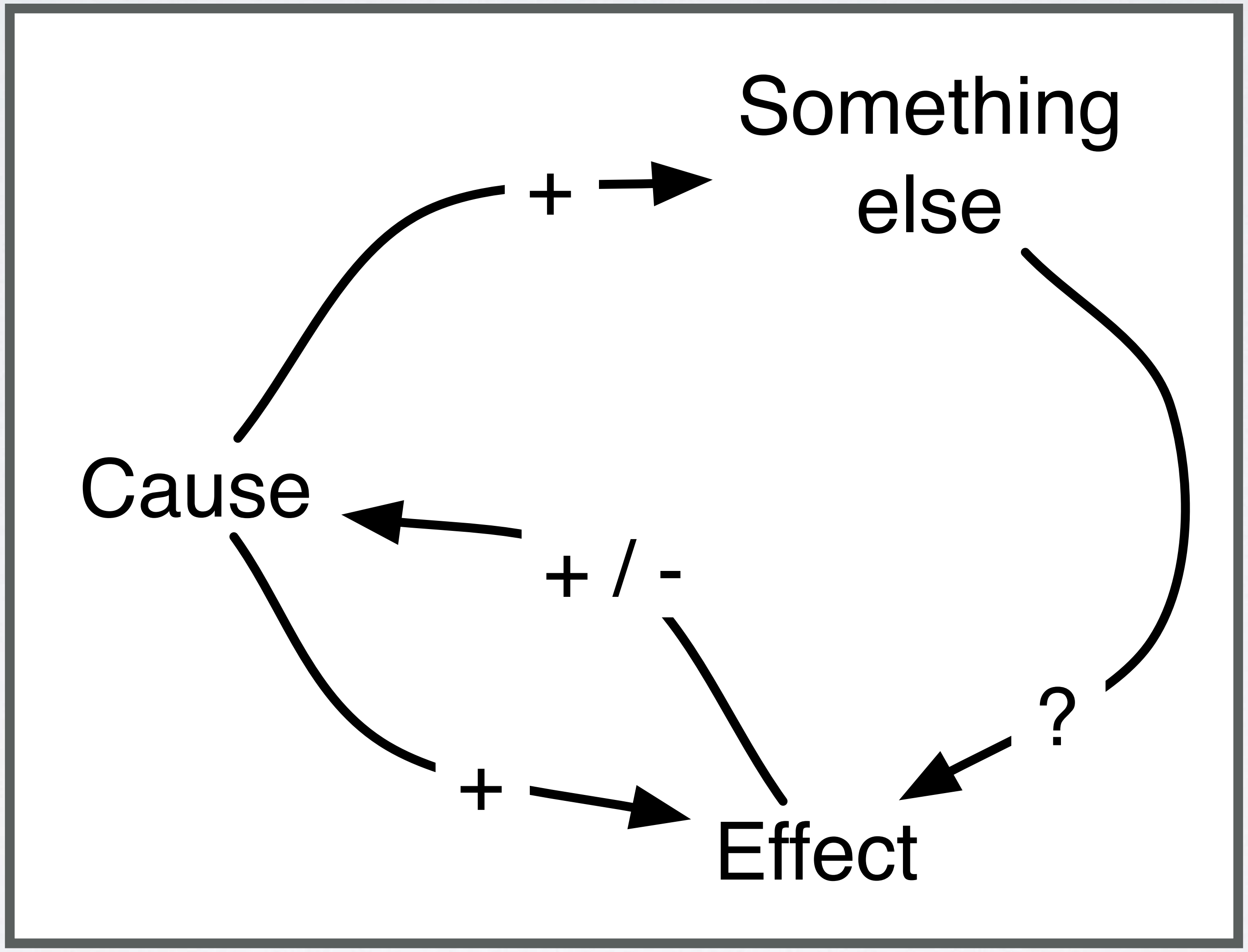
WHAT IS SYSTEM DYNAMICS?



Systems Thinking: The ability to see the world as a complex system, in which we understand that "you can't just do one thing" and that "everything is connected to everything else."



Systems Thinking

System Thinking is the mindset and the philosophy of thinking about whole systems instead of symptoms and event sequences. Inherent in this is the identification of systems of causalities giving rise to events and histories. What is important for System Thinking is the willingness to take an "eagle's view" and the ability to define system boundaries as well as to communicate them.

