An Interpretive Approach to Drawing Causal Loop Diagrams

Mostafa Jafari [a] jafari@iust.ac.ir
Roozbeh Hesam Amiri [b, *] amiri_r@ind.iust.ac.ir
Atieh Bourouni [c] bourouni@ind.iust.ac.ir

[a, b, c] *Department of Industrial Engineering, Iran University of Science and Technology (IUST), Narmak, Tehran, Iran*

Abstract

Causal loop diagram largely influences the effectiveness of system dynamics. The complex interpretive nature of management problems makes it difficult to recognize all the existing causal loop relations. In order to build system dynamics models for ill-defined problems, "Group Model-Building" is developed. As discussed by Vennix, one source of these messy situations is different perceptions of individuals. In this paper, we develop an interpretive approach to drawing causal loop diagrams assuming that there are different perceptions about same concepts and the analyst is closely engaged with finding most agreed causal relationships.

Keywords: *causal loop diagram; system dynamics; interpretive approach; group model building; soft system dynamics; Decision Making Trial and Evaluation Laboratory (DEMATEL)*

I. Introduction

In many complicated problem situations, determining causal relationships is a very complex process because in every organization managing means interpreting and reacting to interacting event and ideas of the real world (Checkland, 2001). From this point of view, there is no unique definition of problem, but each individual has his own perspective in defining and interpreting a problem situation (Lane and Oliva, 1998). The difference is between hard and soft systems thinking. The hard point of view of systems has an "objectivist" that consider problems as independent of individual's point of views and interpretation. The soft systems thinking has a "subjective" that take into consider the importance of participant's perception (Rosenhead and Mingers, 2001).

According to Vennix (1999) one of the individual sources of messy problems is "perception and reality construction". When working with teams, one's perception is affected by his professional background or position in organization.

Group model building is discussed by Vennix et al. (1990, 1992, 1993, 1997), Vennix (1995, 1996), Luna-Reyes et al. (2006), Andersen et al. (1997a , 1997b), Rouwette et al. (2002) and Visser (2007).

The organization of the paper is as follows: in the second section, interpretive systems thinking and practice is presented. In the third section, different types of problems in management science are discussed in order to show the importance of interpretive approaches and group model building methods. In the forth to sixth section, three steps of an interpretive approach to drawing causal loop diagrams are depicted.

[*] Corresponding author. Tel.: +98 912 5356487.

II. Interactive systems thinking and practice

The interpretive systems approach is frequently referred to as “soft systems thinking” because it gives pride of place to people rather than to technology, structure or organization. In contrast to the functionalist approach, its primary area of concern is perceptions, values, beliefs and interests. It accepts that multiple perceptions of reality exist, and sometimes come into conflict, and wants to help managers and consultants to work successfully in a ”pluralistic” environment of this kind.

Interpretive approaches do not assume that organizations are just ‘‘human machines’’ in which people are organized according to their functions, all of which are, geared to some unitary objective. Instead, they assume that people may, rightly or wrongly, fight their own corner rather than be subsumes into some overarching objective. Thus these approaches make different assumptions about the nature of organizations. Soft approaches stress the importance of organizational and individual learning. They stress that, when people face problematic situations this is a chance for them to learn how to cope with such circumstances in such a way that their performance is improved.

In hard approaches, it is typically assumed that a model is a would-be representation of part of the real world. By contrast, in soft approaches the idea is that models are developed so as to allow people to think through their own positions and to engage in debate with others about possible action.

Some interpretive systems approaches are Interactive Management (Warfield and Cardenas, 1994), Social Systems Design (Churchman, 1979), Strategic Assumption Surfacing and Testing (Mason and Mitroff, 1981; Mitroff and Emshoff, 1979; Mitroff, Emshoff, and Kilmann, 1979), Social Systems Science (Ackoff, 1977), Soft Systems Methodology (Checkland, 1976, 1981; Checkland and Scholes, 1990; Checkland and Holwell, 1998), Soft Systems Thinking (Senge, 1990), Soft Operation Research, Soft Cybernetics, Soft System Dynamics (Lane, 2000).

