Chapter 1

GENERAL CONSIDERATIONS

1.1 Introduction

The dominance of uncertainty in agricultural pursuits has long been recognised. Primary producers operate in an uncertain environment of which they have only limited knowledge and an even more limited ability to predict.

It is suggested that a producer can be viewed as an organism acquiring and processing data to form a personal concept of the reality upon which they attempt to moderate their interactions with this essentially stochastic environment. In fact, Bonnen (1975, p. 753) goes so far as to argue that "the problems of agriculture and of rural society, indeed, societal problems are best understood as fundamental problems of information processing" .

Further, as it has long be recognised that efficient managerial decision making requires rational processing of data to form expectations on which decisions can be made (Mill and Longworth 1975a), it can be argued that the efficiency with which producers can observe, analyse and form expectations as to future events in this environment is critical to their economic survival.

It will be suggested that the efficient interaction of primary producers with their information environment (the totality of symbols representing the physical and economic world of the producer) and the integration of information into decision structures represents the greatest bar to economic efficiency rather than any perceived inadequacies in market reporting or deficiencies in theoretical decision structuring. It will also be suggested that the ambiguity associated with producers' price expectations is a major causal factor resulting in minimal use of either aided or unaided analytic decision structures.

This assertion is based on an holistic approach to the analysis of primary producers' information/decision structures in which the functional value of information systems is taken to be determined by the extent to which they fulfil management's requirements for information on both input-output transformation rates and expected input and output prices (Klein 1987). Imperfect information in both these areas has been denoted as "technology uncertainty" and "market uncertainty", respectively (Freebairn 1973). This dissertation, due to space constraints, has been generally restricted to the impact of the latter on agricultural decision making. Such concern with the adequacy of market information is shared by Loyns et al. (1987, p. 70) who noted that "the weakest component of the information set for the farm firm is on the product market side." This assertion is further supported by Dillon's (1977, p. 106) observation that within the realm of crop and livestock production "the product price but not the input price will generally be uncertain at the time a decision has to be made about the level of the controlled input variables."

The relative significance of variations in product price relative to factor-factor conversion instability in Australian agriculture is illustrated by Motha et. al. (1975)(cited by Campbell (1982)) who estimate that the variability of wool price exceeded the variability of Australian wool production by 370 percent. The supposition that product prices can be considered the weakest component of the information set upon which Australian (sheep and beef) producers make production decisions is further supported by the relative stability of input prices and the observation of the minimal degree of input substitution in these industries, due to relative price changes in the short run (Lewis 1987).

While within this holistic approach to the analysis of primary producers' information/decision systems consideration has been given to a range of decision structures varying from the purely heuristic through to formalised expert systems, it is not the intention of this work to adjudicate on the worth of the various decision structures reviewed. Rather, it is intended to place in context the sophistication of the art of decision structuring, both normative and descriptive, relative to the other components of the producer's information/decision systems.

However, this description of the primary producer's information/decision environment must be considered fluid as cost of information relative to the costs of traditional inputs are decreasing, significantly aided by improvements in data collection, storage, processing, and transmission technology and as there is greater recognition that the attainment of a competitive advantage is dependent on the efficient use of information along with the adoption of flexible management strategies (Sonka 1985 , King 1987, Sonka Hofing and Changnon 1988). Such changes have seen the demand for, and the utilisation of, larger quantities of economic data in agricultural decision making increase significantly in the period since the 1960s (Barnard 1975). Co-incident with this there has been an increased availability, on farm, of computers and computable models which has enhanced the capacity of producers to handle larger quantities of information in their decision processes (Barnard 1975). Yet, there appear to have been very limited increases in the utilisation, on farm, of either aided or unaided analytic decision structures.

Given this awareness of the importance of information, the availability of numerous formalised decision structures and the following description of farmer's capacity, Druce (1966, p. 103) considered that "many of the more intelligent farmers" had a capacity to understand the elements of production economics and budgeting techniques, with the proviso that the "necessary economic and technical data " were available. There remains the quandary as to why agricultural decision making remains significantly dependent on heuristic strategies.

Whereas the initial intention of this study was the mechanistic improvement of agricultural decision making by the provision of "better market information" it has been transformed into an attempt to examine factors impacting on the totality of the information/decision process. This occurred following recognition of the futility of providing even more information if the currently available information is not being used, such that the consideration of factors impacting on the quality of the information reaching the producer, the mechanisms by which that information is transformed into expectations, the correlation of expectations with market outcomes and the adequacy of the decision process become important to this analysis of the provision of market information to Australian primary producers.

