IMPROVING REQUIREMENTS ANALYSIS
Rigourous Problem Analysis and Formulation with Coloured Cognitive Maps

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Abstract: This position paper argues that methodical and rigourous attention to problem formulation should be an essential part of requirements analysis and proposes a method for modelling problems and potential solutions. Currently, most IS Development Methodologies ignore the issue of problem formulation. Furthermore, in practice, most IS development projects ignore or pay little attention to this issue. In this paper we argue that the resulting lack of proper problem analysis and formulation is a major cause of IS failures. In place of this lack of attention, this paper proposes and reports on research in progress on the development and evaluation of a new technique, Coloured Cognitive Maps (CCM), for use in problem formulation at the early stages of Information Systems Development. The notation of coloured cognitive maps and a procedure to use them for problem analysis and solution derivation are briefly described. Initial anecdotal results in employing CCM by students and practitioners are briefly described.

1 INTRODUCTION

The IS/IT field is the poor track record of system development and introduction. Information Systems Development (ISD) projects commonly (1) are late and over budget, (2) deliver a system that doesn't meet requirements, cannot be used as intended, is hard to use, or is completely unusable, or (3) fail to deliver a system altogether (project never completed). High failure rates in ISD are widely recognised.

Methodological solutions proposed for these problems address various perceived causes. Design and software engineering methodologies address technical difficulties in making complex systems work properly to insure that requirements are properly translated into designs and implementations. Requirements analysis methodologies precisely state requirements and ensure that they correct and consistent. Project management methodologies aim to overcome poor estimation of time and costs, scope creep, and poor project planning and control. To varying degrees, all of the above try to address changing needs during development.

However, we assert that many failures are due to poor 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. This lack of attention to problems and the organisational situation leads to poor understanding of the problem(s), often to solving the wrong problem(s) (also known as an error of the third kind, Mitroff and), and commonly to poor acceptance and adoption of system(s), a major form of IS failure. None of the above types of methodologies address this issue.

It is the contention of this position paper that absent or cursory problem analysis and formulation is a key weakness in system development. Problems are sometimes completely unstated. Often, they are only weakly examined. Typically, 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. Proposed solutions are then accepted for IS Development without consideration of the proposed systems' effectiveness in solving the unstated

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problem(s) or addressing the needs of various different stakeholders.

Instead, this paper proposes that methodical and rigourous 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 should then incorporate effective transition from problem definition to solution generation, choice, and implementation (via detailed IS development and installation). While some important work has been done in this area (e.g., Soft Systems Methodology, Checkland, 1981, Checkland and Scholes, 1990 and Multiview, Wood-Harper et al., 1985, Avison & Wood-Harper 1990 – see below), it is still an area of perennial weakness and in need of much more attention.

2 ADDRESSING PROBLEMS WITH PROBLEM FORMULATION IN ISD

Various methods and techniques have been proposed that address problem formulation.

An important, relevant method is Soft Systems Methodology (SSM) (Checkland 1981, Checkland & Scholes 1990, Checkland and Holwell, 1998). SSM is a general problem solving method 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, although Checkland and Holwell (1998) do so.

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.

The Multiview methodology (Wood-Harper et al. 1985, Avison & Wood-Harper 1990) incorporates Rich Pictures. 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. 1985, Avison & Wood-Harper 1990).

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.

However, none of the above methods have a technique for formally and rigourously modelling problems and their causes. A form or modelling that includes causal analysis is needed. Fortunately, other work addresses this need.

Problematiques (Roberts 1994) are a diagram for causal analysis that can be used to explore a problem or group of problems, their causes, and their consequences. The technique consists of nodes and links, where the nodes are succinct statements of parts of problems and the links being arrows from a cause to a consequence of that cause. However, problematiques are somewhat limited in their semantics compared to Cognitive Maps, as described in the next paragraph.

Cognitive Maps (Eden 1988, Eden & Ackermann 2001, Ackermann & Eden 2001) were developed primarily for strategy development, not for problem analysis. 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”). While this technique was not developed for problem analysis, the notation can be used to explore conceptualisations of problems and solutions at the front end of ISD.

Venable (2005) proposed a new form of cognitive maps, called Coloured Cognitive Maps (CCMs) to address the above issue and added various enhancements, including: (1) a conceptualisation of two forms of problem statements and corresponding forms of coloured cognitive maps: problems as difficulties, which focus on the current undesirable or problematic situation and problems as solutions, which focus on statements of some different, 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, and (4) an overall process for problem analysis with cognitive maps.

