Information Systems Development Position Paper: Using Coloured Cognitive Mapping to Support IS Development

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Introduction

A long-standing core issue in the IS/IT field is the poor track record of system development and introduction. This has been known by various names, such as *the software crisis*.

To summarise the problem with Information Systems Development (ISD), ISD projects are commonly *late* and *over budget*, deliver a system that d*oesn't meet requirements*, *cannot be used as intended*, *is hard to use*, or *is completely unusable*, or *fail to deliver a system altogether (project never completed)*. Various studies show 50-90% failure rate

There are various causes that can be attributed to the above problems including:

- Technical difficulties in making complex systems work properly
- Poor estimation of time and costs
- Promising too much – before & after budget
- Poor management of projects
- Changing needs during development
- Poor understanding of the problem(s)
- Solving the wrong problem(s)
- Poor acceptance and adoption of system(s)

The last three of the difficulties listed above occur due to practices at the very front end of development, when stakeholders are (or should be) grappling with a problematic situation in order to decide what problems are to be solved and what sort of IS would contribute to that solution.

It is the contention of this paper that this area is a key weakness in system development. Problems are sometimes stated, but only weakly examined. Problem diagnosis and formulation are poorly performed, if at all. Commonly, solutions are proposed in the form of a system request without any examination of the problem situation whatsoever. Furthermore, agreement about problems may not be sought. Solutions are then accepted without consideration of effectiveness in solving the unstated problem or addressing the needs of various different stakeholders.

Instead, this paper proposes that more attention needs to be paid to developing problem formulations that are clear, correct, properly scoped and prioritised among other problems, and agreed by relevant stakeholders. Further, ISD processes must then accommodate effective translation of problem definition to solution generation, choice, and implementation. While some work has been done in this area, it is an area of perennial weakness and in need of much more attention.

Problems with Problem Formulation

Dumdum (1993) proposed a classification of six "problems with problem formulation". These are relevant to all kinds of problems, including problems to be addressed by developing an IS solution.

1. **Insufficient attention to problem formulation:** Problem formulation is often ignored altogether in the 'rush' to solution of a problem. Sponsors seldom allow time for careful problem formulation and analysis and may consider it unnecessary or obvious (from their single perspective).
2. **Bounded (limited) rationality:** Derived from Simon (???), this concerns the limited capacity of the human mind to formulate and solve problems.
3. **The self-sealing tendency:** This occurs in ambiguous situations. A group will often invent/define the 'beliefs' about reality (somewhat arbitrarily or without sufficient info), then cling tightly to those, now familiar beliefs. It is a mechanism to reduce uncertainty and there is a tendency to avoid returning to that uncertainty by not allowing challenge of those beliefs.
4. **Unchallenged assertions:** This concerns the uncritical acceptance of problem stipulations or other assertions about the problem by various stakeholders. Often it's easier not to question the motives or rationality of others because these require too much effort or conflict.
5. **Lack of issue management:** Conflicting information, doubtful assertions, or conflict about the problem and its assumptions may leave many open/unresolved issues. Having too many inter-related issues may be too complex for the bounded rationality of a problem formulating individual or group. As a result, they may overlook or forget about unresolved issues or might even actively discard them to simplify the process.
6. **Lack of common (shared) understanding (of the problem):** Different stakeholders will have different perspectives about, understandings of, and interests in the problem. This causes or enables miscommunication. Such different perspectives cannot easily be summarised or integrated.

To the above list, we add another, which is closely related to number six.

7. **Lack of common (shared) language and culture:** People often have different meanings for the same words. Meanings are built up from people's experiences, especially with the use of words. Words are used locally in different ways. People often do not mean the dictionary definition. To some extent, different meanings are often based on different goals and objectives. We often assume that our background and culture are known to the other participant(s). Like problem number six above, this also leads to ambiguity and miscommunication.

Addressing Problem with Problem Formulation in ISD

Various processes and techniques have been proposed that address the above problems.