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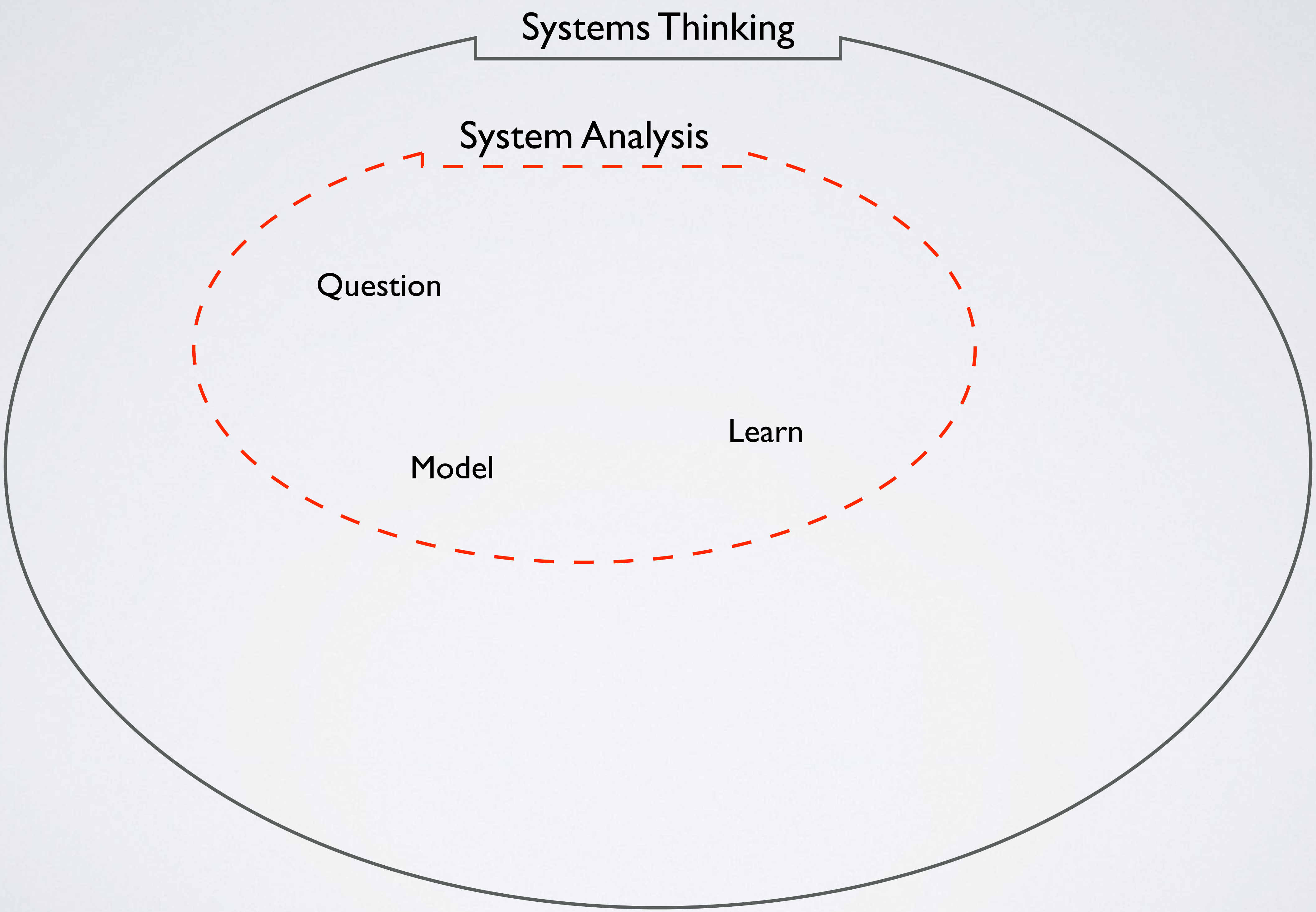

Systems Analysis

System Analysis is the taking apart these systems to understand the causalities, detect and discover their structural arrangement and understand the effects emerging from the flows and accumulations from the causalities acting in the system.

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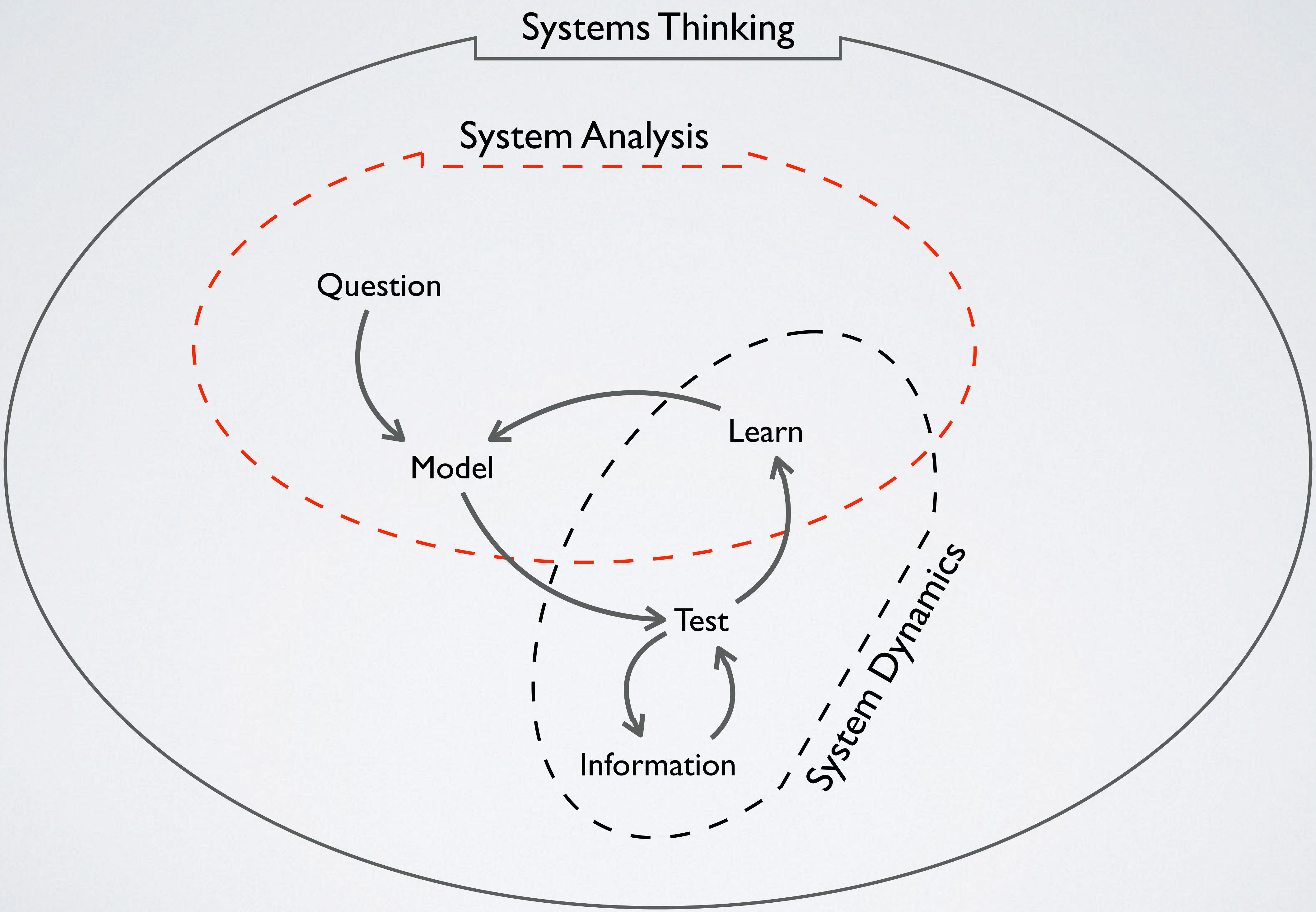

System Dynamics

System Dynamics is the use of the results of System Analysis in order to reconstruct the system of causalities. The use of System Dynamics involves assessing the performance of reproducing the events and histories of the system and to predict future behaviour.