"*Soft systems thinking*" is heavily influenced by the “root metaphor” of contextualism. So it is very important to have a common sense about relevant aspects of the nature of problem.

III. Why an interpretive approach?

It is not always possible for an analyst to recognize and draw different causal relations in a complex system using an “objectivist” approach. It is recognized that there should be no single analyst, but a process of debate should take place among different actors (Guimares Pereira et al, 2005).

According to Ackoff (1974, 1979) problems in management science are three points on a spectrum: puzzles, problems and messes (Figure 1). A “puzzle” is a set of circumstances in which there is no ambiguity whatsoever once some thought has been given to what is happening or needs to be done. Although the nature of puzzles is simple, they are not always simple to solve. A problem is more complicated than a puzzle, but less complicated than a mess. This complication stems from the fact that a problem has no single answer that is definitely known to be correct. A mess is a set of circumstances in which there is extreme ambiguity and in which there may well be disagreement. In a puzzle, there is complete agreement about the nature of the puzzle (a single correct definition) and also a single correct solution. In a mess there is a whole range of possible definitions and descriptions of what is going on, and there may be no way of knowing whether a solution, as such, exists at all.

In management science, problems, puzzles and messes are regarded as social constructs. This does not mean that every aspect of the issues to be faced is within the mind of the analyst or the participants but the interpretation of those "facts" is less certain, and different

people may interpret the same ‘‘facts’’ in different ways. Some of these interpretations may turn out to be wrong, in the sense that they cannot be defended.

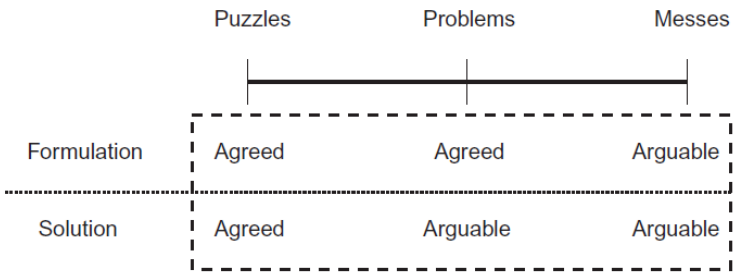


Figure 1: Puzzles, problems and messes (adopted from Ackoff)

Lane (2000) has argued that system dynamics is very different from hard systems thinking. Even on the basis of the classic texts of Forrester it is less austerely “objective” than is often represented. If one considers recent work by Wolstenholme, Senge and Lane, and the various craft skills that have grown up around the modeling, then it simply cannot be considered as “hard”, or “optimizing”, or “deterministic.” At the same time, Lane makes no pretence, and would not wish to, that system dynamics is a “soft” method in the style of SSM. As discussed by Lane (1999), Forrester's ideas operate at the level of method not social theory so system dynamics, though not wedded to a particular social theoretic paradigm, can be re-crafted for use within different paradigms.

Vennix’s (1996) work on “group model building” centers on building system dynamics models with teams in order to improve their performance when tackling strategic, messy problems. As problems become more complex it is clear that any individual can have only a limited view of their nature and causes. Group model building seeks to build on the natural tendency people have to think in terms of causal processes in order to systematically elicit and integrate the limited individual mental models into a more holistic view of the problem. As the result is a shared system dynamics model, this can then be used to explore the dynamics of the holistic view.

The client is involved throughout the model building process. The first step is to construct a preliminary system dynamics model on the basis of individual interviews of participants or the study of research reports and policy documents. This model is then further refined, in consultation with the individuals involved, before being presented at a group session. During the group session the team seeks to elaborate the model to bring it to a point where the dynamic complexity of their view of the problem situation can be explored. This process depends crucially upon the facilitator. This facilitator needs a thorough knowledge of system dynamics and must also exhibit the right attitudes, skills and tasks. If all goes well, the model building process will lead to the team learning their way to a shared social reality.