CCM supports rigourous problem diagnosis and formulation through drawing a model of the problem as difficulties. CCM also supports derivation of alternative problem solutions, which could include

IS solutions and their features. Through the use of the CCM method, problem solutions and their features are rigourously related back to the original problem. The method supports contrasting of different solutions as to how they apply to solving the different aspects of the problem(s) to be solved. Therefore, it also supports contrasting of alternatives for decision making.

3 COLOURED COGNITIVE MAPPING FOR REQUIREMENTS ANALYSIS

Based on the above advantages, we propose that Coloured Cognitive Mapping (Venable, 2005) could be used effectively to support methodical and rigourous problem formulation at the front end of Requirements Analysis in ISD. We will now briefly summarise the notation and mapping process for using Coloured Cognitive Maps (Venable 2005).

3.1 Notation

Two symbols are used in coloured cognitive maps: nodes and arrows (see figure 1). 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, darker shading, or a different node shape for undesirable nodes, as shown in figure 1 below.

Nodes are connected to each other with arrows. 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.

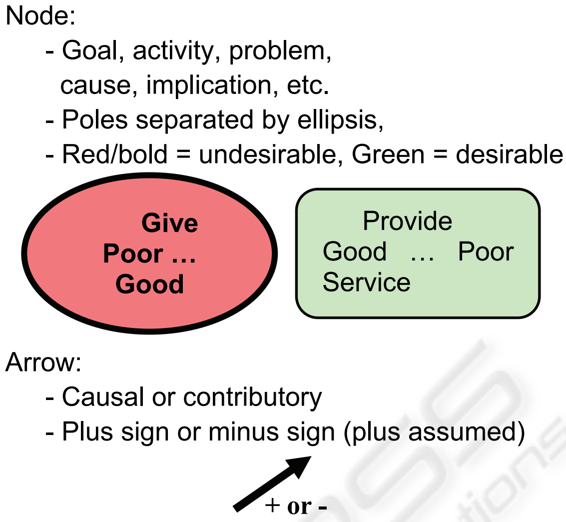

Figure 1: Coloured Cognitive Mapping Notation.

Table 1: Synonyms for the meaning of the arrow.

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

Arrows may optionally have plus or minus signs attached to them. If there is no sign, a plus sign is assumed. If a minus sign is attached, the node at the tail prevents (rather than causes) 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.

3.2 A 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 CCM Conversion, which converts 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

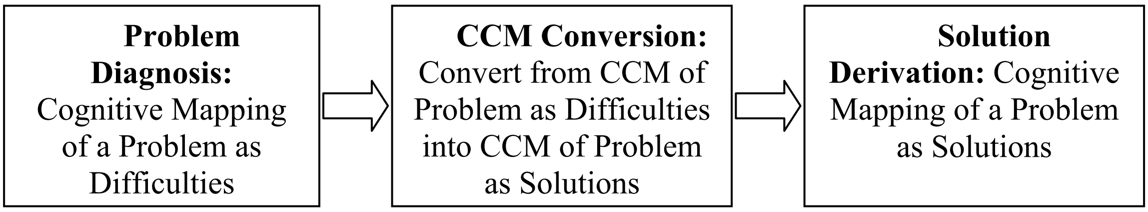

Figure 2: Procedure for Problem Analysis with Cognitive Maps.