CAUSAL LOOP DIAGRAMS (CLDs)

Causal Loop Diagrams (CLDs) are an important tool for representing causalities and feedback structures of complex systems. CLDs are excellent for:

- Quickly capturing your hypotheses about the causes of dynamics.
- Eliciting and capturing the mental models of individual teams.
- Communicating the important feedbacks you believe are responsible for a problem.

Sterman, J. (2000). *Business dynamics: Systems thinking and modeling for a complex world*. Boston: Irwin/McGraw-Hill.

LINK POLARITIES

Positive Link: All else equal, if X increases (decreases), then Y increases (decreases) above (below) what is would have been. In the case of accumulations X adds to Y. **(Same Relationship)**

Negative Link: All else equal, if X increases (decreases), then Y decreases (increases) below (above) what is would have been. In the case of accumulations X subtracts from Y.
(Opposite Relationship)

Link Polarities describe the structure of the system. The do not describe the behaviour of the variables. That is they describe what would happen if there were a change.

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DELAYS

Delays: Delays are critical in creating dynamics. Delays give systems inertia, can create oscillations, and are often responsible for trade-offs between the short- and long-run effects on policies.

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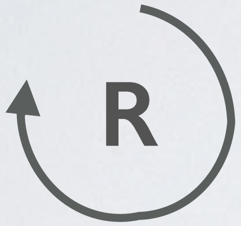
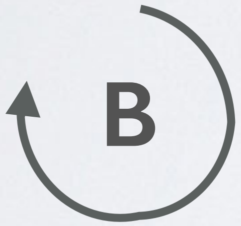
FEEDBACK LOOPS



Positive (Reinforcing) feedback Loops: Positive loops are self-reinforcing, therefore they seek to grow exponentially forever and since no quantity can grow for ever. There must be limits to growth. These limits are created by negative feedback.



Negative (Balancing) feedback Loops: Negative loops are self-correcting. They counteract change.

