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Decision biases and decision support systems development

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Abstract. The view of decision-making that has informed most decision support systems research has been Simon's process theory. Further, the majority DSS work has focussed on the choice phase of Simon's model of decision-making. Decision bias theory does not focus on the choice process but considers the possibility of systematic and persistent errors in all phases of judgement and decision-making. Decision biases are cognitions or mental behaviours that prejudice decision quality in a significant number of decisions for a significant number of people. Using a general model of DSS development, the incorporation of decision biases into DSS development is addressed under two strategies: general debiasing, where a bias rather than a task is the development focus, and using biases as a focusing construct during a specific DSS engagement. The later approach is likely to be the most important in practice. An action research study of a bias focused DSS project is presented, which indicates that the use of biases as a central theme in DSS development can be effective in delivering a system, and ultimately a decision outcome, that is of value to the client.

Keywords: decision support systems, systems development, decision bias, cognitive bias, behavioural decision theory, action research

1. Introduction

Decision support systems (DSS) is the area of the information systems discipline that is devoted to supporting and improving human decision-making. Over time the majority of DSS research has focused on the application of new technology to managerial tasks at the operational and tactical management levels (Raghavan & Chand, 1988; Eom & Lee, 1990; Mallach, 2000). Major changes in technology have acted to create new decision support movements: financial modelling software and spreadsheets created a boom in personal decision support systems in the early 1980s; five years later, multi-dimensional modelling and OLAP technology enabled the deployment of large executive information systems; and advances in storage technology and networks in the mid-1990s led to the data warehousing and business intelligence movements.

Despite this substantial technical progress, laboratory experiments investigating the influence of decision support systems on decision performance have reported mixed, often disappointing, outcomes (Benbasat & Nault, 1990). In contrast to the experimental results, results from case study research show that a focus on decision-making and tailored support can lead to successful systems (Keen & Gambino, 1983; Suvachittanont, Arnott & O'Donnell, 1994; Niehaus, 1995; Rigby et al., 1995; Courbon, 1996; Igbaria et al., 1996; Botha et al., 1997). One implication of these studies is that to be effective in decision support a systems analyst should have considerable knowledge about human decision processes and how to improve them.

Decision support systems theory has been dominated by the process-oriented model of decision-making associated with the Nobel Laureate Herbert Simon (Simon, 1955, 1956, 1960). Simon's model was an integral component of the

framework that first defined decision support systems (Gorry & Scott Morton, 1971) and was part of the theoretical foundation of the most influential early DSS books (Keen & Scott Morton, 1978; Sprague & Carlson, 1982). Despite the importance of Simon's original theory to the history of DSS, more recent contributions to decision-making theory need to be better integrated into decision support systems theory and practice. Angehrn and Jelassi (1994) argue that Simon's theory "has become a serious obstacle for the evolution of DSS theory and practice" (p. 269). Elam Jarvenpaa and Schkade (1992) argued that recent research on behavioural decision-making needs to be integrated with research on the effect of DSS on decision-making.

The aim of this paper is to contribute to DSS development theory and practice by using research on systematic errors in decision-making and judgement as a foundation for systems development. The paper is organised as follows: first, the concept of decision biases is discussed, as well as a number of debiasing strategies. A taxonomy of biases that is useful for DSS systems analysis is presented. A general framework of decision support systems development is described and this is used to structure the discussion of the relevance of decision biases to the decision support systems development process. An action research study of bias-focused development is then reported. Finally, the implications for practice and some propositions for further research are identified.

2. Decision biases

Behavioural decision theory, an area of cognitive psychology, is concerned with how and why humans make decisions the way they do (Yates 1990). One aspect of behavioural decision theory that is of potential value to DSS researchers and

systems analysts involved in developing DSS is the notion of predictable bias in decision-making. Decision biases are cognitions or mental behaviours that prejudice decision quality in a significant number of decisions for a significant number of people, i.e. they are inherent in human reasoning. They are also called cognitive biases and judgement biases. One way of viewing decision biases is to consider that they are predictable deviations from rationality. A rational choice is one based on the decision maker's current assets and the possible consequences of the choice (Hastie & Dawes, 2001, chap. 1). The word bias has a somewhat misleading meaning, as the action of biases is generally a source of decision effectiveness. However, they can have a negative effect and it is the tendency of biases to lead to poor outcomes in important and novel decisions that is relevant to systems analysts working in a decision support role.

Many decision biases have been identified and 37 biases are classified in Table 3. An example of a common decision task illustrates the importance of decision biases for DSS. The scenario is taken from Bazerman (2002, p 12). Imagine that you are a systems analyst supporting a manager in a department store chain with nine locations. The chain depends on the manager you are supporting for quality projections of future sales in order to make decisions regarding staffing, advertising, information systems development, purchasing, and renovation. All stores are similar in size and merchandise selection. The main difference in their sales occurs because of location and random fluctuations. Sales for the base year are shown in Table 1. The company's economic forecasting service has advised that the best estimate of total sales increase between the base year and next year is 10%. Your task is to provide a model that predicts next year's sales for each store. Because your manager believes strongly in the economic forecasting service, it is imperative that

your sales column for next year sums to \$99,000,000. What process or formula will you use to generate the forecasts?

Table 1. The Store Forecast Problem

Store	Base Year (\$)	Next Year (\$)
1	12,000,000	?
2	11,500,000	?
3	11,000,000	?
4	10,500,000	?
5	10,000,000	?
6	9,500,000	?
7	9,000,000	?
8	8,500,000	?
9	8,000,000	?
Total	90,000,000	99,000,000

Decisions similar to the store forecast problem are regularly made in all organizations and many managers use spreadsheets to support such decisions. The 'copy and paste' of a formula from a base year column to the next year column is one of the most common spreadsheet development processes. When shown the store forecast problem many people specify a formula that increases each store's sales by 10% for the forecast year. This is shown in Table 2 as Forecast A. In making a forecast in this scenario a person is deciding on the likely relationship between base and target year sales, that is, they are making a meta-decision of statistical correlation. People who make Forecast A have decided that the base year is a perfect predictor of the following year. Forecast B in Table 2 shows the other correlation extreme where the base year sales are no predictor of the future. Both Forecast A and B are highly unlikely to be correct. All else being equal, the most

likely situation is for store sales to regress to the mean (Einhorn & Hogarth, 1981; Joyce & Biddle, 1981).