Such an approach is adopted so that the constraints on efficient decision making may be placed relative to each other in a framework which allows an evaluation analogous to that of the search for the most limiting factor, common in the fields of animal and plant nutrition (Russell 1973). This approach is believed to be of value given the great amount of agricultural economics literature that concentrates on decision making under risk, market forecasting, information systems and the formulation of "rational expectations". Yet, little has been published on the way in which producers actually formulate price expectations or utilise such expectations in various decision structures.

This situation may be considered similar to the state of research in psychology that prompted Edwards (1971, p. 640) to comment

> "... and even now many deeply sophisticated psychological theorists fail to recognise how much effort they spend in modelling the task, and how little effort they spend in modeling the behaviour of the subject in the task."

This situation can be seen as the product of the disparate nature of much agricultural economics and psychology research, along with the disciplinary divide between marketing (concentrated on post-farm-gate) and farm management (concerned with the pre-farm-gate application of decision procedures and advances in the science of input-output transformation rates). This divide is seen by Loyns (1987) as the major hindrance to developments in this area.

In summation, it is held that any development of an improved market information system, as a component part of an overall agriculture information system, presents a major challenge in understanding, not only in the collection-encoding-transmission-reception-decoding of market signals, but also in the understanding of the integration of such signals into various decision structures.

The challenge goes beyond the normative pronouncements of information systems theory; the identification and the analysis of the efficiency of the structures existing in agriculture. As such, communication-based theories are of questionable value in the consideration of the semantics of, or the effectiveness of, information transfer (Lee and Nicholson 1973). It is suggested that there is a need to review the relevance of the information systems servicing the producer in light of an understanding of: (a) the mechanisms by which the producer forms expectations of future market prices; (b) the level of confidence in those expectations; (c) the mechanisms by which the expectations are incorporated into decision structures and; (d) the decision processes that the producer is utilising.

1.2 Background to the Study

The impetus to undertake this study arose from numerous producer discussions in which the adequacy of market information available 'behind the farm gate' was seriously questioned. Producers perceived this inadequacy in their general operating environment as a major impediment to better farm management. This inadequacy in, and the need to improve the provision of, market information to Australian primary producers has been reported by several authors (Bock 1976 a,b, Johnson 1976, Halls 1977 and Timko and Loyns 1989).

The initial emphasis of the study was orientated towards the description of deficiencies in the market information reaching producers through the application of an information systems approach. This approach was based on the assertion that the problem related essentially to the adequacy of the data set on which producers based their decisions. This was seen as consistent with numerous commentaries in both the general press and academic journals regularly noting the inadequacy of market information provision in Australia, including references to problems with: detail, interpretation, presentation, producer comprehension, timeliness and reliability (Longworth 1972, Bock 1976 a,b, Freebairn 1978, Sheahan 1979, Lively and Nuthal 1983, Timko and Loyns 1990).

However, the need for the study to be expanded to include questions of information semantics and information/decision process structuring soon became evident.

1.2.1 Market information

At both the academic level and on the farm there has been a transformation of the accepted definitions of market information from the 'product price' restricted definitions to far more generalised concepts of market information. This has seen a move away from the restrictive definition implicit in agricultural decision models, where production responses are studied in relation to variations in product price (Gutman 1955, Mauldon 1973), to a more expansionist view of the definition of market information as presented by Hunt (1974) (cited by Halls and Keynes 1974, p. 50) who considers that

> Market information may be defined as information about supply, demand, prices, policies and matters affecting them, which could affect farmers with their production and marketing decisions. (p. 50)

The temporal nature of market information, that is its relevance to the past, present or future environments in which producers may operate, is included in this wider description by Halls (1977).

1.2.2 Changes to the data/information set

The concept of a problem-related "data/information set" will be used, the definition of which is taken to be total of the data/information required to allow agricultural decision-makers to successfully adjust their individual production mix (Watson 1983), with the need for adjustment arising from changes in "the factors which control the market" Halls (1977, p. 50).