An important, relevant method is Soft Systems Methodology (SSM) (Checkland, 1981, Checkland and Scholes, 1990). SSM addresses issues 1, 2, 6, and 7 above. It is a general problem solving methods especially for use where there are differences among stakeholders about their understandings and goals. It can be applied to the formulation and agreement about any kind of problem to be solved and the design of any kind of solution. It is not specifically designed to be applied to Information Systems solutions.

SSM incorporates a number of useful techniques, including Rich Pictures, CATWOE Criteria, Root Definitions, and Conceptual Models. Rich Pictures are especially used to model and explore a problematic situation.

Wood-Harper, Antill, and Avison (1995???) incorporate Rich Pictures into their Multiview methodology. Multiview can be described as an eclectic method, which draws on a number of other methods and their techniques and builds those into a coherent, overall approach to systems development. Multiview incorporates techniques from SSM, Human-Computer Interface (HCI) design methods, and Structured Analysis and Design methods, among others (Wood-Harper *et al*., 1995).

Mathiassen *et al*. (2000) incorporate Rich Pictures into their Object-Oriented Analysis and Design methodology. They also incorporate revised versions of CATWOE and Root Definitions, which they call FACTOR and System Definitions. These revised versions are specifically tuned for modelling the concerns of scoping and defining information systems to be designed and built.

Cognitive Mapping is a form of Causal Mapping developed and popularised by Colin Eden and Fran Ackermann (Eden, 1988, Eden & Ackermann, 2001, Ackermann and Eden, 2001). The technique consists of nodes and links, where the nodes are succinct statements of part of problems and/or their solutions, with the links being arrows from a cause to a consequence of that cause (more on this below). While this technique was not developed especially for IS Development, it can be used to explore conceptualisations of problems and solutions at the front end of ISD. A key element of cognitive maps is that the text in a node may have two 'poles', a primary pole which is the content, and a secondary pole, which provides more meaning through contrast (e.g. "increased sales … (as opposed to) continuing poor sales").

Problematiques (Roberts, 1995) are similar to cognitive maps, but focus on analysing the problematic area. The technique is used to explore a problem or group of problems, their causes, and their consequences.

Coloured Cognitive Mapping for ISD

Venable (2005) has proposed a new form of cognitive maps, called *coloured cognitive maps*. The enhancements proposed in that paper to the cognitive mapping technique developed by Eden and Ackermann include the following.

1. A conceptualisation of two forms of problem statements and corresponding forms of coloured cognitive maps (CCMs): *problems as difficulties* and *problems as solutions*. A CCM of a problem as difficulties focuses on the current undesirable or problematic situation. A CCM of a problem as solutions focusing on statements of some desirable future situation.

2. A procedure for straightforward conversion between these two forms of cognitive maps
3. Colouring of nodes to indicate desirability or undesirability
4. An overall process for problem analysis with cognitive maps

Venable (2005) proposes CCM as a straightforward way to analyse a problem. David Kroenke has defined a problem as "A *perceived* difference between *what is* and *what should be*" [emphasis added]. CCM aids in exploring the *what is* about the problem situation and then effectively transitioning to exploring the *what should be*. CCM thus supports both *problem diagnosis* (problem formulation) and *solution derivation* (alternative generation). It also supports contrasting of alternatives for decision making.

In this paper we propose that coloured cognitive mapping could be used to support ISD and improve its effectiveness, efficiency, efficacy, (a)esthetics, and ethicality (the Five E's, cf. Checkland, 1981).

First we will briefly summarise the notation and mapping process for using Coloured Cognitive Maps (Venable, 2005).

Notation

Two symbols are used in coloured cognitive maps (see figure 1). As in normal cognitive maps (Eden, 1988) nodes are drawn with rounded rectangles, ovals or some other convenient symbol and represent some aspect of a problem. Text is placed within each node, which captures the meaning of the node. The text in the node can also be split into two parts or poles, which are separated by an ellipsis symbol ("…"). In coloured cognitive maps, the nodes are coloured to indicate whether the node represents something that is desirable or something that is undesirable. Green nodes represent desirable circumstances and red nodes indicate undesirable circumstances. Generally, one of the poles in a node should be desirable and the other one undesirable, with the colour corresponding to the primary pole (the text that comes first). Where colour cannot be used, another indication is needed, such as bold print, darker lines, or a different node shape for undesirable nodes.

