A Third Way Between Hard and Soft Methodologies

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ABSTRACT

This paper examines the two extremes of hard and soft systems methodologies and discusses the merits of each approach. It then suggests how the better attributes of the two approaches can be realised with a third way combining the elements of both. The advent of more powerful computing technologies allows a more broadly based approach to decision processes than a strict algorithmic one.

Areas of application to be discussed include yield management and financial management. Specific examples are discussed and computational implementation described.

Keywords: Hard Systems, soft systems, nonlinear programming, asset allocation, yield management.

INTRODUCTION

The seminal contribution of Checkland (1980) was the 'soft systems methodology' that has since taken a place in the range of approaches to systems problems. Checkland himself made the contrast with the 'hard' approaches characterised by traditional, technology-oriented systems analysis and design. The approach of this paper is to reflect on the middle path that we have adopted and found to be effective both in teaching and practice. This paper reviews the 'hard' approaches of information theory, decision theory, operations research and management science, and systems analysis and design. We then examine the key constructs of the soft approach of Checkland, before introducing the 'third way' where we are indebted to the work of Daellenbach. The paper concludes with examination of application in the areas of yield management and asset allocation.

We see the contrast of 'hard' and 'soft' in part to be concerned with the philosophical approach to investigation. The positions of the positivist and interpretivist epistemologies are the subject of intense study for doctoral students, philosophy students and some researchers. However, it is seldom seen as a battleground in its own right. The issues are transferred to methods and methodologies that are developed and applied in particular domains of research and investigation. Collections of methods become "schools of thought" or "accepted professional practice" that are then applied in routine approaches to classes of problems or tasks. Breaking out of the accepted approach can be seen to be heretical and the use of the word paradigm, in the strict sense of Kuhn (1962) is appropriate.

HARD APPROACHES

Information theory exemplifies the hard approach to 'information' where the human, organisational and contextual sense of information is inappropriate. By virtue of its name alone, any approach to theoretical considerations of information is led towards information theory, which appears to suggest itself as a core formulation. The information theory originally proposed in 1948 by Shannon (Shannon and Weaver, 1949) is a mathematical theory of coding rather than a theory that gives any sense of value to information in its widest view. Information theory enables a data coding mechanism to be examined to determine the proportion of a message that will contain relevant, unique data (information) and the remaining proportion that is redundant. The information content of a message, I, is defined as the number of bits required to identify the message. If there are n alternative messages with probabilities p_i, for i = 1, 2, . . . n, then:

$$I = -\sum_{i=1}^{i=n} p_i \log_2 p_i$$

From this it is possible to create coding methods that are in some sense optimal. They may contain the salient data in the minimum message size.

Similarly, from its name alone, **decision theory** creates an expectation that it can deal with the complex decisions in an organisation. Probabilistic models are used in decision theory to examine the decision maker's value for the alternative outcomes and the decision maker's propensity for risk taking so that a more realistic scene was being modelled. However, the mathematical and statistical nature of the formulation has condemned decision theory, like information theory, to use in restricted situations where the models and assumptions are more realistic. In many situations faced by decision makers in organisations, the idea of probability as the measure of uncertainty is not acceptable; there will be no opportunity for, or even concept of, repeated experiments being available from which to determine probabilities. In addition, the complexity of the outcomes may mean that evaluating the effects of particular outcomes is impossible.

A more important limitation for decision theory is its emphasis on the individual decision maker. In an organisational setting, several individuals or groups may be involved in decisions, with their own sets of values, beliefs about the outcomes and, most importantly, power to affect the decision making process. Recent work in group decision support systems makes some progress in the area, in terms of creating models and systems that allow groups of people to collaborate in decision making. But the underlying formulation in terms of probability models for uncertainty and mathematically expressed models for values of outcomes restricts their application.

Operations research and **management science** are widely viewed as 'hard' disciplines, where quantitative data are processed through rigorous, mathematically formulated models. Practitioners in these areas tackle problems that arise in management decision making, by building models to represent the situation. Both stochastic and deterministic models may be developed, with estimation, allocation, optimisation, scheduling and similar words being used to describe the objective of the decision maker. Data is used to activate the models and solutions are derived that may be tested for their robustness and sensitivity by similar formal, mathematical techniques. To those with a positivist, scientific point-of-view, these processes are reasonable, scientific and as rigorous as the model and the data permit.