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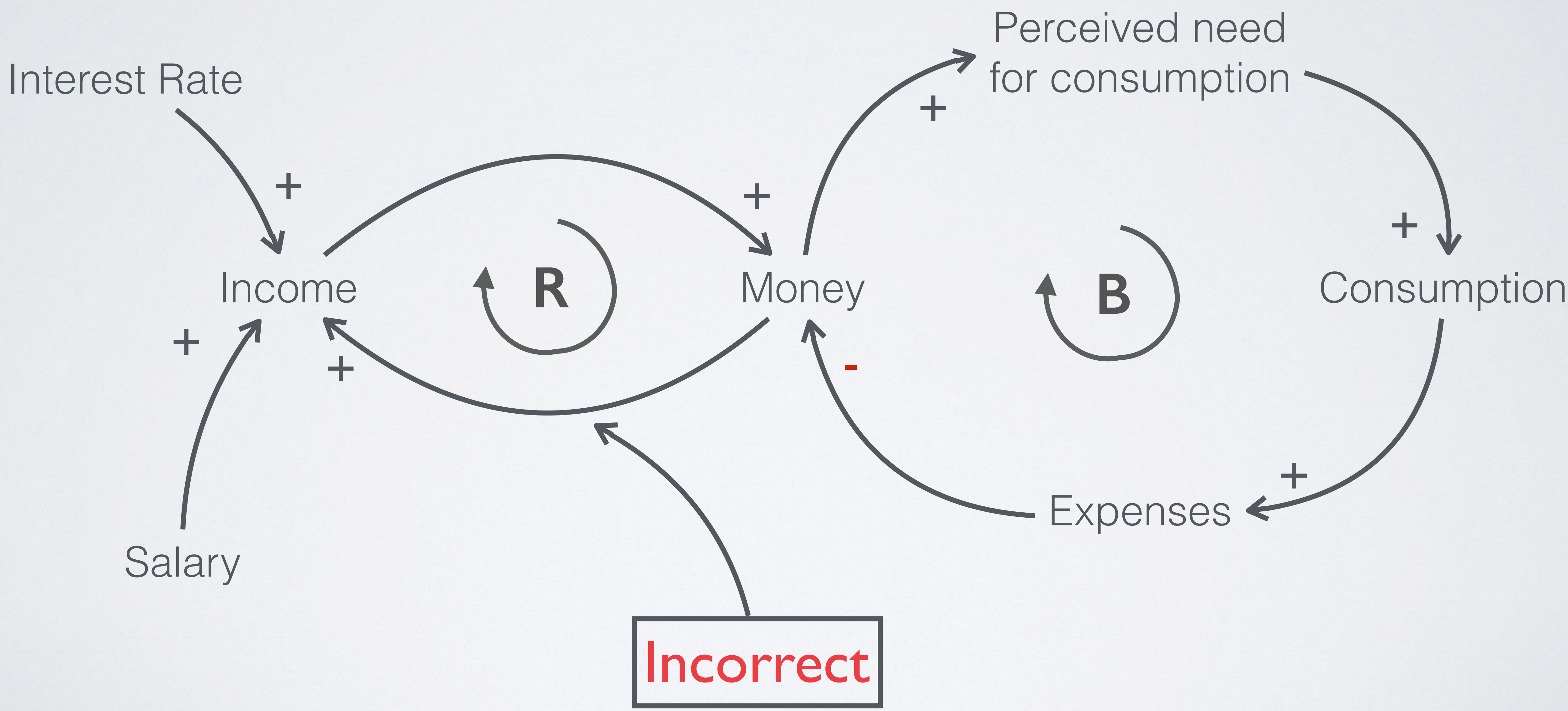
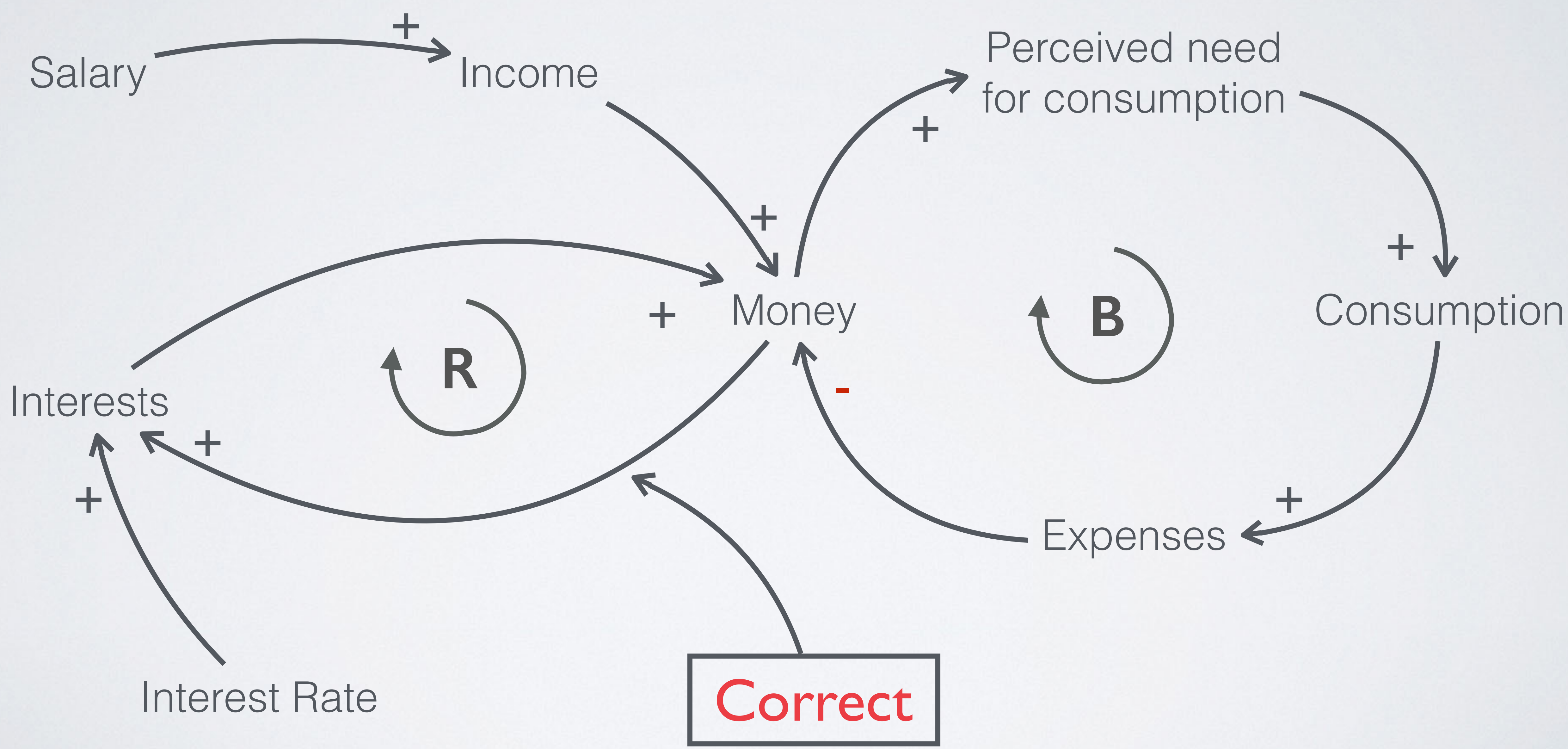
SAMPLE CLD


Perceived need
for consumption
Interest Rate
+
+
+
+
Income
R
Money
B
Consumption
+
+
-
+
Expenses
Salary
Incorrect

SAMPLE CLD


Salary
+
Income
+
Perceived need
for consumption
+
Money
+
+
Consumption
R
B
Interests
+
+
-
+
Expenses
Interest Rate
Correct

STOCK AND FLOW DIAGRAMS (SFDs)

Stocks and flows, along with feedback, are the two central concepts of dynamic system theory.

- Stocks are accumulations, of anything you can count.
- Stocks give systems inertia and provide them with memory.
- Stocks create delays by accumulating the difference between inflow and outflow.