“Group model building” as discussed above is about identifying networks of related variables rather than simple causal chains. It is rare for people to see more than one cause of a problem.

An interpretive systems approach to solve different interpretation of stakeholders is presented. This approach uses Decision Making Trial and Evaluation Laboratory (DEMATEL) method (Gabus & Fontela, 1972, 1973) in order to find a common sense of most important concepts from causal loop diagrams.

IV. Step 1: Drawing causal loop diagram for each individual

In this step, a skilled interviewer individually draws causal loop diagrams for each stakeholder after a deep interview; Sterman (2000) suggests 15 important guidelines for causal loop diagrams:

1. Each link must represent causal relationship between the variables. You must not include correlations between variables.
2. Be sure to label the polarity of every link in your diagrams. Label the polarity of important feedback loops in your diagrams using the definitions in Table 1 to help you determine whether the links are positive or negative.
3. Determine the loop polarity
4. Name your loops
5. Indicate important delays in causal links
6. Indicate variable names
7. Use curved lines for information feedbacks
8. Make important loops follow circular or oval paths
9. Organize your diagrams to minimize crossed lines
10. Don't put circles, hexagons, or other symbols around the variables in causal diagrams.
11. Iterate. You will have to redraw your diagrams, often many times, to find the best layout.
12. Choose the right level of aggregation
13. Don't put all the loops into one large diagram
14. Make the goals of negative loops explicit
15. Distinguish between actual and perceived conditions

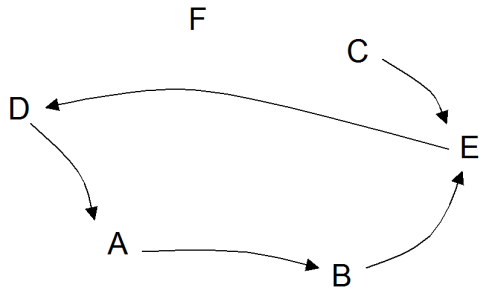
Table 1: Link polarity (Sterman, 2000)

Symbol	Interpretation	Mathematics	Example
X $\xrightarrow{+}$ Y	All else equal, if X increases (decreases), then Y increases (decreases) above (below) what it would have been. In the case of accumulations, X adds to Y.	$\partial Y/\partial X > 0$ In the case of accumulations, $Y = \int_{t_0}^{t} (X + \ldots)ds + Y_{t_0}$	Effort $\xrightarrow{+}$ Results
X $\xrightarrow{-}$ Y	All else equal, if X increases (decreases), then Y decreases (increases) below (above) what it would have been. In the case of accumulations, X subtracts from Y.	$\partial Y/\partial X < 0$ In the case of accumulations, $Y = \int_{t_0}^{t} (-X + \ldots)ds + Y_{t_0}$	Frustration $\xrightarrow{-}$ Results

V. Step 2: Working with diagrams (Identifying the root metaphor)

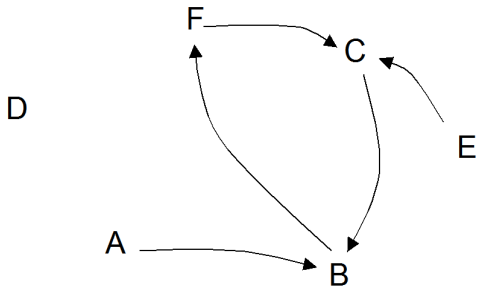
After drawing causal loop diagrams for each individual, they should be analyzed. In order to start analyzing, the first step is to identify the key concepts from diagrams. These key concepts will be used in workshops.

Drawing individual causal loops – Here, it is supposed that we have eight people (S_1 to S_8) who have knowledge about a problem. An expert interviewer can draw these causal loop diagrams and related matrixes (Table 2). Each number in the matrix shows the relationship between two concepts. For example, $a_{ij} = 1$ shows that there is a positive relationship between i and j.