Node:

- Goal, activity, problem, cause, implication, etc.
- Poles separated by ellipsis,
- Red/bold = undesirable, Green = desirable

Arrow:

- Causal or contributory
- Plus sign or minus sign (plus assumed)

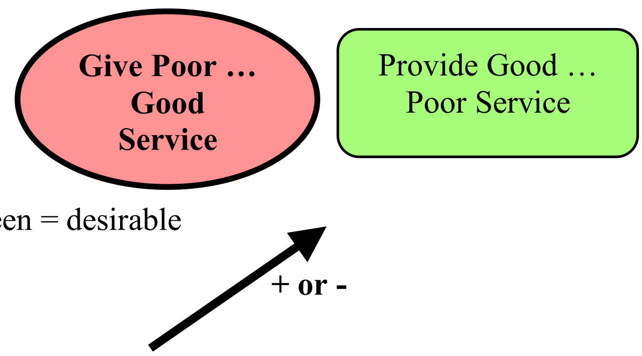


Figure 1: Cognitive Mapping Notation

Nodes are connected to each other with arrows. As with regular cognitive maps, arrows represent causality between the nodes, i.e. the node at the tail of the arrow causes the node at the head of the arrow. Table 1 shows some further synonyms for the meaning of causality. Note that the arrows do *not* mean flow of information or goods and should never be used as such.

As with regular cognitive maps, arrows may optionally have plus or minus signs attached to them. If a sign is omitted, a plus sign is assumed. If a minus sign is attached, it means that the causality is reversed; instead of the node at the tail of the arrow *causing* the node at the head of the arrow, the node at the tail *prevents* the node at the head or *causes its opposite pole*. Table 1 also shows alternative meanings for the arrow when it has a minus sign attached.

An arrow with a plus (or no) sign means	An arrow with a minus sign means
Causes	Causes the opposite pole
Implies	Implies the opposite pole
Enhances	Reduces
Contributes to	Detracts from
Increases	Decreases
Allows	Disallows
Enables	Prevents

Table 1: Synonyms for the meaning of the arrow

Procedure for Analysing Problems with Cognitive Maps

The coloured cognitive mapping procedure is divided into three stages (see figure 2). First is *Problem Diagnosis*, in which a cognitive map is developed of the problem as difficulties. The second stage is *CM Conversion*, in which we convert the cognitive map of the problem as difficulties into a cognitive map of the problem as solutions. The resulting cognitive map is incomplete, but a basis for progressing in the third stage. The third and final stage is *Solution Derivation*, in which the cognitive map of the problem as solutions is expanded with various candidate or potential solutions.

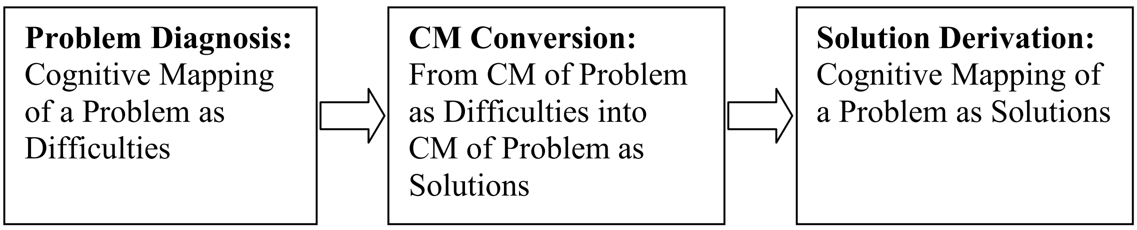


Figure 2: Procedure for Problem Analysis with Cognitive Maps

The goal of problem diagnosis is to obtain a clear (and hopefully agreed) understanding of the causes and consequences of the problematic situation. Solving a problem effectively requires that the problem solver(s) develop a rich understanding of the problematic situation before proceeding. The problem solvers need to understand what is undesirable about a problematic situation, why it is problematic to the stakeholders, and what the causes of the problem are – i.e. what things allow the undesirable circumstances to exist. Note that cognitive maps of problems as difficulties will primarily have nodes that are undesirable (coloured red, bolded, and/or oval shaped), but some nodes will likely be desirable ones. As they say, every cloud has a silver lining.

