Quantifiable nodes in causal diagrams

Anastássios Perdicoúlis

Assistant Professor, ECT, UTAD (http://www.tasso.utad.pt)
Senior Researcher, CITTA, FEUP (http://www.fe.up.pt/~tasso)
Visiting Researcher, Oxford Institute for Sustainable Development, OBU, UK

Abstract

The quantifiable nodes of causal diagrams (e.g. RBP, DCD) — whether *indicators* with directly-obtained values or *indices* with calculated values — are dynamically related to represent a complex *holon*, so their appropriate handling requires both scientific rigour and understanding.

1 Introduction

Purely conceptual causal diagrams such as the reverse blueprints (RBP) of Systems Planning℠ (Perdicoúlis, 2010) and the causal loop diagrams (CLD) of System Dynamics (Sterman, 2000) feature nodes that are *quantifiable* — i.e. able to be expressed as quantities. The grammatical class of these nodes is *nouns* (e.g. population, satisfaction) or *noun phrases* (e.g. local population, client satisfaction), and expressions in their *positive* version (e.g. happiness instead of unhappiness) facilitate reasoning and the identification of feedback loop polarity (Sterman, 2000, p.153).

Specialised causal diagrams such as the descriptive causal diagrams (DCD) of Systems Planning℠ and the stock-and-flow diagrams (SFD) of System Dynamics include nodes similar to those of the conceptual diagrams, tailored to their particular needs — for instance, DCDs feature double-tier action ('X') nodes with *identifiable* but not necessarily *quantifiable* application points (§ 3.2) (Perdicoúlis, 2014b); SFDs distinguish the quantifiable nodes that are *stocks* (e.g. population) or *flows* (e.g. births per year) (Sterman, 2000, Ch.6).

Appropriate handling of the individual node values, relationships between nodes, as well as the *holon* they collectively represent (e.g. system, plan) requires (a) *scientific rigour* (e.g. precision, accuracy) regarding the language and calculations and (b) *understanding*, which is conditioned by rigour — Figure 1.
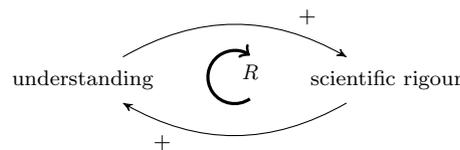

FIGURE 1 Rigour and understanding depend on each other

2 Node values

2.1 Direct obtention vs. calculation — indicators vs. indices

Numerical values for the quantifiable nodes are obtained either (a) *directly* through measurement, count, or estimate (Perdicoúlis, 2014c), in which case they are known as *indicators*, or (b) *by calculation*, in which case they are known as *indices*[1] (Perdicoúlis and Glasson, 2011). Hence, the identification of *sources* (e.g. databases, publications, experts) and *methodology* (e.g. measurement, setup) are crucial for working with indicators, while the definition of *computational relationships* (i.e. equations) is essential for working with indices.

Causal relationships in diagrams indicate *but do not guarantee* whether the value of a quantifiable node is obtained directly or calculated. Computational relationships expressed in equations also indicate the inputs for nodes, but such relationships are not intended to be causal — e.g. Figure 2.
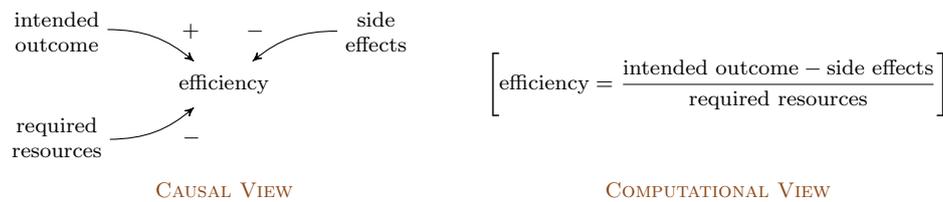

FIGURE 2   Basic definition of efficiency in a technical perspective (Perdicoúlis, 2014a)

