Causal-Loop Diagrams in Information Systems Research into Strategic Alignment

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Abstract

Causal-loop diagrams, a method of documenting non-linear cause/effect relationships, have been used in systems thinking and, in particular, system dynamics for some time. However, their use is still controversial though they have been found to be useful in developing an understanding of complex, non-linear systems. These systems encompass many organizational and social problem areas.

Although causal-loop diagrams have been used by both consultants and practitioners to understand problem areas within organizations, they appear to have been little used in information systems research (or any other discipline of research).

This paper provides a critical reflection of the use of causal-loop diagrams within information systems research. It finds that, although they have many limitations and their validity is highly questionable, they are useful during the exploratory stages of a research project in developing research questions, forming initial hypotheses, and gaining an understanding of the dynamics of a problem situation. The paper describes an exercise to develop a model of IS/business alignment, conducted over three sessions, and highlights some research questions not previously considered in the literature that arose as a result of the exercise.

Keywords

Methodology, causal-loop diagrams, IS/business alignment

INTRODUCTION

This paper introduces causal-loop diagrams and some of the issues identified in the literature surrounding their use. It then describes a series of sessions where a model of IS/business alignment was developed by six senior IT managers. This exercise allowed the participants to understand alignment as a complex dynamic system, something they had not previously understood. The resulting diagram is then critiqued and possible research questions and hypotheses developed from the model. Finally, the limitations and usefulness of the technique is discussed.

Causal-loop diagrams appear to have been first used by systems thinkers in the early/mid twentieth century (Capra, 1996) but were made more popular within systems dynamics in the 1960’s and being introduced to a much wider audience by (Senge, 1990). However, their usefulness is still strongly debated within system dynamics. Some practitioners, including one of the major developers of system dynamics, Jay Forrester, maintain that they should never be used due to their lack of rigour. Others believe that they can be used to develop initial hypotheses, uncover the mental models of participants and then to help explain a quantitative system dynamics model to non-participants (Sterman, 2000). Still others believe that they are sufficient, within limitations, to understand then act upon a complex problem area (Vennix, 1996, Wolstenholme, 1990).

The assumption behind causal-loop models, and much systems thinking, is that the behaviour of a system is due to its internal structure and not to outside influences (Sterman, 2000). Therefore, it is argued, most complex systems consist of cause/effect feedback loops. A change in any variable within the system will cycle through loop(s) to eventually either reinforce the initial change or attempt to negate that change.

Each cause/effect pair in a causal-loop model can be either positive or negative. A positive relationships indicates that a change in the cause will lead to a change in the effect in the same direction – an increase in the cause will lead to an increase in the effect, whilst a decrease in the cause will lead to a decrease in the effect. A negative relationship indicates that a change in the cause will lead to a change in the effect in the opposite direction. Figure 1 shows two relationships with the arrows showing the direction of causality. The “+” signs at the head of the arrows indicate that both these relationships are positive – an increase in Births will lead to an increase in Population whilst a decrease in Births leads to a decrease in Population.

Causal loops can also be either positive or negative. Positive feedback loops can either cause a continuous escalation of the variable under consideration, the classic virtuous cycle, or a collapse of the variable (vicious cycle). Negative feedback loops attempt to remain in equilibrium, with the values of individual variables often showing a tendency to oscillate within a given range. Whether a loop is positive or negative, its polarity, can be
determined by counting the negative links within the loop. An even number of negative links identifies a positive, or reinforcing, feedback loop, whilst an odd number of negative links identifies a negative, or balancing, loop. This is often identified in causal-loop diagrams by a large “+” or “−” symbol in the centre of the loop as in Figure 1. For a complete discussion of causal-loop diagrams, their semantics and rules see (Sterman, 2000).