Cognitive Map Conversion is the process of converting a CM of the problem as difficulties into an initial CM of the problem as solutions. This step is a (nearly completely) mechanical process of changing every node in the CM of the problem as difficulties from either undesirable to desirable or desirable to undesirable. The colour of every node is changed and the text is changed by switching the poles and rewording so that it makes sense. Figure 3 shows an example. The example is of course extremely simplified compared to a normal problematic situation.

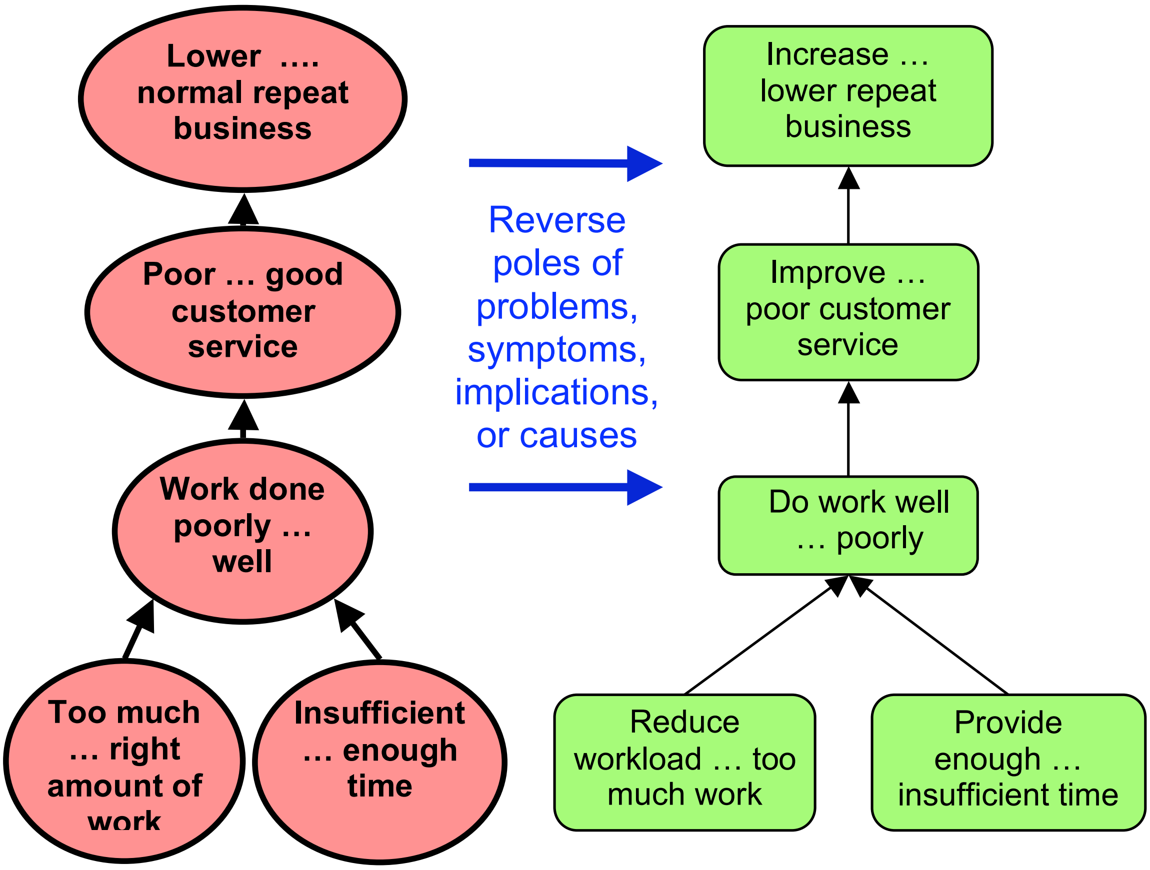


Figure 3: Example Conversion to an Initial Cognitive Map of a Problem as Solutions

In Solution Derivation, the initial CM of a problem as solutions is enhanced to explore different potential solutions and the consequences if someone were to implement one or more of the potential solutions. Solutions cause the reduction or elimination of causes and therefore indirectly solve or alleviate problems.