Table 2. The Forecasts

Store	Base Year	Forecast A	Forecast B	Forecast C	Forecast D
1	12,000,000	13,200,000	11,000,000	13,000,000	12,833,333
2	11,500,000	12,650,000	11,000,000	12,500,000	12,396,010
3	11,000,000	12,100,000	11,000,000	12,000,000	11,901,002
4	10,500,000	11,500,000	11,000,000	11,500,000	11,352,068
5	10,000,000	11,000,000	11,000,000	11,000,000	11,000,000
6	9,500,000	10,400,000	11,000,000	10,500,000	10,534,290
7	9,000,000	9,900,000	11,000,000	10,000,000	10,101,070
8	8,500,000	9,350,000	11,000,000	9,500,000	9,642,197
9	8,000,000	8,800,000	11,000,000	9,000,000	9,240,030
Total	90,000,000	99,000,000	99,000,000	99,000,000	99,000,000

Regression to the mean is a common effect in many populations; tall parents tend to have shorter children, a football team that scores 6 goals in a match is likely to score many fewer in the next, and it is likely in the current example that store sales will regress to the mean (\$11,000,000). A forecast that takes the regression effect into account is shown in Table 2 as Forecast C. Forecast D shows another set of store sales figures that regress toward the mean. The choice of Forecast D may be made not because of recognition of the regression effect but because it appears more logical in the sense that the dollar figures are not rounded to the nearest \$500,000; the figures simply appear more realistic. However, the forecasts in this column are no more likely than Forecast C. Choosing Forecast D can be due to another decision bias, the completeness bias (Hogarth, 1987) where the perception of an apparently complete or logical data presentation can stop the search for further data and create unwarranted confidence in the decision quality.

The regression and completeness biases are only two decision biases that are relevant to a systems analyst's understanding of the decision making process. Table 3 presents a taxonomy of decision biases where biases are classified into the categories of memory, statistical, confidence, adjustment, presentation, and situation biases. Memory biases have to do with the storage and recall of information. Statistical biases are concerned with the general tendency of humans to process information contrary to the normative principles of probability theory. Confidence biases act to increase a person's confidence in their prowess as decision makers. An important aspect of some the confidence biases is the curtailment of the search for new information about the decision task. Presentation biases should not be thought of as only being concerned with the display of data. They act to bias the way information is perceived and processed and as such they are some of the most important biases from a DSS standpoint. Situation biases relate to how a person responds to the general decision situation and as such they represent the highest level of bias abstraction. It is important to recognise that biases are not necessarily as discrete as a taxonomy implies, and that they are likely to significantly overlap in definition and effect.

Table 3. A Taxonomy of Decision Biases

Bias	Description	References
Memory Biases		
Hindsight	In retrospect the degree to which an event would have been predicted is often over-estimated	Fischhoff, 1982a; Buchman, 1985; Connolly & Bukszar, 1990; Polister 1989; Mazursky & Ofir, 1997
Imaginability	An event may be judged more probable if it can be easily imagined.	Tversky & Kahneman, 1974; Taylor & Thompson, 1982
Recall	An event or class may appear more numerous or frequent if its instances are more easily recalled than other equally probable events.	Tversky & Kahneman, 1973,1981; Combs & Slovic, 1979; Taylor & Thompson, 1982
Search	An event may seem more frequent due to the effectiveness of the search strategy.	Tversky & Kahneman, 1973,1974; Bazerman, 2002
Similarity	The likelihood of an event occurring may be judged by the degree of similarity with the class it is perceived to belong to.	Tversky & Kahneman, 1973; Horton & Mills, 1984; Joram & Read, 1996
Testimony	The inability to recall details of an event may lead to seemingly logical reconstructions which may be inaccurate.	Snyder & Uranowitz, 1978; Wells & Loftus, 1984; Ricchiute, 1997
Statistical Biases		
Base Rate	Base rate data tends to be ignored in judgment when other data is available.	Joyce & Biddle, 1981; Christensen-Szlanski & Beach, 1982; Fischhoff & Beyth-Marom, 1983; Bar-Hillel, 1990; Kleiter et al., 1997
Chance	A sequence of random events can be mistaken for the essential characteristic of a process.	Lopes & Oden, 1987; Wagenaar, 1988; Ayton, et al., 1989
Conjunction	Probability is often over-estimated in compound conjunctive problems.	Cohen et al., 1972; Bar Hillel, 1973; Yates, 1990; Teigen et al., 1996
Correlation	The probability of two events occurring together can be overestimated if they can be remembered to have co-occurred in the past.	Golding & Porer, 1972; Tversky & Kahneman, 1973; Alloy & Tabachnik, 1984
Disjunction	Probability is often under-estimated in compound disjunctive problems.	Cohen et al.,1972; Bar Hillel, 1973; Bazerman, 2002
Sample	The size of a sample is often ignored in judging its predictive power.	Tversky & Kahneman, 1971; Kahneman & Tversky ,1973; Nisbett et al.,1983; Sedlmeier & Gigerenzer, 1997
Subset	A conjunction or subset is often judged more probable than its set.	Tversky & Kahneman, 1983; Thuring & Jungermann, 1990; Briggs & Krantz, 1992

Table 3 cont. A Taxonomy of Decision Biases

Bias	Description	References
Confidence Biases		
Completeness	The perception of an apparently complete or logical data presentation can stop the search for omissions.	Fischhoff, Slovic & Lichtenstein, 1978; Hogarth, 1987
Control	A poor decision may lead to a good outcome inducing a false feeling of control over the judgment situation.	Langer, 1975; Greenberg, 1996; Hastie & Dawes, 2001
Confirmation	Often decision makers seek confirmatory evidence and exclude search for disconfirming information.	Fischhoff & Beyth-Marom 1983; Einhorn & Hogarth 1986; Evans 1989; Russo et al., 1996; Heath, 1996
Desire	The probability of desired outcomes may be assessed to be greater than actually warrants.	Einhorn & Hogarth 1986; Budescu & Bruderman 1995; Olsen 1997; Hastie & Dawes, 2001
Overconfidence	The ability to solve difficult or novel problems is often over-estimated.	Lichtenstein et al., 1982; Paese & Feuer, 1991; Russo & Schoemaker, 1992; Brenner et al., 1996, Yates & Lee, 1996; Keren, 1997
Redundancy	The more redundant and voluminous the data the more confidence may be expressed in its accuracy and importance.	Estes, 1976; Remus & Kotterman, 1986; Arkes et al., 1989
Selectivity	Expectation of the nature of an event can bias what information is thought relevant.	Schwenk, 1988; Kahneman & Tversky, 1972, 1973
Success	Often failure is associated with poor luck and success with the abilities of the decision maker.	Miller, 1976; Ross, 1977; Hogarth, 1987
Test	Some aspects and outcomes of choice cannot be tested leading to unrealistic confidence in judgment.	Einhorn, 1980; Christensen-Szalanski & Bushyhead, 1981
Adjustment Biases		
Anchoring & Adjustment	Adjustments from an initial position are usually insufficient.	Tversky & Kahneman, 1974; Joyce & Biddle, 1981; Einhorn & Hogarth, 1986; Chapman & Johnson, 1994; Ganzach, 1996
Conservatism	Often estimates are not revised appropriately on the receipt of new significant data.	Sage, 1981; Fischhoff & Beyth-Marom, 1983; Nelson, 1996
Reference	The establishment of a reference point, or anchor can be a random or distorted act.	Tversky & Kahneman, 1974; Bazerman, 2002
Regression	That events will tend to regress toward the mean on subsequent trials is often not allowed for in judgement.	Kahneman & Tversky, 1973; Joyce & Biddle, 1981