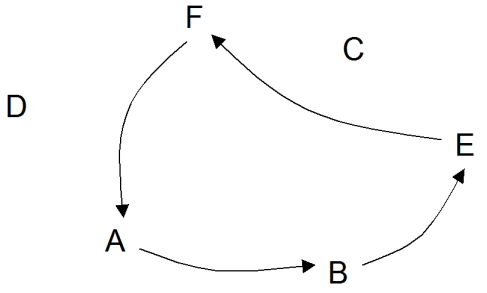
S_1

$$P_1 = \begin{bmatrix} - & 1 & 0 & 0 & 0 & 0 \\ 0 & - & 0 & 0 & 1 & 0 \\ 0 & 0 & - & 0 & 1 & 0 \\ 1 & 0 & 0 & - & 0 & 0 \\ 0 & 0 & 0 & 1 & - & 0 \\ 0 & 0 & 0 & 0 & 0 & - \end{bmatrix}$$



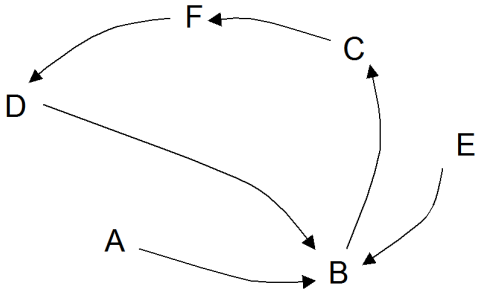
S_2

$$P_2 = \begin{bmatrix} - & 1 & 0 & 0 & 0 & 0 \\ 0 & - & 0 & 0 & 0 & 1 \\ 0 & 1 & - & 0 & 0 & 0 \\ 0 & 0 & 0 & - & 0 & 0 \\ 0 & 0 & 1 & 0 & - & 0 \\ 0 & 0 & 1 & 0 & 0 & - \end{bmatrix}$$



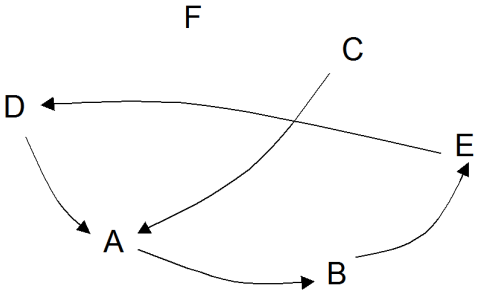
S_3

$$P_3 = \begin{bmatrix} - & 1 & 0 & 0 & 0 & 0 \\ 0 & - & 0 & 0 & 1 & 0 \\ 0 & 0 & - & 0 & 0 & 0 \\ 0 & 0 & 0 & - & 0 & 0 \\ 0 & 0 & 0 & 0 & - & 1 \\ 1 & 0 & 0 & 0 & 0 & - \end{bmatrix}$$



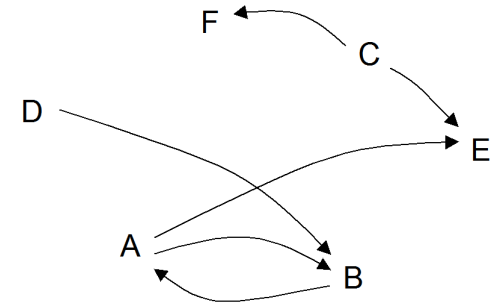
S_4

$$P_4 = \begin{bmatrix} - & 1 & 0 & 0 & 0 & 0 \\ 0 & - & 1 & 0 & 0 & 0 \\ 0 & 0 & - & 0 & 0 & 1 \\ 0 & 1 & 0 & - & 0 & 0 \\ 0 & 1 & 0 & 0 & - & 0 \\ 0 & 0 & 0 & 1 & 0 & - \end{bmatrix}$$