Figure 4 shows a general pattern for an enhanced cognitive map of solutions. The top three nodes in the pattern (marked with asterisks) represent all the nodes derived in the CM Conversion step. The other nodes in the pattern represent the ones that are added during Solution Derivation. There may be multiple instances of each kind of node given in the general pattern, such has more than one potential solution, many nodes showing details of how to support the solution, or many other consequences of implementing the potential solution.

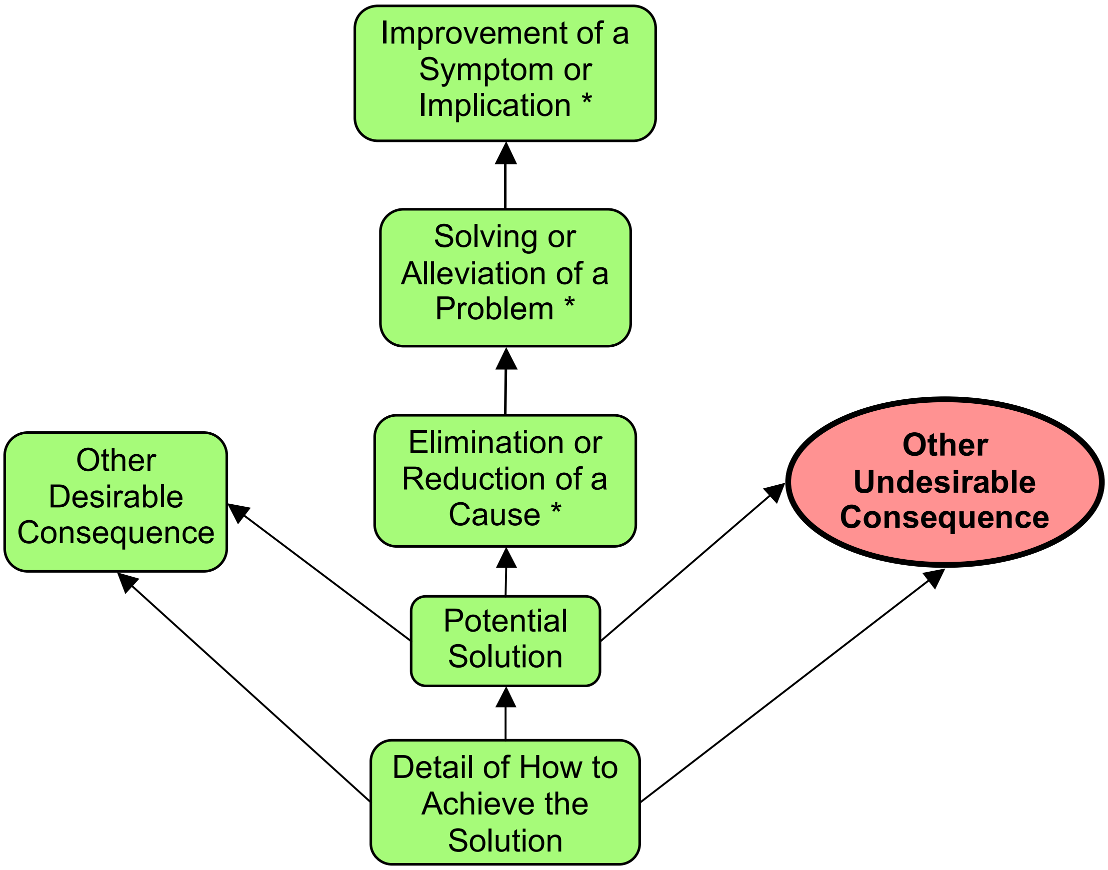