Changes in the control of markets that have arisen from recent developments in the European Community and North America have seen an increasing concern placed on social problems in the agricultural sectors of industrialised economies along with the recognition of the critical role of agriculture in the development of third world countries. These changes, along with the emergence of environmental concerns in resource allocation decisions, has greatly expanded the data/information set relevant to agriculturalists (Hughes 1981).

With the increased significance of such non-price competition factors in agricultural product markets there has been an associated circumscription of the role of price which has confounded marketing economists and farmers alike. Breimyer (1973, p. 135) suggests that "the role of price in guiding distribution of product and allocation of resources is moving towards eclipse in many nations, particularly developed ones."

The change in the relative importance of price in the data/information set has also seen a corresponding change in the role of price in the communication of market information. Bock (1976 a) favours the view that price should be considered as part of a more complex communication system. The resultant decreases in the levels of producer confidence in the accuracy with which market prices can describe the demand conditions, for production yet to be undertaken (that is, for the formation of price expectations), has seen an increase in complexity of the information set demanded by producers.

Along with this expansion of the information set boundaries there has been an increase in the level of demand for market information. This has been attributed to increased market volatility, product differentiation, reduction in the relative cost of information compared with other inputs, improvements in the ability of producers to handle data, market deregulation, and reduced operating margins (Bock 1976 a,b, Carrigan 1990, Hudson 1990, King 1986, Watson 1983).

Such expansion of the data/information set applicable to modern agriculture not only complicates the communication problem facing market reporting services, it also has a major impact on information integration tasks facing producers.

1.2.3 Orientation

Historically, a bias towards production effort at the expense of marketing has been evident in Australian agriculture at the research level and on farm, as a result of which producers have been criticised for their lack of market orientation while themselves criticising numerous institutions for their inability to supply adequate market information (Green Paper 1974, National Rural Advisory Council 1974, Johnson 1976, Bock 1976).

Within the realm of agricultural economics this bias is further illustrated by the dominance of production economics and its application to farm management problems. Traditional marketing research has concentrated on the post-farm-gate problems such as pricing efficiency and market channels (Loyns et al. 1987) with little attention being paid to information (Phillips 1968).

However, this gap appears to be closing, as evidenced by the increasing recognition that

> .. the realised welfare of individuals and of society is positively related to the extent to which forecast prices and quantities on which decisions are made correspond to realised market prices and quantities. (Freebairn 1975, p. 145)

The significance of price expectations in determining economic behaviour is being now widely acknowledged (Fisher 1983a).

This academic re-orientation has seen an expansion of disciplinary definitions, as illustrated by Phillips' (1968) description of marketing as an information gathering activity or Breimyer's (1973, p. 117) wider definition of marketing to include activities not only involved in the delivery of product from producer to consumer but also the function of "coordination and direction of economic activity". These suggest a need to bridge the gap between the two disciplines of marketing and farm management.

This study, with its emphasis on the description of a range of factors which impinge on the interaction between primary producers and their economic environment can be seen in part as a continuation of the trend towards a more holistic approach to the subject area.

1.3 The Problem and Its Significance

In consideration of a particular subject for research it is valid to question whether the problem identified is of sufficient significance to command the application of limited research resources. In industry terms, significance may be measured by the potential for the improvement of economic efficiency resulting from the amelioration of the problem whilst academic significance may revolve around the potential increase in the understanding of a system or in the ability to predict a system.

The level of significance attributed to this area of research is partly demonstrated by the following five observations. First, the quality of managerial decisions are directly linked to the availability of information (Campbell 1973, Rosaasen, Giffin and Storey 1983, Davis and Cosenza 1985). Second, the characteristic extensive delays between production decisions and product sale, changing technology and market volatility of agriculture require that information on both the current and future states of the market environment be available for rational decision making (Dixon 1967, Freebairn 1973). Third, this presents agricultural industries with a considerable problem "given the notorious inaccuracy of even mid-term predictions of the market" (Bardsley 1982, p. 118) . The fourth observation is that information quality problems associated with missing data, delayed transmission, and inaccuracy often result in erroneous decisions and lost opportunities (Andrus 1971, Black and Bulkley 1988). The fifth observation is that significant inefficiencies in resource allocations, and failure to use, or the mis-use of, marketing alternatives result from the lack of market information (Halls 1977, Edleman, Schmiesing and Olsen 1990). The misallocation of resources due to incorrect price expectations is suspected of being, in fact, more prevalent than mis-allocations resulting from inadequate information about production functions (Phillips 1968).