Table 3 cont. A Taxonomy of Decision Biases

Bias	Description	References
Presentation Biases		
Framing	Events framed as either losses or gains may be evaluated differently.	Tversky & Kahneman, 1981,1986; Kahneman & Tversky, 1979,1984; Christensen, 1989; Wang, 1996; Kunberger, 1997
Linear	Decision makers are often unable to extrapolate a non-linear growth process.	Bar-Hillel, 1973; Wagenaar & Timmers, 1979; Mackinnon & Wearing, 1991
Mode	The mode and mixture of presentation can influence the perceived value of data.	Remus, 1984; Saunders & Jones, 1990; Carey & White 1991; Vessey 1994; Dusenbury & Fennma 1996
Order	The first item presented or the last may be over-weighted in judgment.	Anderson 1981; Yates & Curley, 1986; Chapman, Bergus & Elstein, 1996
Scale	The perceived variability of data can be affected by the scale of the data.	Remus 1984; Ricketts 1990
Situation Biases		
Attenuation	A decision making situation can be simplified by ignoring or significantly discounting the level of uncertainty.	Beer 1981; Hogarth 1987
Complexity	Time pressure, information overload and other environmental factors can increase the perceived complexity of a task.	Payne, 1982; Pitz & Sachs, 1984; Yates, 1990; Maule & Edland, 1997; Ordonez & Benson, 1997
Escalation	Often decision makers commit to follow or escalate a previous unsatisfactory course of action.	Brockner & Rubin, 1985; Northcraft & Wolf, 1984; Drummond, 1994
Habit	An alternative may be chosen only because it was used before.	Hogarth 1987; Slovic 1975
Inconsistency	Often a consistent judgment strategy is not applied to an identical repetitive set of cases.	Showers & Charkrin 1981; Moskowitz & Sarin 1983
Rule	The wrong decision rule may be used.	Sage 1981; Goodwin & Wright 1991

The research on biases summarised in Table 3 indicates a predictable propensity of human decision makers towards irrationality in important decisions. While the nature of the underlying psychological processes that lead to biased behaviour is the subject of considerable debate (Keren, 1990; Dawes & Mulford, 1996; Gigerenzer, 1991,1996), the experimental findings on decision biases do show persistent biasing in laboratory studies. This behaviour has also been shown in many cases to generalise to real world situations albeit in reduced effect (Joyce & Biddle, 1981; Wright & Ayton, 1990). Shafir, Simonson and Tversky (1993) suggest that the

value-based analysis of laboratory experiments may fail to capture the significant factors in a decision process and that explanations based on reasons may greatly contribute to our understanding of decision-making. Normally excluded from consideration in bias research are factors that influence decisions arising from psychological pathology, religious belief, or social pressure (including customs, tradition, and hero worship). The role of intelligence and individual differences in decision bias research has been largely ignored, as have the effects of visceral or “hot” factors on decision-making (Loewenstein, 1996).

A major implication of decision bias research is that a systems analyst needs considerable understanding about fundamental human decision-making processes to be effective in a management support role. Technical skills in model development and data provision are not sufficient.

3. Debiasing

Debiasing is a procedure for reducing or eliminating biases from the cognitive strategies of a decision maker. There are two major ways of approaching debiasing. The first is to develop general frameworks or strategies for cognitive change that apply to all biases. The second is to develop cognitive change strategies that are aimed at one particular bias. Both approaches are relevant to DSS. Keren (1990, p. 523) proposed a framework for the debiasing process that is based on medical diagnosis and prescription. His staged process is to:

1. Identify the existence and nature of the potential bias. This includes understanding the environment of the bias and the cognitive triggers of the bias.

2. Consider alternative means for reducing or eliminating the bias.
3. Monitor and evaluate the effectiveness of the chosen debiasing technique.

The possibility of negative side effects should be a particular concern.

In Step 2, Keren distinguished between procedural techniques where the user is unaware of the internal structure of the problem and hence the operation of the bias, and structure modifying techniques whereby the user can manipulate the internal structure of the task. Most reported debiasing research is of a procedural nature, although the deeper understanding of the task and biases required for structure modifying may lead to more effective outcomes.

In one of the most influential works on debiasing, Fischhoff (1982b) proposed a classification of debiasing methods that focused on the source of bias. Fischhoff identified the sources as faulty decision makers, faulty tasks, and mismatches between decision makers and tasks. Fischhoff's first problem category of faulty tasks implies that a redesign of the task environment may have an effect on decision biases. Klayman and Brown (1993) supported this view and recommended that redesign of the task environment is an alternative to debiasing the individual decision maker. Information systems has much to offer in this area, as task and process redesign is a core activity in systems analysis and design (Avison & Fitzgerald, 1995, chapter 3).

The aspect of Fischhoff's classification that has attracted the most attention is his strategy for "perfecting individuals". This assumes that it is the decision maker rather than the task that is the primary source of the biased judgement. Kahneman and Tversky (1982) distinguished between those situations where people lack competence (comprehension errors) and those where they are competent but fail on a given decision (application errors). A debiasing strategy for an application error needs to focus on educating the decision maker about the decision task, relevant

biases, and decision rules. Comprehension errors are more difficult to overcome than application errors. Fischhoff's strategy to overcome these errors is an escalation design where each level represents an increase in the degree of support provided to the individual. The steps in this escalation of involvement are:

1. Warn the decision maker about the possibility of bias without providing a description of its nature.
2. Describe the nature of the bias. This description should include the direction (positive or negative influence) and the strength of the bias.
3. Provide feedback. This feedback should personalise the warning and description of the bias and the decision maker's reaction to the bias for the target task.
4. Provide an extended program of training, with coaching, feedback, discussion or any other intervention that will overcome the bias effect.