The most familiar of the OR / management science approaches are applied to systems only indirectly. The inventory control problem, for example, is concerned with representing a system where inventory levels rise and fall according to replenishment and utilisation, with management control input determining the reordering rules to be applied. Textbook approaches ignore the complexities of the situation and establish rules that may be applied mechanically to day-to-day inventory levels, with these rules sufficiently clear that they may be embodied in inventory management software. In many situations this may be satisfactory, however system-wide effects can seriously disturb the effectiveness of the model, as Senge (1990) describes.

> More often that we realise, systems cause their own crises, not external forces or individual mistakes (Senge, 1990, p.40).

Perhaps we should attribute this to the 17th century foundation work of Descartes, which argued strongly for 'analysis' followed by 'synthesis' as a problem solving method.

> Divide each of the difficulties . . . into as many parts as might be possible and necessary in order to solve it (Descartes, 1968 translation, p.41).

When we look at the 'hard' approach to systems, the **systems analysis and design** approaches, formalised by the RAND Corporation are the backbone of many approaches still adopted today in the development of computer-based information systems - the over-riding model being 'providing information for decision-making'. The method is summarised by Checkland (1980):

> 1. An objective or objectives we desire to accomplish.
>
> 2. Alternative techniques or instrumentalities (or 'systems') by which the objective may be accomplished.
>
> 3. The 'costs' or resources required by each system.
>
> 4. A mathematical model or models; i.e. the mathematical or logical framework or set of equations showing the interdependence of the objectives, the techniques and the instrumentalities, the environment, and the resources.
>
> 5. A criterion, relating objectives and costs or resources for choosing the preferred or optimal alternative. (p.136)

This clearly demonstrates the positivistic, mathematical approach, where there is a truth 'out there' that we can approach by developing models. Such an approach is demonstrated frequently in textbooks such as Bodily (1985).

SOFT APPROACHES

Peter Checkland's work (Checkland, 1980; Checkland and Scholes, 1990) represents the landmark in soft approaches to problem solving, where systems are taken to be the fundamental unit of investigation and systems models are developed to facilitate desirable changes in the real world situation. The methodology is summarised as a cycle of activities:

1. The problem situation unstructured
2. The problem situation expressed
3. Root definitions of relevant systems
4. Conceptual models (drawing on formal systems concepts and other systems thinking)
5. Comparison of 4 (conceptual models) with 2 (problem situation expressed)
6. Feasible, desirable changes
7. Action to improve the problem situation (adapted from Checkland, 1980 , page 163)

The cycle can continue to operate with different activities taking place at the same time. The approach is one of action research where an iterative approach leads towards some resolution of the problem situation.

The classes of problems dealt with are broad and there has been significant adoption in the area of information systems design.

Tools developed by Checkland for the soft systems methodology (SSM) include 'rich pictures' and 'root definitions', employing the use of the CATWOE mnemonic. A rich picture is a cartoon-like representation of the problem situation, created to show a synoptic view, embodying the essential complexity and the underlying conflicts. Root definitions are developed abstractions that attempt to show the underlying systems in the situation. For their completeness they are compared with the CATWOE (customers, actors, transformation, Weltanschauung, operators, environment) schedule.

While the SSM approach has had some successes, particularly in Britain, it has not seen widespread adoption. However, the tools of SSM have had a wider acceptance and help form the basis for the 'third way'.

THE THIRD WAY

Hans Daellenbach has brought together the systems tools of SSM and the traditional management science mathematically-based methods in a pragmatic marriage that enables quantitative tools to be used while maintaining a systems view (Daellenbach, 1995). This approach has been adopted in teaching MBA students where rich pictures are used to surface the complexity of a situation and identify the underlying conflicts or inconsistencies. The placement of the problem in a nexus of interlocking systems already offers the student a better perspective. It brings out issues of power, interpretation and alternative viewpoints. The move from the rich picture to a particular quantitative model is then highlighted for the drastic simplification that it may be.

As a bridge between the complexity and depth of detail in the rich picture, and the stark mathematical model, it has been useful to develop influence diagrams as an intermediary tool. These retain the systems features but are more readily accepted into rigorous model formulation.

In a typical problem, students (typically middle managers) will use rich pictures to scope the field and influence diagrams to describe the potential interaction of management decisions with the on-going systems. Quantitative data is then used on adjacent items in the influence diagrams to inform further discussion. Whatever quantitative results are obtained, they are then interpreted using the rich picture as the reference frame. This approach has obtained wide acceptance from students, who value being able to balance rigour with interpretation.