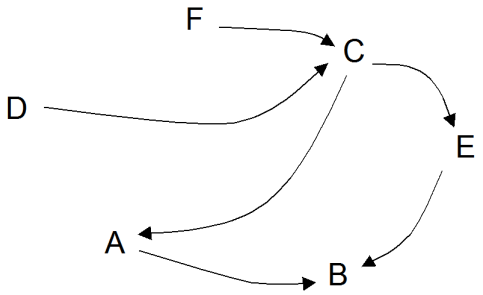
S_5

$$P_5 = \begin{bmatrix} - & 1 & 0 & 0 & 0 & 0 \\ 0 & - & 0 & 0 & 1 & 0 \\ 1 & 0 & - & 0 & 0 & 0 \\ 1 & 0 & 0 & - & 0 & 0 \\ 0 & 0 & 0 & 1 & - & 0 \\ 0 & 0 & 0 & 0 & 0 & - \end{bmatrix}$$



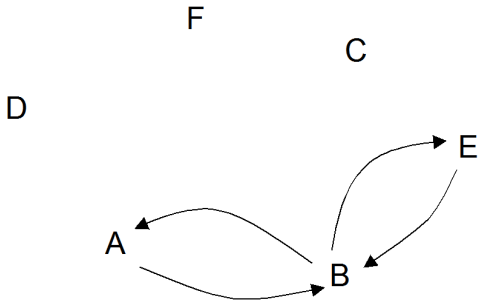
$$P_6 = \begin{bmatrix} - & 1 & 0 & 0 & 1 & 0 \\ 1 & - & 0 & 0 & 0 & 0 \\ 0 & 0 & - & 0 & 1 & 0 \\ 0 & 1 & 0 & - & 0 & 0 \\ 0 & 0 & 0 & 0 & - & 0 \\ 0 & 0 & 0 & 0 & 0 & - \end{bmatrix}$$

S_6



$$P_7 = \begin{bmatrix} - & 1 & 0 & 0 & 0 & 0 \\ 0 & - & 0 & 0 & 0 & 0 \\ 1 & 0 & - & 0 & 1 & 0 \\ 0 & 0 & 1 & - & 0 & 0 \\ 0 & 1 & 0 & 0 & - & 0 \\ 0 & 0 & 1 & 0 & 0 & - \end{bmatrix}$$

S_7



$$P_8 = \begin{bmatrix} - & 1 & 0 & 0 & 0 & 0 \\ 1 & - & 0 & 0 & 1 & 0 \\ 0 & 0 & - & 0 & 0 & 0 \\ 0 & 0 & 0 & - & 0 & 0 \\ 0 & 1 & 0 & 0 & - & 0 \\ 0 & 0 & 0 & 0 & 0 & - \end{bmatrix}$$

S_8

Determining the key concepts – According to interviewees' matrixes, we have

$$T = P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 + P_8$$

$$T = \begin{bmatrix} 0 & 8 & 0 & 0 & 1 & 0 \\ 2 & 0 & 1 & 0 & 4 & 1 \\ 2 & 1 & 0 & 0 & 3 & 2 \\ 2 & 2 & 1 & 0 & 0 & 0 \\ 0 & 3 & 1 & 2 & 0 & 1 \\ 1 & 0 & 2 & 1 & 0 & 0 \end{bmatrix}$$

The T matrix is normalized as the DEMATEL method suggested, so we get matrix M as

$$M = \begin{bmatrix} 0 & 0.889 & 0 & 0 & 0.111 & 0 \\ 0.222 & 0 & 0.111 & 0 & 0.444 & 0.111 \\ 0.222 & 0.111 & 0 & 0 & 0.333 & 0.222 \\ 0.222 & 0.222 & 0.111 & 0 & 0 & 0 \\ 0 & 0.333 & 0.111 & 0.222 & 0 & 0.111 \\ 0.111 & 0 & 0.222 & 0.111 & 0 & 0 \end{bmatrix}$$