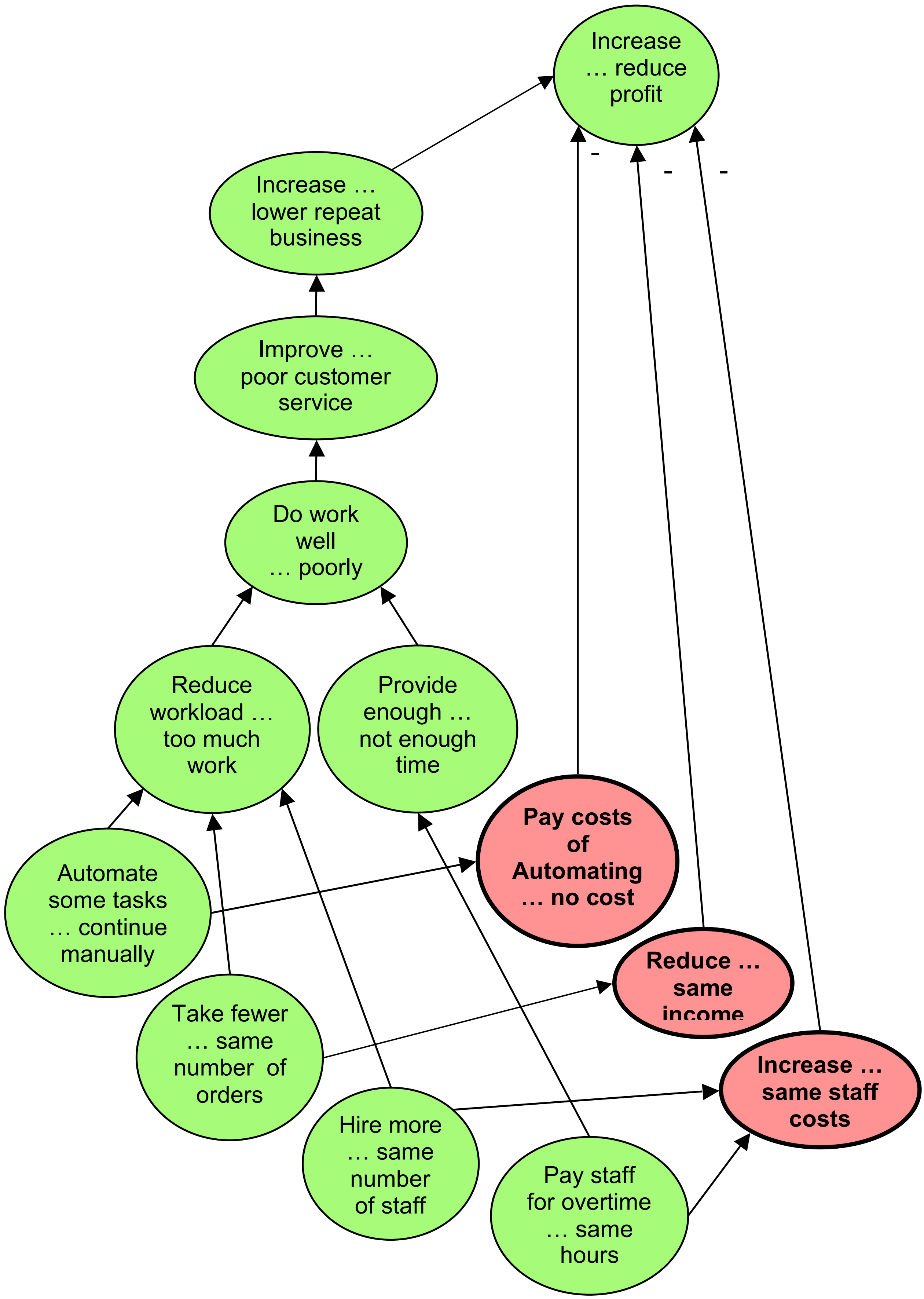


Figure 4: General Pattern for an Enhanced Cognitive Map of a Problem as Solutions

Figure 5 shows an example of an enhanced cognitive map of a problem as solutions, i.e. with the solution nodes filled out and the potentially undesirable consequences of proposed solutions considered. We can see that there are both desirable and undesirable consequences of the potential solutions. The diagram gives a good perspective for understanding the benefits and costs of the potential solutions and how they trade off against each other.