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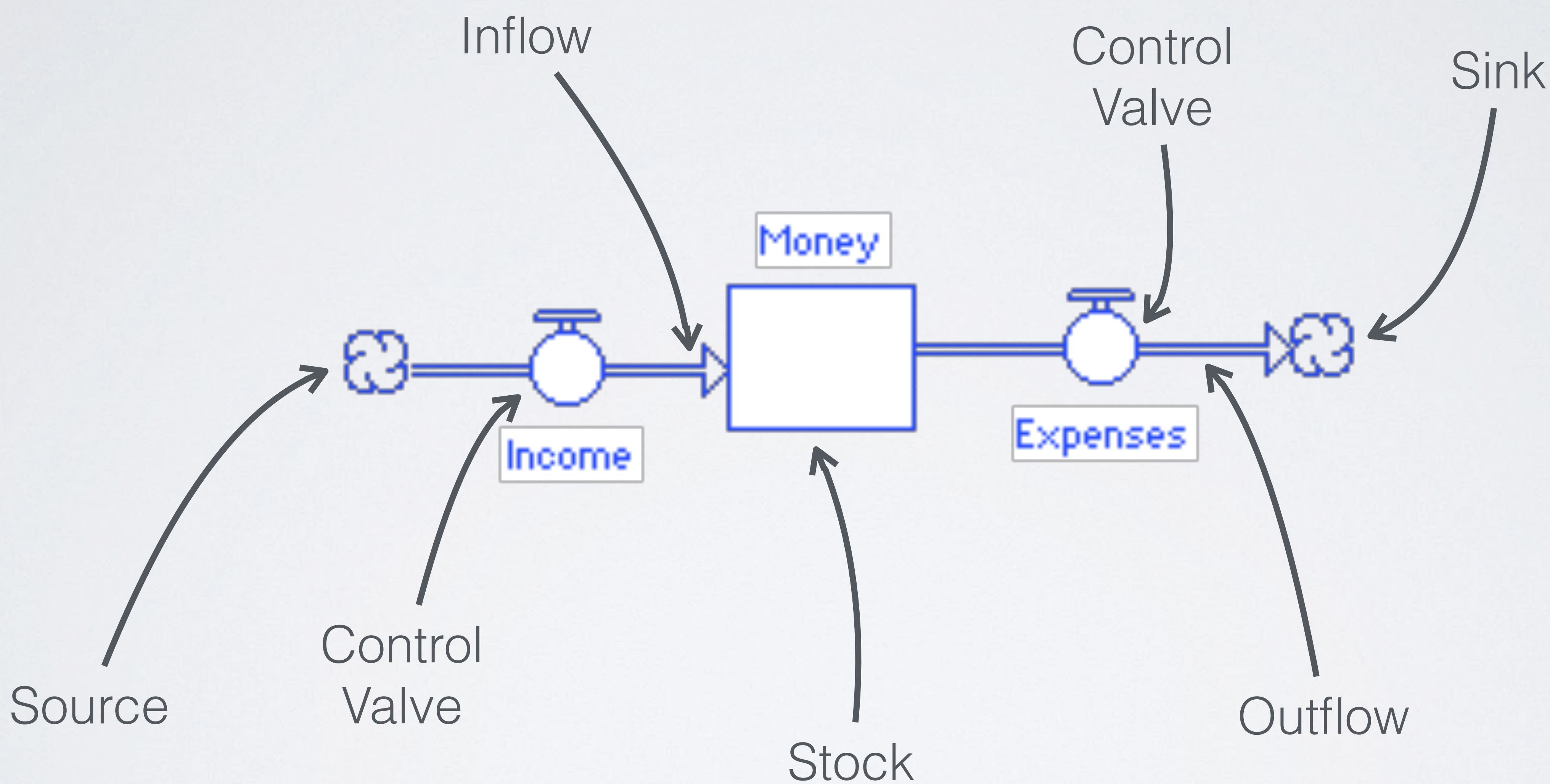
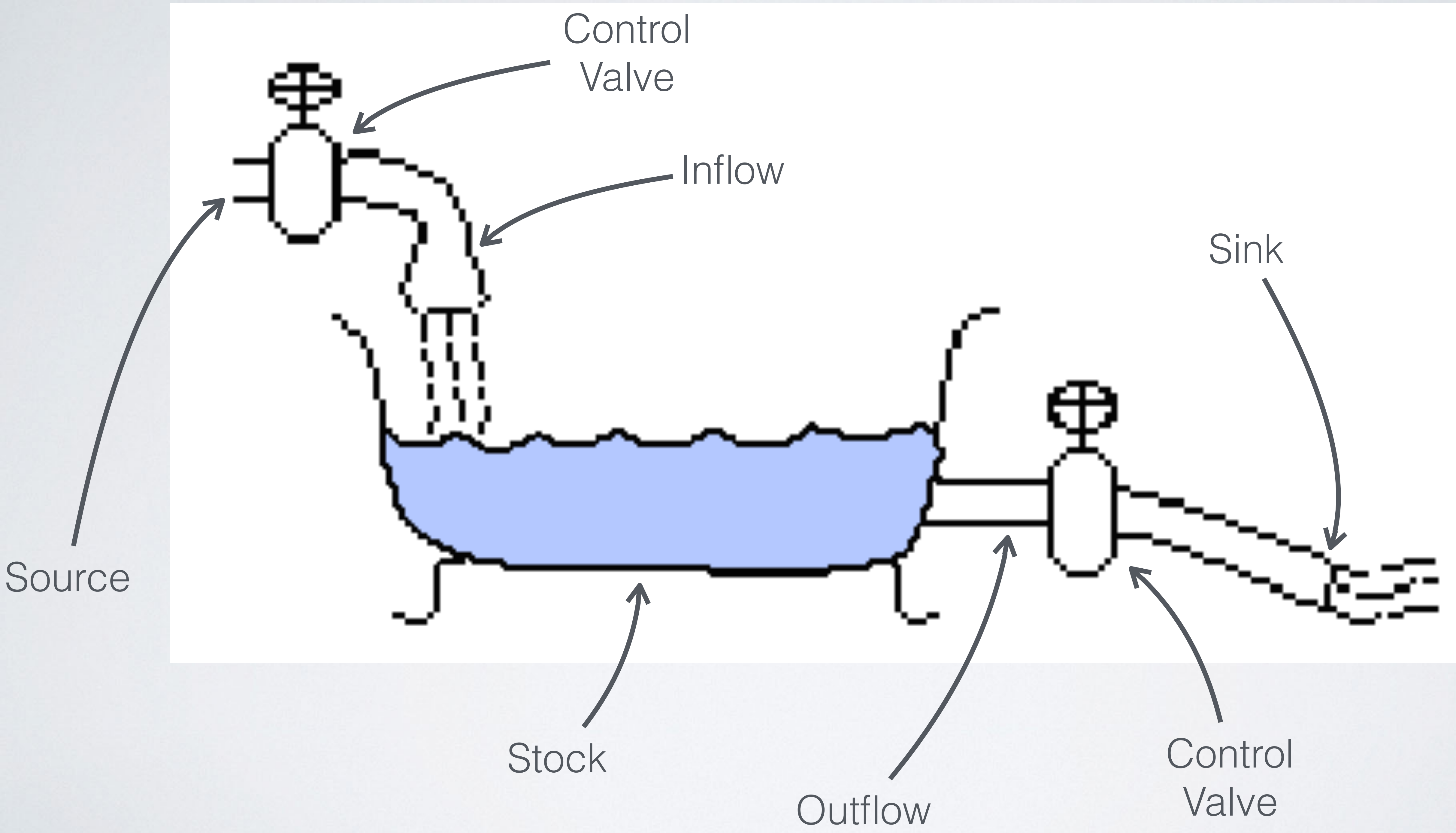
SAMPLE SFD