According to DEMATEL method, Q is calculated as

$$Q = M \times (I - M)^{-1}$$

$$Q = \begin{bmatrix} 0.709 & 2.083 & 0.522 & 0.341 & 1.289 & 0.491 \\ 0.734 & 1.195 & 0.528 & 0.329 & 1.233 & 0.498 \\ 0.725 & 1.24 & 0.423 & 0.31 & 1.106 & 0.577 \\ 0.623 & 1.088 & 0.391 & 0.183 & 0.684 & 0.284 \\ 0.51 & 1.181 & 0.468 & 0.434 & 0.738 & 0.428 \\ 0.42 & 0.628 & 0.418 & 0.238 & 0.465 & 0.214 \end{bmatrix}$$

Table 2 shows both "direct influence" and "indirect influence" which are calculated from the Q matrix.

Table 2: DEMATEL direct and indirect influences

concept	direct influence index	indirect influence index	total influence	normalized total influence
A	5.435	3.721	9.156	0.193
B	4.517	7.415	11.932	0.251
C	4.381	2.75	7.131	0.150
D	3.253	1.835	5.088	0.107
E	3.759	5.515	9.274	0.195
F	2.383	2.492	4.875	0.103

According to the normalized total influence, we can sort concepts from most important to least important one.

Table 3: Total influence

concept	normalized total influence
B	0.251
E	0.195
A	0.193
C	0.150
D	0.107
F	0.103

It should be mentioned that these important concepts will be used in workshop sessions in order to have a more effective discussion about the concepts that are more important than others. In this example concept B, E, A and C are selected to be discussed.

In another approach we can mention all of the concepts in workshop sessions form B to F.

Analyzing clusters - Since practical causal loop diagrams may contain a lot of concepts, even when produced from one person, some way is needed to support their use. One important feature of such analysis is the idea of a cluster of concepts. These are sets of concepts that are similar in some way and could, in some sense, be more or less separated from the rest of the diagram. Clearly, if a diagram contains concepts that are all strongly interlinked, it may not be fruitful to attempt this sort of analysis. This might be the case if the ratio of links to nodes is high.

A cluster indicates that there is an issue of some importance that may have an effect rather greater than just on a single input and output link. Underlying the cluster identification is the notion that ‘‘language is the common currency of organizational life.’’ That is, people’s words have meanings, and a good starting point is to assume that, though the meanings will change over time, the same words may have more or less the same meaning. Clusters can be formed around the names and words that are used - this explains the importance of capturing the words used by the interviewee.

VI. Step 3: Sessions and workshops

The idea of a workshop is to gain commitment to agreed and negotiated action. The consultant is, as would be expected in this negotiative approach, not just a neutral facilitator, but also has interests and may have other expertise.

When planning for a workshop the facilitator must establish a clear set of workshop objectives and should anticipate the potential workshop stages that might be useful. This process design should be negotiated with the client, during which the facilitator and client both learn their way into the problem situation and the issues that need to be tackled.

Most teams of managers have a shared life or culture of some kind if the team is at all cohesive, and may not be over-welcoming of attempts to question their ideas. It is thus vital that the consultant starts these workshops in a carefully planned and facilitative mode. Given that many senior managers are extremely powerful personalities then this may be easier said than done! Perhaps the best approach is for the consultant to be explicit with the group about her role as chair.

In these sessions most important concepts (from step 2) should be discussed. The goal is to negotiate with different actors and finally draw some most agreed causal loop diagram of the system.

VII. Conclusion

System dynamics modelers look forward to an approach for drawing causal loop diagrams which can consider different perceptions of people. Hence, we have developed an interpretive approach. With the proposed approach, the complex causal relationships between concepts are discovered, key concepts are identified using DEMATEL, groups and team are created and after a negotiative discussion, the most agreed causal loop diagram is drawn.

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