Increase … reduce profit
Increase … lower repeat business
Improve … poor customer service
Do work well … poorly
Reduce workload … too much work
Provide enough … not enough time
Pay costs of Automating … no cost
Automate some tasks … continue manually
Reduce … same income
Take fewer … same number of orders
Increase … same staff costs
Hire more … same number of staff
Pay staff for overtime … same hours
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-
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Figure 5: Example Enhanced Cognitive Map of the Problem as Solutions

Contribution of CCM to Solving Problems with Problem Formulation

As we saw earlier, Dumdum (1993) proposed six problems with problem formulation, to which we added a seventh. In this section, we explore the potential contribution of Coloured Cognitive Mapping to solving these problems.

1. **Insufficient attention to problem formulation**
   Using CCM explicitly gives attention to important aspects of 'the problem'.
2. **Bounded (limited) rationality**
   Pictorially representing how concepts relate to each other reduces complexity. Also, engaging in a group process exploring different perceptions and suggestions draws on the rationality of multiple participants. Further, utilising computer support (e.g. Decision Explorer or Group Explorer – see http://banxia.com) aids editing and analysis.
3. **The self-sealing tendency**
   Use of CCM encourages reasoning and discussion rather than premature closure.
4. **Unchallenged assertions**
   Assertions about solutions can be placed in context within diagram. Drawing links brings the attention of group members. Group processes then allow for questioning of assertions.
5. **Lack of issue management**
   Open issues still need full discussion, but incomplete nodes and links indicate issues for further discussion.
   Facilitator keeps a list of open issues for discussion
6. **Lack of common (shared) understanding**
   Collaborative development and exploration of CCMs helps people to share their perceptions and learn about others' perceptions, whether the CCMs are developed individually and merged or whether CCMs are developed collaboratively.
7. **Lack of common (shared) language and culture**
   The use of CCMs helps people learn about other stakeholders' language and culture. This comes about through explanations of CCMs as they are developed or merged.

Conclusions

In this paper we have asserted the importance of properly accomplishing the very first stages of IS Development – that of adequately exploring the problems to be solved by an ISD effort before deciding on a solution and trying to implement it. We have focussed on the difficulties inherent in that effort and some existing solutions to that effort. In particular we have proposed that Coloured Cognitive Mapping could be usefully employed to improve the effectiveness, efficiency, efficacy, (a)esthetics, and ethicality (Checkland, 1981) of ISD. The use of CCM could reduce the problems of problem formulation (Dumdum, 1993) explored in this paper.

References

Ackermann, F. and C. Eden (2001) SODA – Journey Making and Mapping in Practice, Chapter 3 in *Rational Analysis for a Problematic World Revisited*, J. Rosenhead & J. Mingers (eds.), John Wiley & Sons, Chichester.

banxia.com (n.d.) http://banxia.com (accessed 30 October 2005).

Checkland, Peter B (1981) *Systems Thinking, Systems Practice*. Chichester: Wiley.

Checkland, Peter B and Scholes, J (1990) *Soft Systems Methodology in Action*. Chichester: Wiley.

Eden, C. (1988) Cognitive Mapping, *European Journal of Operational Research*, Vol. 36, pp. 1 – 13.

Eden, C. and F. Ackermann (2001) SODA – The Principles, Chapter 2 in *Rational Analysis for a Problematic World Revisited*, J. Rosenhead & J. Mingers (eds.), John Wiley & Sons, Chichester.

Roberts, Peter (1994) Systems and the Problematique, *Futures*, Vol. 26, No. 7, September, pp. 730-740.

Venable, John R. "Coloured Cognitive Maps for Modelling Decision Contexts", *Proceedings of the First International Workshop on Context Modeling and Decision Support*, Paris, France, 5 July 2005, CEUR Workshop Proceedings, ISSN 1613-0073, online http://CEUR-WS.org/Vol-144/03_venable.pdf (accessed 30 October 2005).