Fischhoff's third category, mismatch between judge and task, addresses Kahneman and Tversky's application errors in that the decision maker is thought to have the requisite cognitive skills but somehow they are not applied effectively. Fischhoff calls the debiasing strategies in this category, cognitive engineering. Another classification of debiasing approaches is provided by Evans (1989, chap. 6) who suggested four categories: replacement, education and training, redesign of the task environment, and the development of decision aids or decision support systems.

Bazerman (2002, pp. 155-157) suggested a general debiasing strategy based on the Lewin-Schein model of social change (Lewin, 1947; Schein, 1962). The Lewin-Schein model views change as a sequence of unfreezing, moving, and refreezing processes. Unfreezing involves altering the forces on an individual such that the current equilibrium is disturbed to the extent that the individual wants to change. This can result from external direct pressure or indirectly by a reduction in

the forces that constrain change. Moving involves instruction into the nature of change and the actual process of learning new social behaviours. Refreezing involves integrating the changes into the personality or cognitive make-up of the individual. Bazerman used the Lewin-Schein model because he argues that debiasing must be guided by a psychological framework for changing.

Bazerman believes that unfreezing is the key to debiasing for three reasons. The first is that decision makers are likely to have used their current strategy for a considerable time and that any change will be psychologically disturbing. People will avoid disturbing information that questions their cognitive abilities. Second, most managers (who are the principal users of decision support systems) will have been rewarded for their current decision making strategies. Indeed, their successive promotions will probably have been based on the results of their intuitive strategies. Third, individuals tend to keep cognitions in order. Debiasing is a threat to this order or cognitive balance. Bazerman argues that a non-threatening quiz-answer-feedback approach is best for unfreezing. He believes that this approach will provide decision makers with concrete but private evidence of predictable errors in their judgement.

The moving stage of the Lewin-Schein model Bazerman calls change. He prescribes three steps for decision-making change: clarification of the existence of decision biases, explanation of the causes of the biases, and reassurance that the biases are not a threat to the decision maker's self esteem (Bazerman, 2002, p.156). It is important for the decision maker to realise that everyone's decision making is biased and that debiasing is meant to make an already effective decision maker a little more effective. Refreezing is important as biases can easily resurface after the effort of the moving/change stage is over. The decision maker needs to continually use the new approach to ensure that it becomes the dominant cognitive process.

In addition to these general approaches to debiasing there is research on debiasing specific biases. Some examples include Buyukkurt & Buyukkurt (1991) who described a number of techniques to assist with overconfidence, choice, and sample biases; Friedlander & Phillips (1984) who investigated anchoring effects; Kling & Bessler (1989) and Arkes, Christensen, Lai & Blumer (1987) who addressed overconfidence; Lopes (1987) who investigated debiasing Bayesian inference or the base rate effect; and Wexler & Schopp (1989) who studied the hindsight bias. None of these involved the development of a decision support system.

In summary, human decision-making is subject to biases that can often adversely affect decision quality, but importantly for managers, they may lead to serious errors of judgement in strategic decisions. The research on debiasing hints that the development of decision support systems may help to overcome some of the negative influence of decision biases.

4. Decision support systems development

Before considering the relevance of decision biases to DSS this section describes a framework for DSS development. The development model presented in Figure 1 conceptualises DSS development at two levels: a major cycle level, represented in the figure by rectangles, and a development activity level, represented in the figure by ellipses. The major cycles are initiation, analysis, and delivery.

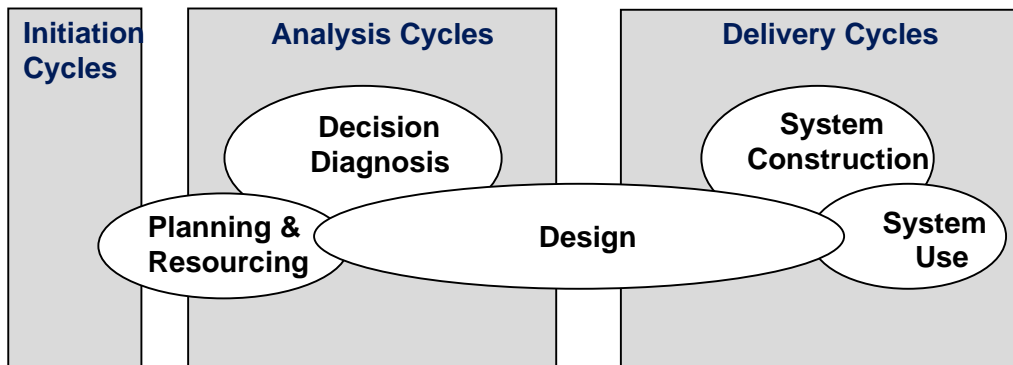


Figure 1. A Model of Decision Support Systems Development

Figure 1 attempts to portray DSS development in a realistic manner. It is unlike most systems development schematics in that it does not indicate procedural flow through a model using arrows that link discrete elements. While the development of the first generation of a decision support system often progresses from left to right in the figure, as the project continues many of the activities will overlap in time and nature. For example, it is common for system construction, use, and design to be undertaken in rapid succession, sometimes simultaneously. Figure 1 shows that the major cycles are linked together by shared activities - planning & resourcing links initiation and analysis cycles, and design links analysis and delivery cycles. This attempts to capture the organic nature of DSS development although it is very difficult to depict the dynamic nature of DSS development in a two dimensional static diagram.

Decision support systems generally address ill-structured management decisions and it is extremely difficult *a priori* to specify the system requirements. Systems analysts tend to adopt an evolutionary development strategy to cope with this environment (Courbon, 1996). The initial versions of the system will help to clarify these requirements and the functionality of DSS will evolve over a series of generations where both the client and the systems analyst are active contributors to

the shape, nature, and logic of the system. It is also useful to think of a DSS project as the development of one or more applications. Applications may be developed to support a sub-decision or may be the result of the use of different technologies to support the same decision or sub-decision (for example, Botha et al., 1997). Decision support systems development can also be viewed as a social process. Like Bazerman with debiasing, in their seminal work Keen and Scott Morton (1978, p. 199) saw DSS implementation as process of social change and used the Lewin-Schein model as an organising construct. They observed that resistance to change is a common behavioural pattern in DSS development and argued that this indicates a failure of the unfreezing process. They also argued that refreezing is an often-overlooked process in system development and a lack of attention on refreezing may explain many DSS failures.

