GST 84 — Causal Chains and Networks

Formal Description

Individual causal relationships concatenate into causal chains and networks. A causal chain is a sequence of causally connected causes and effects in which an effect may subsequently become a cause of a further effect. A causal network is a broader interconnected organisation of processes and transfers in which causal pathways may branch, converge and interact.

Linear causal chains are therefore special cases within wider causal networks. One process may produce transfers contributing to several subsequent processes, creating branching causality, while several causal pathways may converge upon a single recipient process. The convergence of pathways is particularly important where an effect depends upon several necessary or enabling causal contributions of the kind considered in the previous module.

Causal relationships may also be direct or indirect. A direct causal relationship involves a relatively immediate causal pathway between the phenomena under consideration. An indirect relationship operates through one or more intermediate processes and transfers. As the number of intermediate interactions increases, additional opportunities arise for the pathway to be enabled, inhibited, redirected or interrupted.

The boundaries of a causal network are partly determined by the purpose of an investigation. A causal pathway may extend far beyond the portion presently being examined, and the same causal reality can be represented at different levels of granularity. A broad representation may compress many processes and transfers into a few apparent causal relationships, while a more detailed representation may decompress them where greater causal understanding is required.

Causal networks should therefore be understood as physically connected organisations extending through space and time, while particular diagrams or explanations are epistemic representations of selected portions of those networks.

Plain English Explanation

When we say:

A → B

we focus upon one causal relationship. In a previous module we saw that B may subsequently become a cause of C:

A → B → C

We now need to go further, because most causality is not simply a chain.

Imagine heavy rainfall over a town. Some rainfall may infiltrate into the ground, some may become surface runoff, some may enter drains and some may fall directly into a river. Those pathways can subsequently interact. Surface runoff may enter both the drainage network and the river. Groundwater may contribute to river flow. Drainage may become restricted when river levels are high. The resulting causal organisation begins to look much more like a network than a chain.

Causal networks can branch:

one causal contribution → several subsequent effects

and converge:

several causal contributions → one recipient process or effect.

Branching matters because a single event can have several consequences. Convergence matters because an effect that appears to have one cause may actually depend upon several causal pathways arriving together.

Networks also contain indirect causality. Heavy rainfall may contribute to property damage, but the rainfall does not need to act directly upon the property. Its causal influence may propagate through runoff, river flow, rising water levels and flooding before water reaches the building.

Each additional stage matters. If the causal pathway contains several intermediate processes, there may be several places where it can be changed. Runoff might be stored, drainage improved, river flow diverted or property protected. A longer causal pathway can therefore provide more opportunities for intervention.

There is another important issue: where should the network stop?

There is no requirement to represent the whole causal history of an event. If we are investigating flooding, we might begin with rainfall. We could trace the causes of the rainfall backwards into atmospheric processes, but that may add nothing useful to our investigation.

Similarly, we could represent:

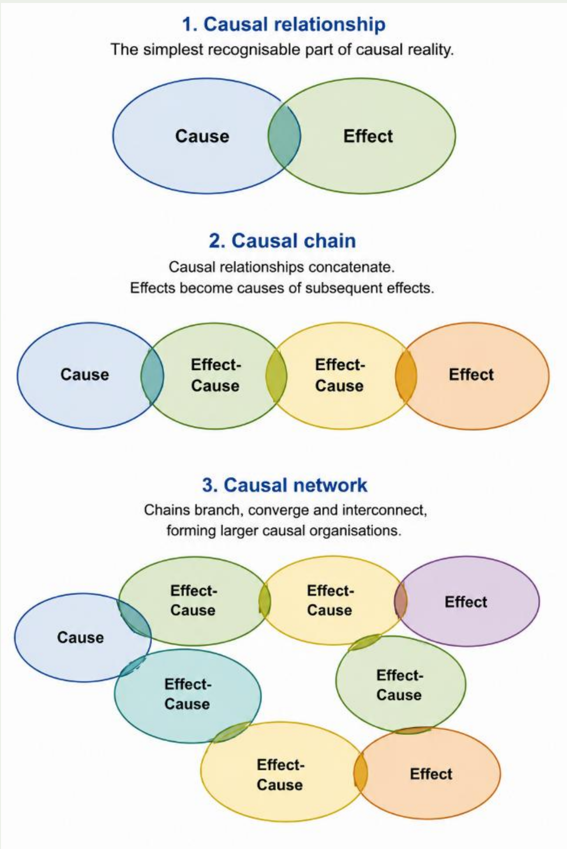
Heavy rainfall → flooding

or decompress the same relationship into:

Heavy rainfall → infiltration and runoff → drainage and river flows → rising water levels → overtopping → flooding

Neither representation is automatically correct or incorrect. The appropriate level of detail depends upon what we are trying to understand or do.