Causal-loop diagrams, or more precisely the modelling sessions conducted to develop the diagrams, have been promoted as an effective method of developing initial hypotheses and uncovering the mental models of participants. The latter are due, in part, to the participant’s culture, beliefs, position within the system, problem-solving techniques and simply to the cognitive limitations of the human brain when dealing with cause and effect that are separated by either time and/or space (Vennix, 1996).

Although successes in addressing complex problems have been attributed to the use of causal-loop diagrams (Vennix, 1996, Wolstenholme, 1990), they have also been criticised. (Richardson, 1986), one of the few researchers to systematically critique the causal-loop technique, maintains that a major limitation is that, due to the cognitive limitations of the human brain, we cannot determine the behaviour of a system from a diagram. It can also be argued that the same is true of the linear models that are dominant in information systems (IS) research. This means that we cannot determine the results of a change in any one variable on system behaviour. This argument, if followed to its logical conclusion, indicates that the beneficial outcomes of changes made due to causal-loop modelling were more attributable to luck than any real understanding of the system.

Another criticism put forward by (Richardson, 1986) is that causal-loop diagrams confuse rates and levels. For example, the classic model beloved of writers introducing causal-loop diagrams is that of Births and Population. The model, shown in Figure 1, infers that an increase in Births causes an increase in Population. The increase in Population then causes an increase in Births so creating a positive feedback loop indicated by the large “+” sign at the centre of the loop. However, Births can also decrease and the model infers that a decrease in Births causes a decrease in Population. This is not the case. A decrease in Births causes a decrease in the rate at which Population increases. Births should, in fact, be Birth Rate for the model to make sense. A more correct way of reading the model is that “an increase in Birth Rate leads to an increase in Population beyond what it would otherwise have been.” The converse of this is “a decrease in Birth Rate leads to a decrease in Population beyond what it would otherwise have been” (Sterman, 2000).

Note that both of these criticisms of the technique are related to the interpretation of diagrams, not to their development. This is due to Richardson’s belief that causal-loop diagrams should only be developed from existing, and validated, quantitative system dynamics models and never as a result of group modelling sessions. His belief is that the only valid use of a causal-loop diagram is to explain a system dynamics model to people who were not involved in the construction of that model.

However, causal-loop diagrams can be developed during group modelling sessions (Vennix, 1996) and as we describe in this paper. When used in this way we believe there are two aspects that are actually their most problematic areas. These are the lack of richness in the diagram itself, and the validity of the structure of the model. These two issues are rarely addressed in the literature but have a profound affect on the usefulness of the model.

The next section discusses the use of causal-loop diagrams used by the authors during the commencement of ongoing research into IS/Business alignment. We then reflectively critique the method and, in conjunction with this, identify some of the hypotheses and research questions that resulted from the exercise to show its potential use. The conclusion briefly summarises the advantages, disadvantages and pitfalls of the method.

**CAUSAL-LOOP DIAGRAMS IN ALIGNMENT RESEARCH**

It is generally accepted that to be effective, an information system must be aligned with its relevant business goals and visions (Chan, Huff, Barclay and Copeland, 1997, Coakley, Leader and White, 1995, Henderson and
Earlier research concentrated on the alignment of the strategies and structures of the business and IS units (Henderson and Venkatraman, 1993) and led to an investigation of the methods and level of integration of business and IS strategic plans (Earl, 1993, King, 1988, King and Teo, 2000, Teo and King, 1996, Teo and King, 1997). This has now been characterized as the intellectual dimension of alignment (Reich and Benbasat, 2000). However, the relationships between people and units within an organization can also affect the process of alignment (Campbell, 2003, Chan, 2002, Nelson and Cooprider, 1996, Reich and Benbasat, 1996). This has been termed the social dimension of alignment (Reich and Benbasat, 2000).