Initiation cycles are triggered when the client realises the need for a new decision support system application or recognises the need for significant change or addition to an existing application. During initiation the general problem area or decision is defined, resources allocated, and stakeholders engaged. An initiation cycle is completed when a decision is made by the client to continue further with the development of the application. Decision diagnosis is the unique development activity of analysis cycles. In decision diagnosis the client and analyst develop an understanding of the decision in sufficient detail to form a basis for the technical design of the information system. This description is used as a foundation for the design of the user interface, system logic, data structures, and network requirements. There may be a tendency once the decision description is complete to feel that no further analysis is required and that development can proceed in a linear or sequential fashion. However, no decision can ever be completely or unambiguously specified. As development proceeds, both user and analyst will learn more about the

nature of the decision, and the new knowledge will require a change in the decision specification. Delivery cycles of design, construction, and use is the aspect of DSS development that has received the most research attention. Keen's adaptive design model (Keen, 1980) remains the most cited exposition of this cycle. Courbon (1996, p. 119) describes these cycles as sequences of "action - whenever the designer implements a new version and the user works with it and ... reflection i.e. the feedback where the user and the designer think about what should be done next based on the preceding active use." Often the action of a delivery cycle triggers a new analysis cycle, and occasionally a new initiation cycle.

Technology is not a serious constraint on decision support systems development and many appropriate information technologies are available (Power and Kaparthy, 1998). In addition to spreadsheet, modelling, and database tools, DSS are constructed using executive information systems (Suvachittanont et al., 1994), OLAP tools (Thomsen, 1997), data warehouses (Gray & Watson, 1998), and the World Wide Web (Kimball & Merz, 2000). The most important considerations in choosing technologies for a DSS application are their relevance to the understanding of the decision by the client and analyst, and their ability to support adaptive change in the major development cycles.

5. DSS development using decision biases as a focusing construct

The concept of decision biases can be used as a key element in a decision support systems project. Debiasing can be included in the development process in two fundamental ways:

1. General debiasing - where the system is not designed for a particular decision task or manager but rather for a particular bias for any manager, and
2. Specific debiasing - where the system is developed to support a particular decision task for a particular user and the idea of biases provides focus to the development project.

5.1. General debiasing

Information systems can be constructed to educate managers about the action of most biases. By focussing the development of a decision support system on a particular bias the impact of the system on managerial practice could be significant if it improves the performance of the user in a large number of decision tasks. This approach assumes that individual differences and decision context are not important in debiasing. Following the DSS development framework presented in Section 4, an analyst may detect the importance of a bias to the target task in the decision diagnosis activity. If a general debiasing tool is available there may be no need to construct a new computer-based system for the decision support application. This is analogous to the use of packaged solutions in operational applications. A key motivation of general debiasing is to generate economies of scale in interventions, that is, build one system that can support many managers for many decision tasks.

Arnott, O'Donnell & Grice (1993) proposed an architecture for general debiasing systems that includes a training program, testing procedures, response analysis, feedback delivery, and a user interface. They described a system, DECAID, which uses hypertext, spreadsheets and knowledge-based systems to provide a training aid for the overconfidence bias. DECAID uses a Bazerman-style quiz-answer-feedback approach to unfreeze the decision maker with respect to overconfidence and adopts an iterative approach to debiasing that helps with the

Lewin-Schein moving process. Zakay (1992) found that simple computerised feedback effective in reducing overconfidence, while non-computerised feedback did not affect the overconfidence bias. Humble, Keim and Hershauer (1992) found that using an information system to provide immediate feedback did reduce overconfidence and raise decision quality.

Nisbett et al. (1983) found that general training had a significant impact on a number of statistical biases. They argued that statistical procedures are part of individual's intuitive equipment and that training increases the likelihood that decision makers will take a valid statistical approach to a problem. Evans (1989, p. 119) described training software he developed to help people improve their statistical reasoning. The software uses a graphical image of the problem in feedback to the decision maker. Graphical images were used by Roy & Lerch (1996) to mitigate the base rate bias. General debiasing has also been used in the intelligent decision support systems area. Courtney, Paradise and Ata Mohammed (1987) used biases indirectly in the development of a knowledge-based DSS to support managerial problem diagnosis while Remus and Kottemann (1986) used biases in a more direct fashion in the development of an artificially intelligent statistician. Silverman (1990) used aspects of heuristics and bias theory to propose an automated critique system using knowledge acquisition techniques, and Jacobs and Keim (1990) described the development of a knowledge-based system to help overcome the effects of the confirmation bias. Lim, Benbasat & Ward (2000) showed that multimedia presentations can reduce the influence of the order bias.

In summary, there have been a number of attempts to develop decision support systems that embody a general debiasing strategy. While these attempts are useful in exploring the relevance of debiasing to decision support systems, they have had little or no impact on practice. This may be because clients are

not involved in the development process and the evolutionary cycles that typify successful DSS are absent or severely constrained. The major gains in DSS practice may come from the use of biases in a specific DSS engagement. That is, to use decision support systems development as a debiasing approach in its own right. This is addressed in the next section.

5.2. *Specific debiasing*

Specific debiasing is based on the assumption that decision context and individual differences are important in debiasing. Evans (1989, chap. 6) argued that the development of decision aids that support rather than replace human cognition could be an effective debiasing strategy. It is likely that the development process will have a greater influence on decision biases, and therefore on human decision performance, than the actual use of the decision support system. Lim and O'Connor (1996) in a study of the use of DSS for judgemental forecasting concluded that internal debiasing mechanisms should be incorporated into decision support systems at every stage of the judgemental adjustment process. This remainder of this section describes how such incorporation can be achieved,

5.2.1. *Initiation Cycles*

Initiation cycles commence the unfreezing process. A cycle commences when the client realises the need for a new decision support system application or recognises the need for significant change or addition to an existing application. This realisation means that the decision maker feels that some improvement to decision making is required. As the user is motivated to begin the change process this makes unfreezing easier than if a system development project is imposed on the user, as is often the case with large-scale operational systems. If a decision support system is

using a debiasing strategy it is ethically important to make the client aware of the nature of the strategy. Debiasing can be more personally challenging than other DSS development approaches and the manager/client has the right to choose the level of cognitive process intervention that they are comfortable with. This is a concern with all forms of active DSS development (Jelassi, Williams & Fidler, 1987).

5.2.2. *Analysis Cycles*

In the decision diagnosis activity an analyst develops an understanding of the decision in sufficient detail to form a basis for the technical design of the information system. The frameworks for debiasing discussed in Section 3 can be used as part of the decision diagnosis activity. Decision diagnosis is part of the unfreezing stage of the Lewin-Schein model and can also involve the moving/change stage. The cognitive engineering strategies of Fischhoff (1982b) are useful at the start of debiasing. They are:

- Making the decision maker articulate what they know about the decision. This strategy has similarities with protocol analysis (Ericsson & Simon, 1993).
- Encouraging decision makers to search for discrepant information or information that challenges the adopted or preferred position.
- Offer ways to decompose the problem into more understandable sub-problems or themes. Systems analysis has many techniques or methods to assist this strategy (Avison & Fitzgerald, 1995, chapter 4).
- Consider a wider set of decision situations or scenarios. Then consider the nature of the current situation in light of the expanded conception.
- Propose alternative formulations of the problem. For example, reformulate a production problem as a marketing problem.