Inflow
Control Valve
Sink
Money
Income
Expenses
Source
Control Valve
Stock
Outflow

SFD "BATHTUB" EXAMPLE



GROUP SYSTEM ANALYSIS

When dealing with complex systems, no single person has the complete view of the system, that is why system analysis is often performed in groups and is called group system analysis or group modelling. In group system analysis, participants formulate mental models with the help of Causal Loop Diagrams (CLD) over a series workshops. The process is divided into three Steps.

Definition → **Clarification** → **Confirmation**

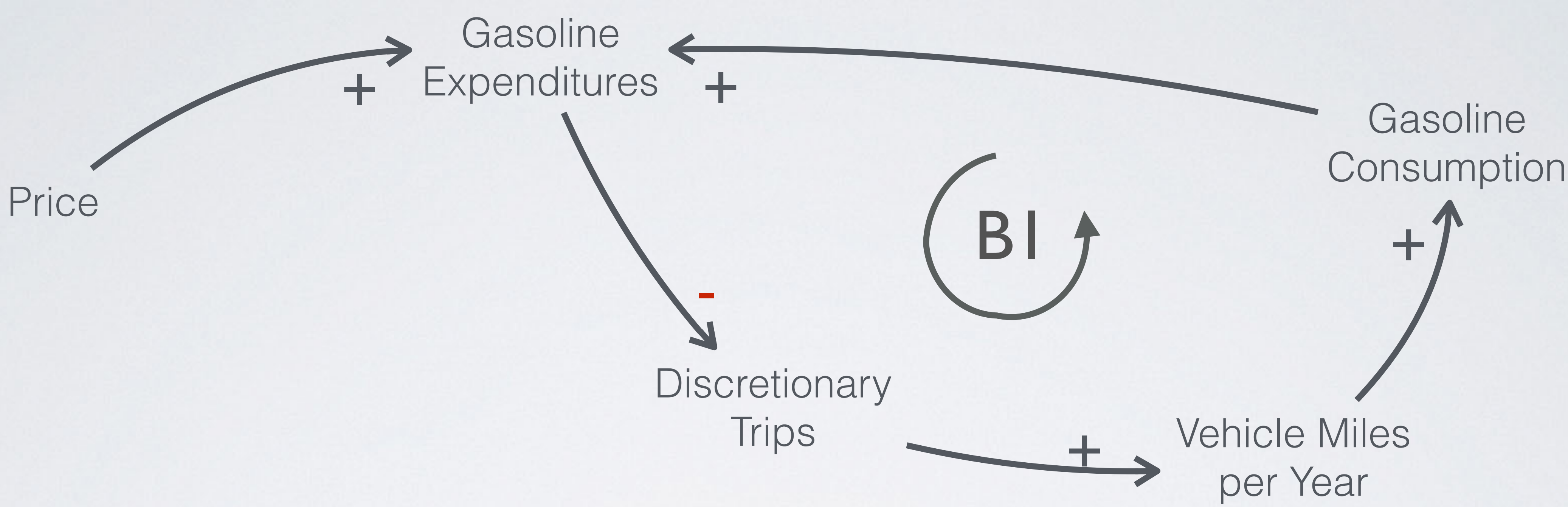
Definition	Clarification	Confirmation
Problem Boundaries Brainstorming Deliverables CLDs	Redefinition Brainstorming Conclusion CLDs SFDs	Final CLD Final SFD Model Tested Results

GROUP SYSTEM ANALYSIS

Definition	Brainstorming on key variables and system boundary and then make the first attempt at the causal loop diagram.
Clarification	Exchange knowledge to allow better understanding of the system and then build on the CLD from the definition step by causally structuring key variables together.
Confirmation	Gather all the information, (CLDs, SFDs and sketches) generated in the clarification step and combine and iterate it into a final version of the CLD that is within the system boundary and is accepted by all participants.

After the last workshop a system dynamic model based on the final version of CLD can be developed. However the CLD on its own can be used as an decision support tool for formulating policies and decisions.