It is the social dimension of alignment that is of interest to us. Although we are familiar with much of the literature in the area, we did not believe that this gave us a good understanding of how the various aspects “fitted” together, nor that all issues had already been raised (even if they had not been investigated). For this reason, the decision was made to employ a series of separate focus groups consisting initially of IT managers and then business managers. We used the technique of causal-loop diagrams to document aspects of the focus groups. We separated IS and business managers for two reasons: we wish to investigate any possible differences in the worldviews, or mental models, between them, and we also wish to avoid the disruption that can occur with heterogeneous groups when incompatible differences of opinion arise (Vennix, 1999, Vennix, 1996). We hope to capture further richness later by inviting selected members of each group to a follow up series of meetings. The diagram presented in this paper is the result of a series of three modelling sessions of a single focus group of IT managers that has been selected to demonstrate the use of the technique.

Each series of meetings commenced with a group interview that lasted for approximately 1.25 hours and was then followed by a causal-loop modelling session of 45 minutes. This was followed up by two further 2 hour sessions to complete the model. The sessions involving the IS managers consisted of 6 senior, but not top, IS managers plus the two researchers who acted as facilitators. The diagram that resulted from these sessions, the only one considered in this paper, is shown at Figure 2.

About 15 minutes was spent introducing the participants to causal-loop diagramming and introducing the problem. This was used to model the relationships between the enablers and inhibitors to alignment, and then to include the effects of alignment. The facilitators/researchers attempted not to influence the construction of the model as we wanted the participants’ representation of the alignment system. However, due to the very nature of facilitating a causal-loop modelling session this is difficult. We recorded the sessions as suggested by (Vennix, 1999) although this is by no means a universal practice.

**CRITIQUE OF CAUSAL-LOOP DIAGRAMS**

Like other methods of research that involve organizing groups of people, it can be frustrating getting the group together (Morgan, 1997). A number of false starts were made before each of the groups could be successfully convened. However, once the group commenced working together, follow up sessions were easily organized as they created enthusiasm and understanding of alignment among the participants.

Although software is available to draw the diagrams (we used VensimPle available free for academic use at [www.vensim.com](http://www.vensim.com) to draw the models in this paper), it is not practical to use it during model construction. Participants find it more intuitive to use a white-board where they can modify the diagram and write comments easily. This means that the facilitator must formally reconstruct the diagram before the next sessions before any further progress can be made.

We believe a major limitation of the technique, however, is that the diagram only contains the causal relationships that were eventually agreed upon by the participants. It does not include any of the rich discussions and disagreements that went into its development. This is a major limitation when this technique is used in research. It is for this reason that we now believe that recording sessions is essential rather than a suggestion as previously advocated (Vennix, 1999) as the richness over and above that contained in the causal-loop diagrams can be captured. The recordings can then be transcribed and analysed with any appropriate text analysis method. We used NVivo from QSR International ([www.qsr.com.au](http://www.qsr.com.au)) to manage this process although the results which used grounded theory as the analysis method are not presented here as they are beyond the scope of this paper.

In most previous uses of causal-loop diagrams this lack of richness has not been a limitation as it has been the process of developing the diagrams that is of most importance, not the documentation of the result in a diagram. The objective in these instances has been to facilitate the understanding of a complex system of inter-related cause/effect relationships. The diagram is little more than an aide-memoire in recalling aspects of the discussions that ensued during its development.
Figure 2. Causal-Loop diagram, representing alignment, constructed by 6 senior IS managers.
This contrast in lack of richness in the diagram itself compared to the richness of discussion in its
development also makes it difficult to communicate the meaning of a diagram to those who were not
involved in its construction. This is also related to the next major limitation that we found with the
technique, discussed next.

Most causal-loop diagrams are constructed at a high level of abstraction. Details are often omitted and
the structure has useful meaning only to the participants. For example, in Figure 2 there are a number
of loops associated with *Ability to deliver*. These indicate that if this variable improves, then *Successful
projects* increases and then *Knowledge gap* decreases. However, it then goes on to infer that a result of
this is that there is a decrease in *Learning* that then reduces *IT knowledge & skills* and then *Ability to
deliver*. Similarly, an initial improvement in *Ability to deliver* will eventually increase *IS credibility* that
then leads to an increase in *Requests for new projects* and an erosion of *Ability to deliver* due to the
extra work pressure. Anybody investigating this structure could make any number of criticisms.