The analyst can work through some or all of these steps depending on the nature of the project. After this process the user will have become accustomed to thought experiments about the decision task and will be ready to explicitly consider decision biases. Keren's diagnosis and prescription framework, Fischhoff's perfecting individuals escalation design, and Bazerman's steps for decision making change (all presented in the Section 3) can be combined into a strategy that the systems analyst can use to approach debiasing. The steps in this combined approach are:

1. Identify the existence and nature of the potential bias.
2. Identify the likely impact and the magnitude of the bias.
3. Consider alternative means for reducing or eliminating the bias.
4. Reassure the user that the presence of biases is not a criticism of their cognitive abilities.

To help with the identification of biases the taxonomy presented in Table 3 can be used. The analyst should start bias identification at the highest level of the taxonomy (memory, statistical, confidence, adjustment, presentation, and situation categories) and judge if there is any likely effect under each classification. The analyst may then proceed to the individual bias level. The descriptions that are provided in Table 3 for each individual bias are useful with this identification. For example, the decision maker may seem extremely confident about the likely outcome of the target decision task. This suggests the possible action of a confidence bias. On further analysis it may become obvious that the manager has repeatedly received memos and reports on the proposed course of action from a subordinate. This oversupply of information could trigger the redundancy bias. Under the redundancy effect people overestimate the probability of the occurrence or the importance of an event or data set that is repeatedly presented to them (Arkes, Hackett & Boehm, 1989).

In identifying the likely impact and magnitude of the bias or biases, the systems analyst is specifically interested in that subset of the identified biases that may have a strong negative influence on the target decision. The selection of the method for reducing or eliminating the bias will depend on the particular bias and the particular decision maker. The citations for each bias in Table 3 can be consulted to provide the systems analyst with knowledge about the bias and possible corrective action. Structure modifying approaches should be preferred to procedural debiasing (Keren, 1990). The nature of the bias and the debiasing strategy will then guide the systems design activity. The systems analyst will consider what is possible to implement in a computer-based system and this may cause a change in the debiasing approach that is used. In some cases, knowledge of the bias can be used as part of the structure of the DSS (see Section 6).

5.2.3 *Delivery cycles*

The delivery cycles involve both iterations and parallel application of design, system construction, and use. These cycles cover the moving/change and refreezing stages of the Lewin-Schein model. The use of a decision support system can be viewed as a process of feedback and training. Training will be more effective when the decision maker misunderstands the basic principles of the task and has the experience and ability to learn these principles (i.e. an application error exists). It also relies on the bias being triggered by the characteristics of the task. Analyst and client learning has always been a central theme in decision support systems development (Keen, 1980; Courbon, 1996). A decision support system is usually a small-scale information system and as the decision maker changes their understanding of the decision task and the biases associated with that task, the systems analyst should redesign the

DSS and construct new versions or applications. In this sense a decision support system can be viewed as a learning system.

The systems analyst should pay particular attention to refreezing the decision processes. Refreezing will be enabled by the continued use of a stable DSS. Given the probability of many iterations of the delivery cycle, it could be that a decision maker might remain in a constant state of moving/change that may be psychologically stressful. The DSS may even be abandoned. On the other hand, if the moving/change stage is completed too quickly the possible benefit of the decision support systems development will be reduced. An important activity during delivery cycles is to monitor and evaluate the effectiveness of the chosen debiasing technique (Keren, 1990). In particular, the possibility of negative side effects of the debiasing effort, including the triggering of other decision biases, should be assessed.

6. A study of bias focused development

6.1 *Background and design*

In order to gain insight into the use of decision biases as a focusing construct for DSS development, a decision support system project that used the specific debiasing approach was studied intensively in the field. The research reported in this section can be termed action research (Baskerville & Wood-Harper, 1998). The systems development process within an organisational context was the subject of study. Within action research, the method adopted by this study can be classified as clinical research (Schein, 1987) as the project was client and problem centered, aimed at helping the client, and the researcher (or rather the university department) received fees for development services. The changing of fees is central to clinical research as

it establishes a different psychological contract between the subject/client and the researcher to that embodied in ethnographic and standard action research studies. The psychological contract in this research involved a charter for cognitive process change. Schein argues that a clinical approach enables the study of more senior subjects than if the researcher is the active recruiter of subjects and the client does not pay for services. The author was the systems analyst for the DSS project and two systems developers constructed the applications. The development team recorded their experiences in diaries and some sessions between the client and the systems analyst were audio recorded. In addition, the analyst kept a meta-diary that reflected on the overall development process in the spirit of Schon (1983). A condition of approval of the research project by the university ethics committee was anonymity for the organisation and subjects and as a result the identity of the organization has been disguised. The essential elements of the project description are unaltered.

6.2 Project description

The Company is a business services firm whose services include strategic consulting, project management, training, and IT development. These areas reflect the interests of the founders - one came from a large multi-national consulting firm and the others from an academic environment. The Company has five office staff and 26 principal consultants. When required, external contractors are employed for specific projects. The service/product portfolio of the Company was under formal review by the Board of Directors. The IT development area was experiencing high demand for its services, strategic consulting and project management were demand stable and profitable, while training was barely breaking even. The Board had commissioned an external consultant to review the Company's performance and prospects. The consultant once worked with the Managing Director and had recently

left a large multinational firm to build his own consulting business. He was not considered a competitor to the Company. The external consultant's report recommended that the Company maintain its core activities of strategic consulting and project management at the current level. He recommended that the training area be wound up and that a strategic alliance with a specialist-training provider be investigated as a substitute to an in-house function. He argued that the consultant time and energy that the Company would save from this alliance could be devoted to the IT development area that he believed had a huge potential for revenue growth. The Company's training services involved 19 courses that ranged from half-day to three-day programs. Most of the Company's consultants were involved in training but the only full-time employee in the area was the training manger. The Board considered the external consultant's report and other briefing information and after 15 minutes discussion there was a general feeling that the closure of training services was a desirable strategy, although no final decision was taken. The possible closure of the training area was flagged as an item for a Board meeting in two months time. After the meeting the Managing Director began to have reservations about the external consultant's recommendation and the prospect of the Company not having a training function. At this time the Board meeting to consider the training area closure was five weeks away.