GASOLINE DEMAND AND EXPENDITURES



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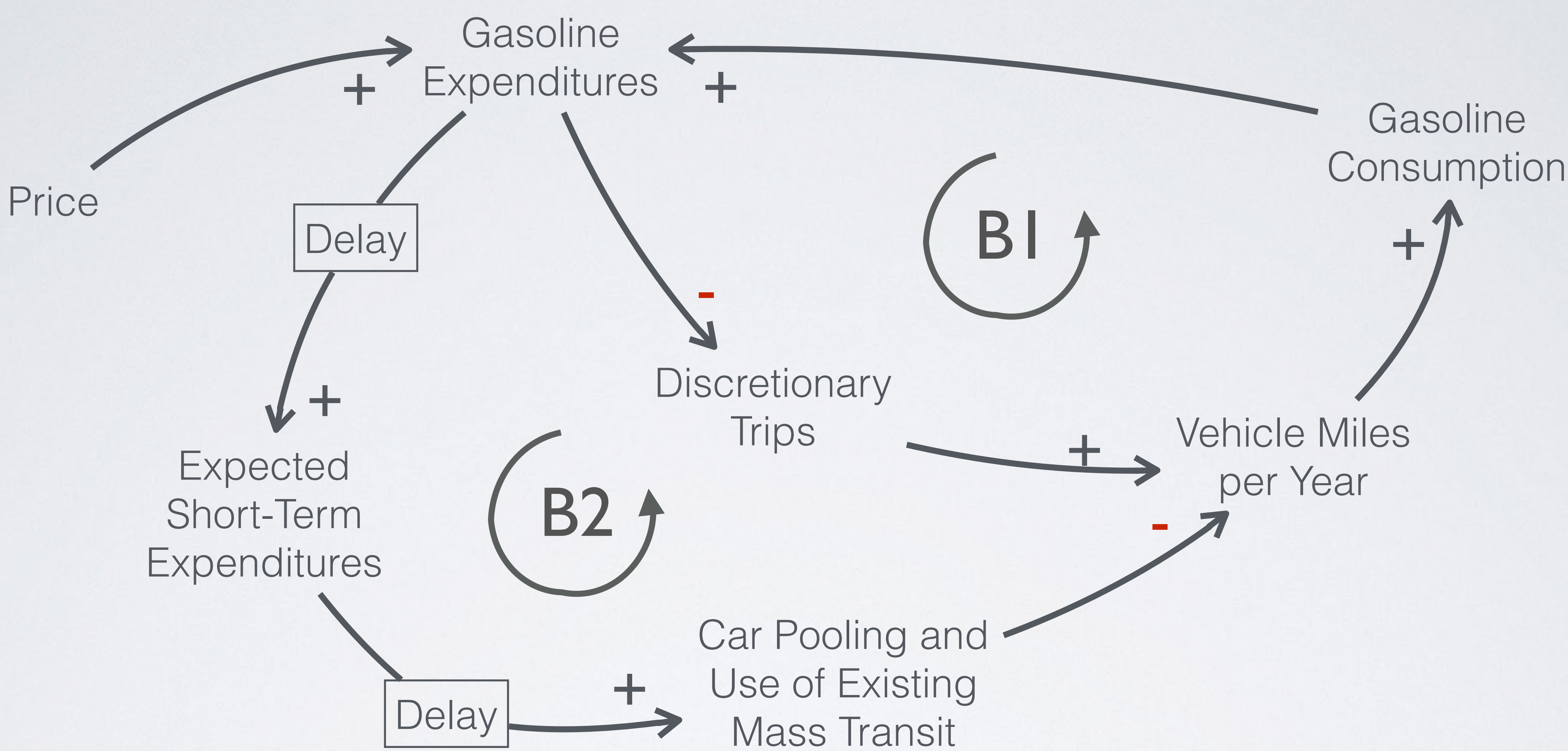