2.2 Estimation

When direct obtention of indicator values (§ 2.1) is not possible, they may be *estimated* by experience[2] (Perdicoúlis, 2014c) so that the related indices may be calculated — Figure 3. Estimation may also be applied directly to the indices (e.g. efficiency), bypassing their decomposition into indicators (e.g. outcome, resources) and thus providing a 'global' empirical value that cannot be verified.
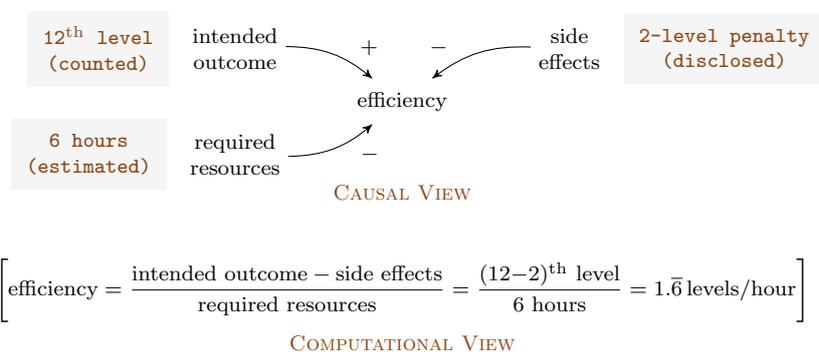

FIGURE 3   Calculation of efficiency by a particular set of data

---

[1] Variations across time, space, and cultures (e.g. disciplinary conventions) is to be expected (Perdicoúlis, 2014d)
[2] Εμπειρία [Gk]

3 Expression

3.1 Relative values

Conceptual causal diagrams such as RBP and CLD are essentially 'reasoning exercises' about causal relationships and operate with *relative* values — for instance: *ceteris paribus*[3], *if 'factor A' increases, then 'ranking' increases; if 'factor A' decreases, then 'ranking' decreases*. Nonetheless, the mark-up of quantities next to selected nodes (e.g. Figure 4) or value charts placed by the diagram (Sterman, 2000, e.g. p.151) function as 'quick references' or *aides-memoir* (Perdicoúlis, 2014b).
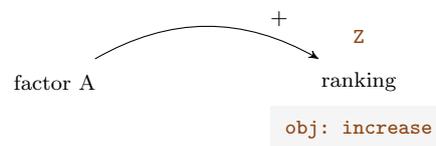

FIGURE 4   Relative value next to a selected RBP node, marking an objective (Z)

3.2 Absolute values — abstract vs. concrete

For specialised causal diagrams such as DCDs, the definition of the problem in 'XYZ' mark-up requires realistic 'absolute' node values and relationships (Perdicoúlis, 2014b). The nature of the DCD elements calls for differential *precision* — for instance, the declaration of the high-level concerns (Y) can be expressed in *abstract* terms (e.g. 'strength'), while the concrete objective (Z) is conveniently defined in *specific* terms (e.g. '12-gauge') — Figure 5.
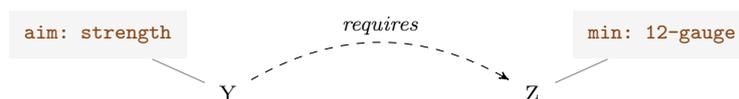

FIGURE 5   DCD node mark-up with appropriate values: *abstract* for Y and *specific* for Z

3.3 Annotation techniques

Adding values or other annotations to the nodes can be achieved with framed or plain *labels* (Figure 4) and alternatively with *pins* (Figure 5). A third alternative are *compound nodes*, which are most suitable for *intrinsic* node properties such as measurement units or data sources (Perdicoúlis, 2014b) — Figure 6.
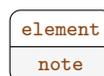

FIGURE 6   Sample compound node

---

[3] This condition indicates that the change takes place *besides* 'what it would have been' (Sterman, 2000, p.152), in the same sense as an 'impact' (Perdicoúlis, 2015)