Although the Managing Director had to formally recommend a course of action to the Board he had the strong impression that the decision was largely his and that the Board would probably adopt his recommendation as it had on numerous other occasions. However, with five weeks to the meeting he was unsure of the correct strategy. To help his decision process he engaged a consultant systems analyst to develop a decision support system, triggering the first initiation cycle of the project. He had no firm idea about what support he needed, just that he needed more

information and more options. There was no need for the analyst to explicitly address unfreezing the decision-making process as the manager had effectively unfrozen himself when he identified the need for specialist support. The decision problem was classified as mainly an application error (Kahneman & Tversky, 1982) that is, the Managing Director was a competent decision-maker but was faced with a decision situation that he had not encountered before. The analyst discussed the general notion of decision biases with the Managing Director and outlined the degree and nature of the possible interventions into his decision-making processes that could accompany a bias-focused DSS development. The manager agreed to follow a bias-focused strategy. The analyst began the first systems analysis cycle with a number of unstructured conversations with the Managing Director. He did not talk to any of the consultants or any other people related to the Company. He studied the financial documentation that was presented to the Board, as well as the external consultant's report.

The project then moved from planning & resourcing to a decision diagnosis activity. The training closure decision was modelled using functional decomposition (Avison and Fitzgerald, 1995, p 62) and influence diagrams (Bodily, 1988). The decision was then analysed for the influence of any major decision biases using the taxonomy presented in Table 3. It became apparent that the confirmation bias was likely to have a major negative impact on the decision, as the information available to the Board seemed to strongly support a closure strategy. The confirmation bias acts against a fundamental principle of scientific method that holds that information that refutes a hypothesis is at least as valuable than information that supports a hypothesis. However, under the confirmation bias, people tend to search for information that confirms their hypotheses and gloss over, or even actively ignore, disconfirming information (Evans, 1989; Russo, Medvec & Meloy, 1996). The analyst

then researched the confirmation bias to better understand the effect. Following this he undertook a series of semi-structured interviews to elucidate the hypotheses that were addressed by the Managing Director and the Board when the *prima facie* case to close the training area was made. The information sources that were known to be used by the Managing Director and the Board were then attributed to the various hypotheses and the information was classified as being confirming, disconfirming, or neutral. Virtually all of the information was found to be confirming in nature.

During this diagnosis activity the analyst began to develop a vague idea of what kind of DSS could help the Managing Director. It would probably have a data focus rather than a model focus but it would probably not be a standard database application. This vague speculation about the information system marked the start of design activities in the engagement. The next event in the project was deeply symbolic. Rather than refer to the project as the “training closure decision” the analyst convinced the Managing Director to rename the project the “training area evaluation”. This neutral reframing of the decision task was noticed and commented on by a number of Company staff. It was the first time that they knew the training area closure was not a “done deal” and that the Managing Director was considering other strategies.

To counter the effect of the confirmation bias the analyst adopted the escalation approach to debiasing “perfectible individuals” discussed in Section 3 (Fischhoff, 1982b). The analyst described the nature of the confirmation bias to the Managing Director and briefed him on the results of the information stream analysis. They mutually decided to develop a system that would attempt to reduce the effect of over-confirmation in the target decision. A search for possible disconfirming information was undertaken, led by the Managing Director and assisted by the Company’s Office Manager. Much of this information was of a qualitative nature and

was included in documents such as office memos and consultant performance reviews.

The first delivery cycle produced a decision support system, which became known as the Intelligence System. The system was named by the Managing Director. It was constructed using hyperlinked documents on a dedicated personal computer; in essence it was an unpublished web site. The document navigation tree was based on the decision influence diagram and a hierarchy chart of the identified hypotheses. In this way, the theory of the confirmation bias was used to provide the physical structure of the information system. Financial statements and other Board reports were pasted to the relevant documents, as was relevant disconfirming information. The system was then used by the Managing Director to explore the training area decision. All other Board members were given access to the system. While the document structure implied which information sources could be used in arriving at the decision, the system did not force a set retrieval pattern on the user. The developer inserted as many hyperlinks as possible into each document to allow users to follow hunches that were triggered by system use. While using the system the Managing Director repeatedly asked for additional information to be added, as did another director who briefly used the system. These minor delivery cycles significantly increased the amount of information contained in the Intelligence System but did not significantly change the logic or structure of the system.

While using the Intelligence System the Managing Director developed new ideas about the role of the training area. He began to wonder if training was generating business for the other areas of the Company or if it was important in retaining clients. The possible presence of a cross subsidy was difficult to assess as the additional business generated by the training activities could follow the initial work by a significant period of time, or be from a seemingly unrelated client because

a person previously related to the Company through training could have changed employer. These ideas triggered the second initiation cycle of the project. The Managing Director called this second stage, the “Subsidy System”, because it emerged from his training cross-subsidy hypothesis.

The Subsidy System was not a discrete decision support application or set of applications in the sense of the Intelligence System. Rather, it is best described as a series of ephemera – applications that existed sometimes for hours, sometimes for days, but were ultimately discarded. This phase of the overall project was characterised by chaotic analysis and design cycles. Design cycles were much more numerous and used more human resources than the analysis cycles, although it was hard at times to tell when one cycle ended and another began.

The people involved with the Intelligence System were also involved with the Subsidy System. The Managing Director was personally involved in virtually every DSS application and devoted significant time to the “system”. He indicated that the project was one of his highest priorities and asked to be interrupted in meetings if new reports became available. The analyst and system developers remained engaged full-time on the project and at times their effort was augmented by a Company IT consultant who was not engaged on client projects. The Office Manager was more involved in this stage of the project than for the Intelligence System. Her main role was as data provider for models and databases developed by the development team.

The applications that made up the Subsidy System were organised around questions articulated by the Managing Director. Once a question was defined, the analyst and programmers built an information system as quickly as possible and populated it with data. The applications were developed using relational database and spreadsheet packages. The pivot table feature of a spreadsheet was used as a

rudimentary OLAP tool. Answering some of the questions involved non-IT support or data gathering, for example, asking a long-standing client about an issue at a business lunch to inform system development. Table 4 illustrates some of the Subsidy System applications.