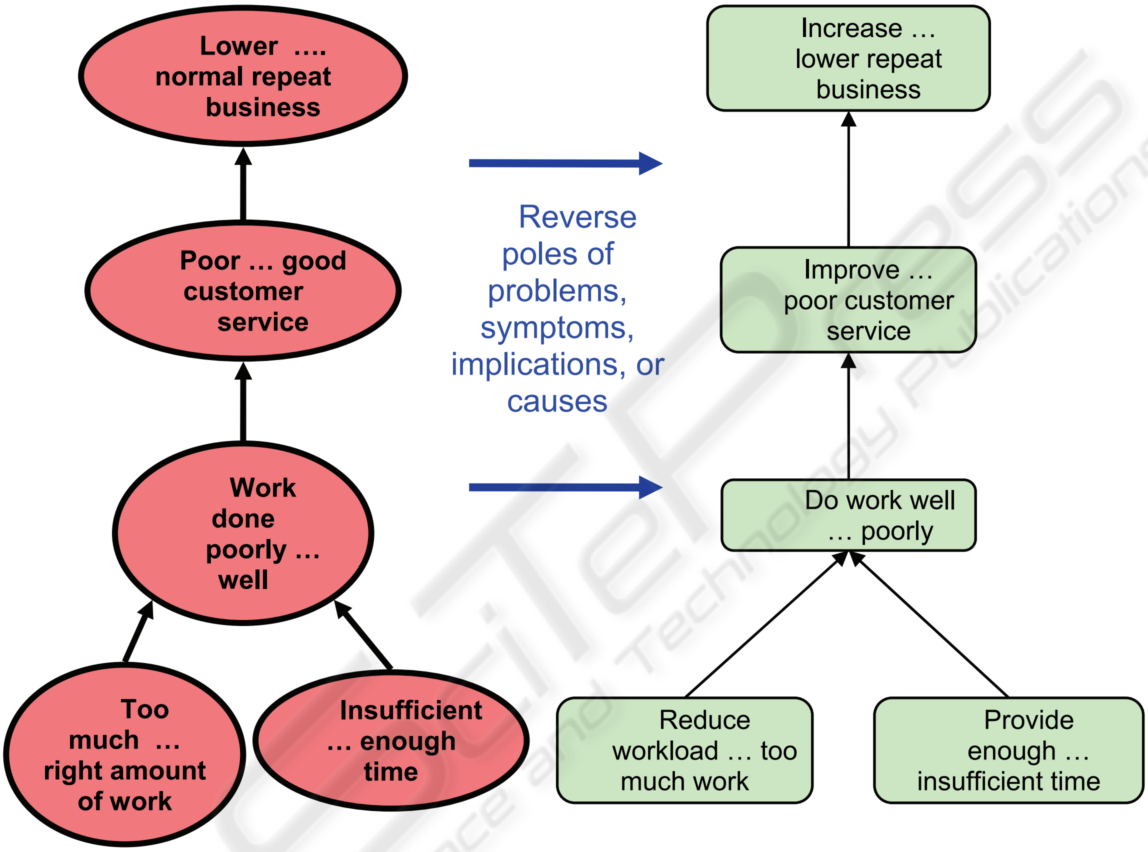

Figure 3: Example Conversion to an Initial Cognitive Map of a Problem as Solutions.

map of the problem as solutions is expanded with various candidate or potential solutions.

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 CCM of the problem as difficulties into an initial CCM of the problem as solutions. Figure 3 below shows an example. This step is a (nearly completely) mechanical process of changing every node in the CCM 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. The example is of course extremely simplified compared to a normal problematic situation.

In Solution Derivation, the initial CCM 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.

In the case of using CCM to support Requirements Analysis for IS Development, Solution Derivation would add nodes pertaining to IS solutions to the problems at hand. In the example given in figure 3, nodes would be added showing means for reducing workload or providing enough time. One can imagine various different IS-based means for reducing workload. Placing them on the diagram allows one to visualise what problems will be solved or reduced by an IS solution, and what consequences there will be of introducing an IS solution. Of course, one must also ask what other consequences there might be, some of which might be undesirable.

One can also consider alternative candidate solutions and analyse tradeoffs or one alternative vs. others through the use of the CCM diagram of the problem as solutions.

Thus, using CCM can be helpful for rigourously and systematically analysing a problematic situation and considering potential IS (or other) solutions.

4 RESEARCH PROGRESS

The author has taught the CCM technique to one of the principal owners/operators of a small company engaged in IT infrastructure and systems development, who have introduced CCM into their organisational practice. The owners report that use of the technique is straightforward and easily learned and adopted by their staff. They also report significant (ca. 20%) drops in project completion time, due to fewer problems being encountered during projects that use the technique.

While the above initial result is encouraging, much more rigourous and detailed evaluation of the technique is needed. We plan to undertake action research so that we develop a richer understanding of CCM in use.

5 CONCLUSION

This paper asserts the importance of methodically and rigourously analysing and formulating the problem(s) to be solved when analysing requirements for solution via IS Development – before deciding on a solution and trying to implement it. In particular we have proposed that Coloured Cognitive Mapping could be usefully employed to improve the efficiency, effectiveness and efficacy of ISD.

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