Having achieved some success with students, we have used this approach in some research areas, most notably yield management and asset allocation.

YIELD MANAGEMENT

Yield management is the task of deciding how to optimise the expected return from products which are perishable. In particular the nature of airline seats, hotel rooms, rental cars and other time-sensitive products is such that in the passage of time their value reduces abruptly to zero; once the flight has departed, or the day or night passes, the product no longer can be sold at all for that period. In endeavouring to sell more units by offering a discount, the problem arises of deciding how many units to protect at the full price for customers who are willing to pay it (and are assumed to book later than the discount customers). The problem grows in size and complexity with several levels of discount, however it is common practice to have multiple discount classes particularly in the airline industry.

A rich picture of all the aspects to be considered from a systems point of view would contain many quantitative sub-pictures. All these could be considered on a piecemeal basis, and would provide a contribution to part of the picture. A model of each issue is tractable, and would be solvable within itself. The first quantitative model would be forecasting of demand for each level of discount. Further than that would be not just a single expected value but a probability density curve showing the probabilities of occurrence as a function of demand.

A further unknown , but at least estimable in terms of a probability distribution, would be the probability of 'sell up' , i.e. the customer paying the next higher rate if space at a particular discount level is unavailable.

Another part of the rich picture is the optimisation model where, given the above probability distributions, the model optimises the number of spaces to make available at each discount level, known as the protection level. The objective function would contain complex integrals representing the expected value of total revenue as a function of protection levels for the different discount classes. The complicating factor is the concept of "nested protection", where a customer in a higher cost class is not refused any unit as long as there are units available in any of the discount classes.

There is a significant body of research on this latter problem. Belobaba (1987) examined the concept of nested protection in the airline industry, and developed a heuristic approach labelled the Expected Marginal Seat Revenue model. This compared the expected revenue to be gained from one more seat protected for the higher fare class versus allowing it to be sold at a lower fare.Curry (1990) used a continuous distribution and expressed his result in terms of a convolution integral.

Recent work (Mitra and Murtagh, 2000) has involved using the equations directly as the objective function in a nonlinear integer programming model. This approach has the advantage of allowing side conditions to be imposed on the solution rather than relying on general optimality conditions of a solution. These side conditions appear as explicit constraints in the optimisation model, and may include user-specified upper and lower limits on protection levels. They may also include more general limits on the proportions of units in each discount class in relation to each other, for example the protection level for the full cost class be at least sixty percent of the protection level for the first discount class. The model has been implemented for a total of nine fare classes, consisting of three groups of three nested protection levels.

ASSET ALLOCATION

A major area of investigation in the field of finance is that of asset allocation, particularly in more recent times where technology allows the rapid transfer of funds both internationally and between asset classes. The emergence of day traders in the capital markets is testimony to the ease of funds transfer.

Components of a rich picture that would be identifiable as having a quantitative element would include probability estimates for both upside and downside risk, and also financial tools for offsetting risk such as futures and options. Pareto curves for risk and reward represent a very early venture down the path of obtaining a systems viewpoint insofar as they portray the interactions of competing ideals in asset allocation.

Obtaining a Pareto curve for risk and reward for the asset allocation problem in funds management involves solving a sequence of optimisation problems where the objective is to minimise some (nonlinear) definition of risk, subject to the requirement that the expected return from the optimised solution exceeds a sequence of specified target returns. There are other constraints as well, such as the requirement that the allocation of funds to each asset class satisfies upper and lower limits, and the change in funds allocated to a particular asset class in each time period be within a specified limit. There is also of course the requirement that the allocations in each class sum to the total funds available.

For the objective function the preferred representation is one of downside risk i.e. minimising the likelihood of downside movement from expected value. Raw data iscollected and used in the form of accumulation indices reflecting capital gain and dividend reinvestment. Returns are measured by the relative movement of indices over each time period. In determining the likely performance of individual sectors for the next period in the future a state-space vector version of an auto-regressive integrated moving average forecasting technique may be used (Dunsmuir & Murtagh, 1993).

CONCLUSIONS

This paper has attempted to show a third way for systems thinking via the use of rich pictures, where quantitative aspects of parts of the picture may be dealt with using the 'hard' algorithmic approach, but the perspective of each contribution is held in check by the rich picture viewpoint. Different scenarios can be explored easily with power of recent hardware advances and improved software capabilities.

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