Table 4. Example applications from the Subsidy System

Question	IS based Decision Support	Data Sources	Non-IS based Decision Support
How many of our clients for strategic consulting were initially clients of the training area?	Databases	Client files, Training mailing list	MD contacts selected clients
Is there a relationship between consultant participation in training and their consulting performance?	Databases, Spreadsheets	Sales data, consultant staff files, training evaluations, survey	MD has conversations with selected project leaders and consultants, formal survey of all consultants
What are the infrastructure and HR costs of expanding IT development?	Spreadsheets	Generic building cost data, HR budget	Office Manager consults with office landlord

As a result of the use of the various applications that made up the Subsidy System phase of the project, the Managing Director decided to retain the training area of the Company. He believed that consultants benefited significantly from the formalisation of knowledge and experience that was required to conduct a training course. He believed that this benefit manifested in increased consultant performance and in increased sales. That is, he believed that a significant cross-subsidy existed between training and the core consulting areas. He also discovered that the consultants enjoyed the training work and that this contributed to their decision to remain with the company. This was an important finding because maintaining a high-quality staff establishment in the highly mobile consulting industry is very difficult. Using material from the decision support applications the Managing Director prepared a paper for the Board that recommended retaining the training function. As

predicted, the Board accepted the Managing Director's recommendation and resolved to investigate potential efficiencies in other areas of the Company.

6.3 Discussion

The first issue is whether or not the DSS project can be considered successful or not. The assessment of success is a difficult problem for action research studies and for clinical research in particular. This is because it is impossible after the research intervention to determine if an alternative intervention would have been more successful or led to a difficult outcome. The main argument indicating a successful project is the opinion of the Managing Director. Finlay and Forghani (1998) in a study of DSS success factors argued that success is "equated with repeat use and user satisfaction" (p 54). The Managing Director regarded the engagement as a success; he even offered a bonus payment to the development team, citing the importance of the outcome to his company as the reason for the offer. His continued personal involvement in the project "equates with repeat use".

A common circumstance in decision support projects is that the commissioning manager has already made their decision before project initiation and wants a DSS developed to justify the decision. This circumstance is unlikely to have occurred in this case. The bias-focussed approach adopted by the project represented a significant challenge to the Managing Director's cognitive strategies. The approach required much more personal involvement than a standard DSS engagement. If his object was post-decision justification then a less demanding development process could have been followed.

The development process followed in the project was informed by the method outlined in Sections 4 and 5.2. In one sense it was a classical evolutionary DSS

development in the spirit of Keen (1980) and Courbon (1996). By using the DSS the Managing Director learnt more about decision task, triggering system evolution. Sometimes this evolution involved changes to an application; sometimes it led to the development of new applications. Of particular importance in the conduct and outcome of the project is the close working relationship that developed between the Managing Director and the systems analyst. Interactions between the two were frank and open. Many discussions took the form of passionate debate rather than the more usual set-piece analyst/client interviews that typify large-scale operational information systems development. Two clusters of adaptive loops defined the major development cycles of the engagement. The analysis cycles that linked planning & resourcing, decision diagnosis, and design were quite chaotic and occurred over short periods of time. The loops clustered in systems delivery were more orderly and tended to be cycles of design to system construction to use to design again. As with many DSS, the development activities were non-linear and often aspects of the development process proceeded in parallel and in an opposite direction to that normally assumed. For example, in the Subsidy System some database applications were built (delivery cycle) in order to begin understanding the nature of the question that was guiding development (analysis cycle). This is contrary to the normal perception of a systems development life cycle.

The interpretation of the Subsidy System as a series of ephemera may be of considerable theoretical and practical importance. Most information systems research is focussed on projects that are relatively large in terms of the resources used in development. This is natural because the effect of a large operational system on an organization is likely to be greater than a small system. This makes the larger system an interesting subject to study. In the decision support domain it may be that the majority of systems are more like the ephemera that composed the Subsidy

System. As in the case of the Company's training area decision the impact of these micro-systems on an organization may be much more significant than a high-cost large-scale operational system. This is because the decisions based on the use of ephemeral DSS can determine the strategic success or failure of the organization.

When ephemeral DSS are developed they are less likely to be developed by experienced professionals, and therefore less likely to have the quality assurance and control associated with professional development. Panko and Sprague (1998) in a study of spreadsheet development found that 24% of models developed by MBA students with substantial spreadsheet training contained major errors, that is, they contained errors that would have major negative consequences for the organization if the output of the spreadsheet was used to inform strategic decision making. Other research has reported error rates of 63% (Brown & Gould, 1987). In the Subsidy System, the ephemeral systems were not only developed using spreadsheet technology they used database systems as well. More research into the ephemeral nature of many DSS is required.

The decision support project reported in this section was undertaken to see if a specific debiasing approach could be used as a focussing construct in DSS development. The action research study shows that it can and that it can be successful. In the project the theory of the confirmation bias actually determined the technical structure of the Intelligence System. Using a specific debiasing approach the systems analyst has a clear process or strategy to guide the development project. The approach used in this process adds a theoretical layer to the evolutionary development of a decision support system. The layer is a psychological theory of cognitive process change. In the study reported here the process change involved the agreed intervention into the fundamental decision-making process of an experienced and successful chief executive officer. The approach in the Company's

project was a combination of cognitive engineering and procedural debiasing (Section 5.2.2).

Without the overlay of the specific debiasing approach on the DSS development it is likely that a different, perhaps radically different, decision outcome would have occurred. As mentioned earlier in this sub-section, it is difficult to speculate on the relative utilities of other possible outcomes. In this study, the important issue to stress is that the client strongly felt that the specific debiasing focussed development had contributed significantly to the strategic direction of the organization.

7. Concluding comments

The view of decision-making that has informed most decision support systems research has been Simon's process theory. Further, the majority of DSS research has focussed on the choice phase of Simon's model of decision-making. Decision bias theory does not focus on the choice process but considers the possibility of systematic and persistent errors in all phases of judgement and decision-making. There is a growing body of decision support research that uses, or is strongly influenced by decision bias theory. Most of this work has adopted a general debiasing approach. General debiasing has much in common with the philosophy of operational information systems as it involves the development of generic systems that can be used by a variety of managers for a variety of tasks. If successful, general debiasing leverages scarce systems analyst resources and leads to economies of scale in use. To date, general debiasing has had little impact on practice.

The research presented in this paper shows that a specific debiasing approach can be successful in an actual DSS development. Specific debiasing provides a systems analyst with a psychological framework for systems development and decision process intervention. Such a framework is absent in traditional evolutionary approaches to DSS development.

Further field studies, particularly using action research and case study methods, are needed to both further develop and to assess the effectiveness of the specific debiasing approach. This approach to systems development is likely to be more demanding for both the systems analyst and the manager/client. This is an area that needs further research. Determining what knowledge, skills, and abilities are needed by a systems analyst using a specific debiasing approach is one avenue of study. The use of bias theory in the decision diagnosis activity of the development model is another area of future research. The bias taxonomy presented in Table 3 is a relatively crude instrument for systems analysis. Better ways of identifying the likely presence of biases are needed. A model or framework that links different decision biases to different decision tasks would be particularly useful.

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