However, it captured the experiences of the participants. They maintain that *Ability to deliver* seems to
remain at a fairly constant level regardless of attempts to improve it. The diagram captures the essence
of this experience at a high level of abstraction but it is almost certainly structurally incorrect. Having
modelled the phenomenon they were attempting to capture, the participants just moved on to the next
section of the overall alignment problem with scant regard to the validity of the construct. In the
experience of one of the authors, who has used causal-loop diagrams previously, this is not uncommon.

This, then, raises another major issue in the use of causal-loop diagrams in research. There is no way of
determining their validity. They are normally used to uncover the mental models of participants and to
quickly capture hypotheses. Their structure is suspect and it is rare that the variables have been
precisely defined. These issues only come to the fore during a more thorough investigation of the
problem. The validation techniques used for quantitative system dynamics models (Barlas, 1996,
Forrester and Senge, 1980), which have also been criticised for their lack of rigour (particularly in their
measurement of variables), are generally not relevant and rarely used.

Even with so many seemingly fatal flaws, causal-loop diagrams can still be of use to researchers when
their structure is compared to the literature. The most interesting structure, to the current writers, of the
diagram presented in Figure 2 is the total absence of feedback from either *Formulation of business plans*
or *Level of IS/business alignment* to *Ability to deliver*. This is in contradiction with much of the
existing literature which argues that integrated business and IS plans will lead to an improvement in IS
performance (Henderson and Sifonis, 1988, Lederer and Sethi, 1996, McLean and Soden, 1977,
Sabherwal, 1999). Note that the participants believe that IS/business alignment is only achievable with
fully integrated business and IS planning processes. This explains the omission of any variable in the
diagram that refers to IS strategic planning. In their view business planning should incorporate IS
planning. However, the issue is the lack of feedback from *Formulation of business plans* or *Level of
IS/business alignment to Ability to deliver*.

There are a number of possible explanations for the lack of this feedback linkage all of which may
require further investigation. Firstly, it may be a mental model held only by these participants. Secondly,
it may reveal a commonly held view of planning within IS groups. This is more problematic as it then
indicates that IS groups do not consider that strategic plans guide their activities. That is,
there is little connection between the visions and goals within a plan and the activities of the IS group.
There is support for this view within the literature. (Lederer and Sethi, 1988) found a disconnect
between projects identified in plans, and the projects that were actually undertaken within an
organization. Even though their research is relatively old, it may well be that the problem still exists.

Thirdly, Figure 2 tends to lend support to the research of (Sabherwal, 1999) who found a positive
relationship between IS success and planning sophistication, but a less strong relationship between
planning sophistication and IS success. However, being statistically based, Sabherwal’s research
indicates a simple correlation between IS success and planning sophistication. The model in Figure 2
indicates that although this relationship appears to exist, there are a number of intervening variables, all
of which may have an effect on the outcome as they are also impacted by other variables. This needs
further investigation.

During the construction of the causal-loop diagram the participants were insistent that, to be effective
in the long term, alignment must occur at all levels of the organization, not just at senior management
level. Most current research restricts itself to investigation at senior management level with (Reich and
Benbasat, 2000) even defining the social dimension of alignment only in respect to senior managers.
Very few papers consider relationships at lower levels of an organization with (Henderson, 1990) being an exception. Figure 2 should be considered at all levels of the organization. The level(s) of an organization at which alignment is achieved needs to be researched further.