4 Operations

4.1 Aggregation — generalisation/ abstraction

Indicator (and even index) nodes can be *aggregated* into indices — e.g. various objectives (Z) into a concern (Y), as illustrated in the complementary views of Figure 7. This operation is typically encountered in reverse blueprints (RBP).
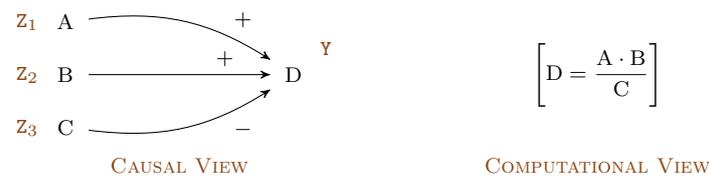
$$\left[D = \frac{A \cdot B}{C} \right]$$

CAUSAL VIEW   COMPUTATIONAL VIEW

FIGURE 7   Aggregation of system elements (A–C) into a more 'inclusive' element (D)

4.2 Specification — decomposition/ resolution

The reverse operation is also possible, albeit limited to descriptive causal diagrams (DCD): indices such as concerns (Y) or complex objectives (Z) can be *explicated*, *analysed*, *decomposed*, or *specified* through *logical causality* into subsequent levels of detail, as deemed necessary — Figure 8.
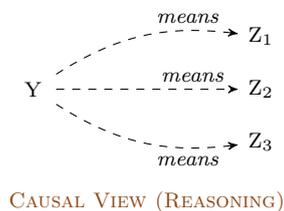
CAUSAL VIEW (REASONING)

FIGURE 8   Specification of a general or abstract concern (Y) into objectives (Z_1–Z_3)

4.3 Importance

Indices manage to synthesise sizeable portions of reality, which is convenient when a 'zoom out' or aggregated view is desirable — for instance, a patient's overall health or the global efficiency of an operation. Despite its aggregation quality, though, an index is not necessarily more important than its parts — for instance, equal efficiency values may hide 'top results' among inferior outcomes, as illustrated in Figure 9.

$$\left[\text{efficiency} = \frac{8^{\text{th}} \text{ level}}{4 \text{ hours}} = \overbrace{\frac{12^{\text{th}} \text{ level}}{6 \text{ hours}}}^{\textit{top result}} = \frac{10^{\text{th}} \text{ level}}{5 \text{ hours}} = 2 \text{ levels/hour} \right]$$

COMPUTATIONAL VIEW

FIGURE 9   Equal efficiency with different actual outcomes

5   Discussion

Diagrammatic, textual, and mathematical languages must cater to the scientific rigour required for working with quantifiable nodes in causal diagrams — for instance, the obtention of their *values* (§ 2) regarding measurement, calculation, or estimate, the *expression* of these values (§ 3) as relative or absolute figures, and then in an abstract or concrete form, as well as basic *operations* (§ 4) such as aggregation and specification.

Keeping a selected set of nodes and relationships in perspective is a balancing act and helps to visualise and understand the structure and function of systems and/ or plans. On the other hand, calculating 'final' index values is quite popular, but 'terminal' practice when these values cannot be decomposed to track causality. The most interesting and constructive challenges arise from bringing the two views together, as any discrepancy between causal and computational views must be resolved.

6   Conclusion

Quantifiable nodes in causal diagrams work with indices and indicators, raising scientific and cognitive issues related to measurement, reporting, and operations. Parallel causal and computational views help to seek, question, and understand structure and function, as well as to select the most important nodes together with their relationships.

References

Perdicoúlis, A. (2015) *Impacts.* Perdicoulis Publishing: Folio Division, Technical Collection.

Perdicoúlis, A. (2014d) *Terminology.* Perdicoulis Publishing: Folio Division, Technical Collection.

Perdicoúlis, A. (2014c) *Science.* Perdicoulis Publishing: Folio Division, Technical Collection.

Perdicoúlis, A. (2014b) *Language.* Perdicoulis Publishing: Folio Division, Technical Collection.

Perdicoúlis, A. (2014a) *Cause.* Perdicoulis Publishing: Folio Division, Technical Collection.

Perdicoúlis A. (2010) *Systems Thinking and Decision Making in Urban and Environmental Planning.* Cheltenham: Edward Elgar.

Perdicoulis, A., and J. Glasson (2011) The use of indicators in planning — effectiveness and risks. *Planning Practice & Research*, **26**(3):349–367.

Sterman J.D. (2000) *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: Irwin McGraw–Hill.