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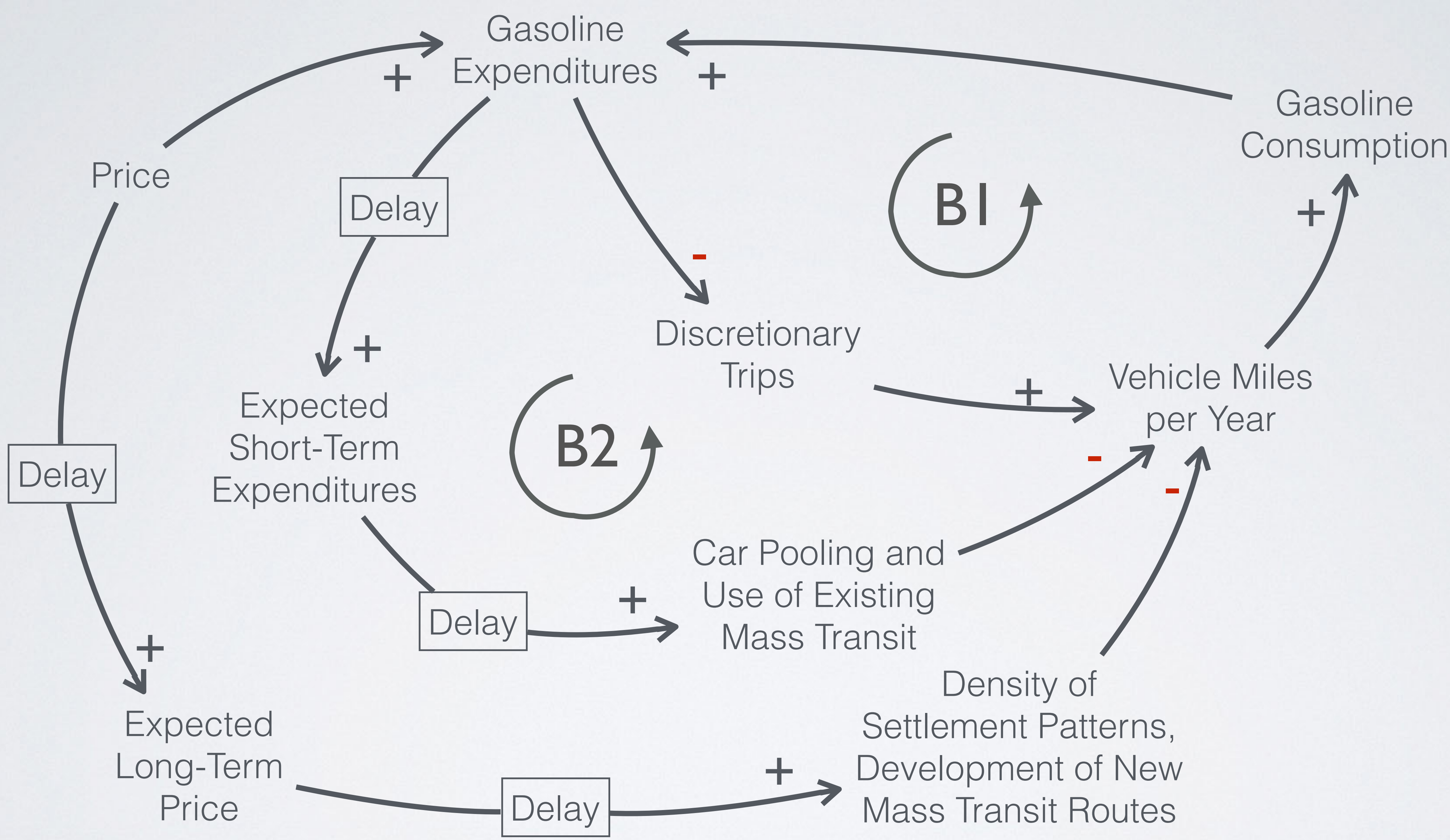
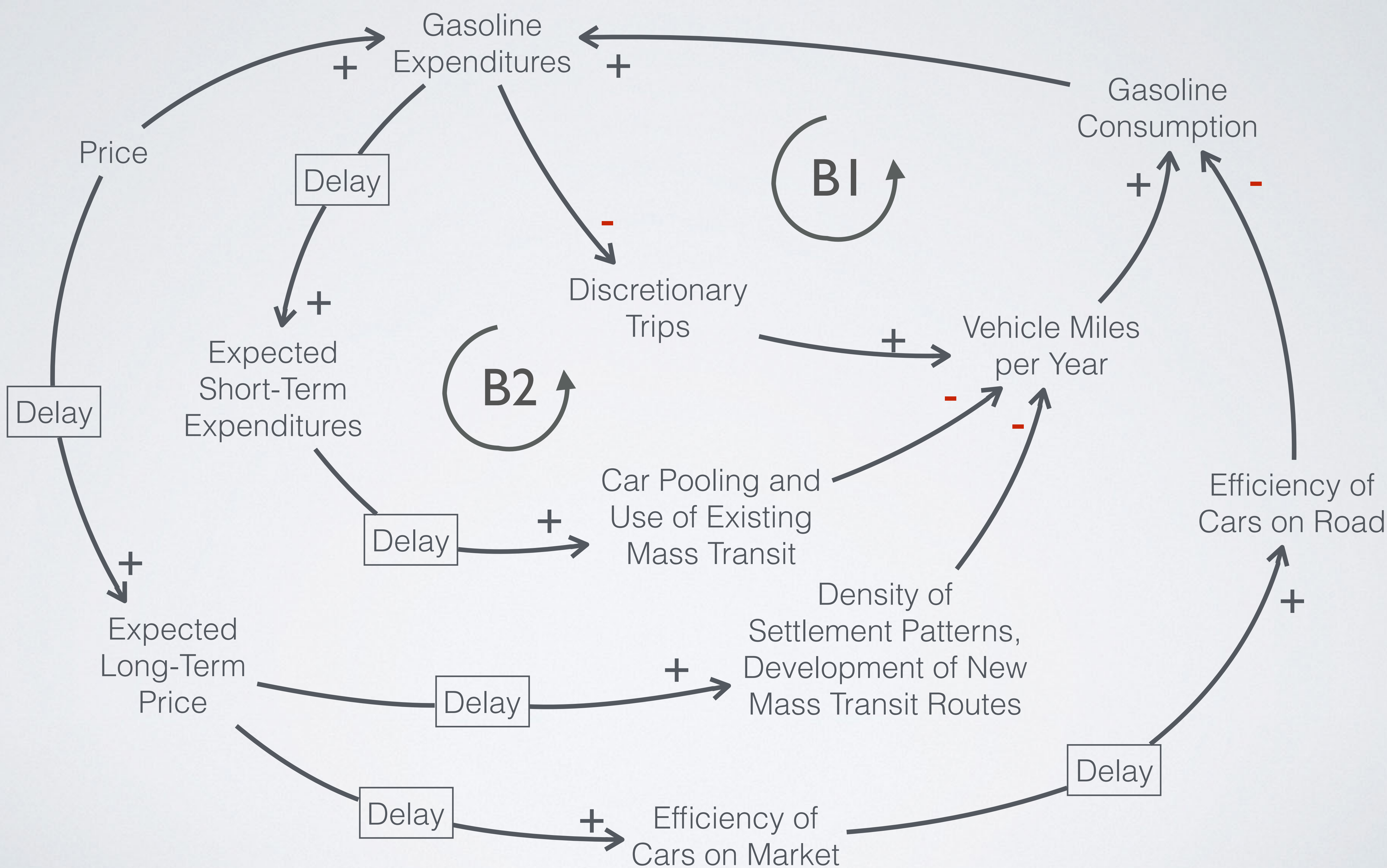


GASOLINE DEMAND AND EXPENDITURES



CAUSATION VERSUS CORRELATION

A system dynamics model must capture the causal structure of the real system well enough that the model behaves the same way the real system would.

A statistical model uses correlations among variables to reflect the past behaviour of the system, but past correlations are not necessary valid in the future. Correlations of parameters do not represent the structure of the system.

A model that can explain and recreate the past, has a better predictability for the future.

What we mean is that with causal structure the model can be better explained for example, there can be a correlation between two events though they are not causally connected.