When compared to the literature other areas of the model also indicate the mental models of the participants. For example, the work of (Nelson and Cooprider, 1996) shows that mutual trust and ability to influence are prerequisites to shared domain knowledge and it is this that leads to improved IS outcomes. The model in Figure 2 totally ignores the issue of trust. When questioned about this, the participants dismissed it by saying that trust is an integral part of IS credibility. The other aspect of interest is that the model indicates that only the IS knowledge of the business is important in developing alignment. It mostly ignores the reciprocal understanding of IS issues by business personnel. The exception to this is the loop that includes Senior Mgt’s knowledge of IT. The model seems to indicate, by omission, that it is not necessary for business personnel to understand IS issues except at senior management level. This does not conform to the research of (Nelson and Cooprider, 1996) and again needs further investigation to discover whether it a widely held view within IS groups, and whether it is held by business managers.

Another interesting aspect of the model that the current writers have not encountered previously is the section relating to the selection of IS personnel in a project group and the observation that many IS personnel are poor communicators (indicated in Figure 2 by the variable Level of introversion). The participants indicated that when selecting personnel for a project they tend to include personnel who may have lesser technical skills but good communication skills. Their aim is to help other members of the group improve their communication skills. This is a long term objective with the aim of improving communications, relationships and collaboration between IS and business personnel. Note that there is a link missing in the diagram. This connects IT Personnel with soft skills to IT communication skills. It was omitted simply because it crosses so many other lines in the diagram and represents limitations of the software used. We have not come across this objective of project managers previously. However, the group did indicate that it is extremely difficult to achieve. Whenever a project is put under pressure, the tendency is to stack it with technically proficient members and to place less emphasis on the need for communication. In fact, communication is actively avoided in this situation. A related issue is the tendency, in the participants’ experience, of retaining technically superior staff in a period of staff layoffs and to again place less importance on the ability of staff to communicate effectively. The effect of selection, training of staff in soft skills, the make-up of project teams and the effect of project pressure on alignment needs to be investigated.

CONCLUSION

The foregoing is not an exhaustive exploration of possible research questions that could be derived from the model, but we suggest that the following areas need to be investigated:

- Are strategic plans used to guide IS activities?
- What are the intervening variables between IS success and planning sophistication, and how do these interact and affect planning? What other variables affect these intervening variables and how do they impact the correlation between IS success and planning sophistication?
- Is it necessary for social alignment to occur at many levels of an organization to maintain alignment in the long term?
- How does trust affect IS credibility, effective communication and collaboration? What affects trust?
- How does the perception of the need for shared domain knowledge differ between IS and business managers?
- Does alignment require the development of shared domain knowledge by both IS and business personnel (or does it only require knowledge of the business by IS personnel)?
- How does the selection of staff, training of staff in soft skills, and the make-up of project teams affect IS/business relationships? Does this affect alignment? In the short term, or long term?
These research questions indicate that even though causal-loop diagrams have many deficiencies, they can be used to gain an overview of a problem area and, when combined with a thorough literature review, can help in identifying research questions that may not be obvious when using more conventional methods. As such, we believe their use is beneficial during the exploratory stages of a research project. Many of the issues identified above are being pursued in the ongoing research into alignment referred to previously.

Most of the previous analysis of Figure 2 would not be possible if a researcher was presented with just the model. The researcher must have either been a part of the model construction and/or have access to the recordings made during model development. From our experience we strongly recommend, unlike (Vennix, 1999), that researchers who use this technique are both a part of the modelling team and record, transcribe and analyse the discussions held during model construction. Note, however, that analysis of the recordings made during the development of Figure 2 are not presented here as it is beyond the scope of this paper.

Researchers must resist the temptation to consider the model that their research participants construct as accurately reflecting reality. It almost certainly doesn’t due to the lack of rigour in its development and the deficiencies of the causal-loop modelling technique. They must also be very careful in interpreting causal-loop diagrams.

Like strategic planning itself, the benefit of causal-loop diagrams lies in the discussions that occur in their development and the questions that the model generates, rather than any answers it supplies.

References