Causal investigation therefore involves choosing useful boundaries and granularity while remembering that the underlying causal reality extends beyond our representation.



Examples

A road collision can initially be represented as a simple sequence:

Driver brakes → vehicle slows

But decompression may reveal several causal pathways. The driver's perception of a hazard contributes to braking behaviour; braking produces mechanical interactions within the vehicle; tyre-road interactions contribute to deceleration; road surface conditions affect available friction. Several pathways converge upon the eventual movement of the vehicle.

Branching occurs after the collision as well. The same collision might damage the vehicles, injure occupants, obstruct the road and trigger an emergency response. One causal episode therefore contributes to several subsequent pathways.

Disease transmission provides another example of branching. One infectious individual may transmit an infection to several others, each of whom may subsequently initiate further causal pathways. Conversely, the development of illness within one individual may depend upon several converging contributions involving exposure, susceptibility and physiological processes.

A blocked road illustrates indirect causality. A road closure may divert traffic onto alternative routes. The additional traffic may then cause congestion on another road some distance away. The road closure has not directly caused vehicles on the distant road to slow down; its causal influence has passed through several intermediate processes, including traffic diversion and increased traffic flow. The road closure and distant congestion are therefore indirectly causally connected.

These examples illustrate why searching for a single “root cause” can sometimes be misleading. A causal network may contain multiple antecedent pathways, and the appropriate causal explanation depends upon the purpose and granularity of the investigation.

Provenance and Links

The representation of causality as interconnected rather than simply linear has important antecedents across several disciplines. Sewall Wright's path analysis provided an early formal means of representing multiple causal relationships, while later graphical approaches to causal inference, particularly those associated with Judea Pearl, developed causal diagrams in which branching, convergence, indirect relationships and common causes can be explicitly represented.

The idea that complex phenomena should be understood through networks of interacting causal mechanisms is also consistent with the mechanistic approach to scientific explanation, including the work of Machamer, Darden and Craver. Such approaches direct attention beyond observed associations towards the organisation through which effects are produced.

The treatment developed in these course modules emphasises the physical continuity of the network through processes and transfers while distinguishing that ontological network from the boundaries and granularity of its epistemic representation. A statement such as “heavy rainfall caused flooding” can therefore be understood as a compressed representation of a physically connected network rather than as an alternative to one.

This treatment prepares the way for the next module, where the same underlying causal organisation will be represented from two complementary perspectives: Process–Transfer–Process (PTP) and Transfer–Process–Transfer (TPT).

Practical Exercise

Continue your investigation of the town experiencing local flooding after heavy rainfall. In previous modules you identified several causal contributions that might be necessary, enabling or inhibiting in relation to property flooding. You will now begin combining these into a causal network.

Start with the compressed sequence:

Heavy rainfall → surface runoff → increased river flow → rising water level → flooding → property damage

Do not discard this sequence, but treat it as the main pathway through your developing causal network.

Now identify at least two places where the pathway could branch. For example, not all rainfall need become surface runoff. Consider where else the water might go and what other effects might result. Add these pathways to your representation.

Next identify at least one point of convergence. Consider whether rising river levels or property flooding could depend upon several causal contributions arriving through different pathways.

Incorporate some of the necessary, enabling or inhibiting contributions you identified peviously.

Now choose the relationship:

Heavy rainfall → property flooding

Identify the intermediate causal pathway through which the rainfall contributes to the flooding.

Decide whether you would describe rainfall as a direct or indirect cause of the property flooding and explain your reasoning.

Look along the resulting indirect pathway and identify places where the causal sequence could potentially be interrupted, inhibited or redirected. Do not yet decide which would be the best intervention. Simply recognise that intermediate causal interactions create possible intervention opportunities.

Next consider the boundary of your investigation. Decide where your causal representation should begin. You might begin with heavy rainfall, but you could extend the network backwards to the atmospheric processes producing the rainfall. Explain why including or excluding those earlier causes would be appropriate for an investigation concerned with reducing local flood damage.

Do the same at the other end of the network. Decide whether your investigation should terminate when water enters the property or extend onwards to damage to contents, disruption to occupants, insurance claims and other consequences.

Finally, examine the granularity of your representation. Choose one arrow that currently connects two phenomena and ask whether it conceals intermediate processes and transfers. Decompress that relationship by one additional level of detail.

You should now have something noticeably different from the simple causal sequence with which the exercise began: a bounded representation of part of a causal network containing branching, convergence and indirect causal pathways at a level of detail chosen for a particular purpose.

Keep this network for the next exercise. In the next module, PTP, TPT and Causal Duality, you will examine portions of the same causal reality from two complementary perspectives: one foregrounding causal interactions between processes and the other foregrounding systems transforming inputs into outputs.