In addition, the "information problem" impacts on the economic well-being of the agricultural sector through the need to expend limited resources on the definition and representation of variables, along with the acquisition, transmission and interpretation of information describing those variables (Andrus 1971, Watson 1983).

Some hidden costs have also been partly attributed to the inadequacy of agricultural data/information/decision structures, in that the ability of the agricultural sector to compete for resources in the general economy appears to be adversely affected, as illustrated by the time it takes credit agencies to revise their expectations of agricultural profitability (Campbell 1973).

The significance of this area of study can also be seen from a theoretical aspect in that the essence of the data/information set question, and by extension the sub-set composed of market information, is one of the validity of the assumption of perfect information in the classical study. Lee and Nicholson (1973) state that

> .... economic theory has long been able to deduce the efficiency of resource use attainable when pure and perfect information is available to the micro or decision making units within the economic system. (p. 922)

yet

> In short we do not have an acceptable 'theory of information '. Communication-based information theory leads to a 'quantity-of-

> information theory' which is useful in dealing with information transmission as a technical problem but is of doubtful value when dealing with the semantic or effectiveness problem of information transfer. (p. 921)

Implicit in Lee and Nicholson's (1973) extension from a "quality of information theory" to the consideration of the "semantic or effectiveness of information transfer" is the need to address the question of expectation/outcome correlations, for central to the use of such decision structures as "cash flow budgeting" or "utility theory" is the incorporation of some measure of producers' expectations as to market outcomes.

Finally, "the rational processing of information and expectations is an essential step in all managerial decision making" (Mill and Longworth 1975, p. 108) and the understanding of the mechanisms influencing the transformation of market data/information into expectations is a major constraint in the modeling of decision making. Thus, if "we view management as the processing of information constrained by environmental factors (and resources, managerial skills, etc.)"(Loyns et al. 1987, p. 80), if agricultural economics is to contribute to the welfare of the sector it studies it must develop a greater understanding of the interaction of producers and their economic environment. A robustness in its normative theories and decision aids must be developed which allow such structures to deal with: an imperfect information set; limitations in individual's conceptual capacities; inefficient communication channels; and which can accommodate changes in the relative importance of price and non-price information in decision making.

1.4 Organisation of the Study

This study has been based on a structuring of the human environment interaction originally proposed by Humpreys and Berkeley (1983)(Figure 2.1) in which the interfaces between the environment and semantic memory and between semantic memory and the decision process provide the conceptual boundaries within the model.

Within Chapter 2, a decision taxonomy, based on level of problem conceptualisation, is used to develop a taxonomy of decision structures. This provides a framework for the review of various decision structures. Both normative theories and descriptive decision models are reviewed. A product of this development is the description of the data set demands and the data manipulations of various decision structures within particular classifications such that the cognitive complexities of the decision structures reviewed are shown to influence the informational demands placed on producers who wish to apply such structures. In addition to the discussion of these decision structures, consideration is given to the differentiation of decision uncertainty and the various descriptors of risk encountered.

The consideration of the capacities of humans as information processors forms the basis of Chapter 3. There the emphasis is placed on the human constraints on the acquisition and transmission of data/information and its subsequent transformation into expectations for incorporation into decision structures. As such, the chapter can be seen as addressing the capacities and limitations governing the relationship between the organism (in this case the primary producer) and the environment. The chapter concludes with an examination of the human constraints on the verbal and numerical communication of uncertainty measures, information search activities and learning in a stochastic environment.

Chapter 4 reviews the area of Information Systems theory and its use as a tool to describe the market information environment of the Australian agriculturalist. Reference is made to the generation of data, its filtering, summation, transformation and interpretation. The externalisation of various functions normally undertaken by a producer operating in a totally heuristic manner is traced through the development of the various information/decision systems. The latter part of the chapter concentrates on the structures influencing the interaction between producer and the global information environment, including communication constraints and perceptual influences on source/recipient interactions. The chapter can therefore be seen as an attempt to describe the structures (information systems) and their impact on the relationship between the environment and the organism. Chapter 4 concludes with a review of the art of forecasting. This is undertaken so that informed commentary can be made as to the "rationality" of producers' adoption of externally generated forecasts in preference to their own inferences.

Irrespective of the degree of process externalisation, a producer is obliged to communicate with data/information sources external to their own operation. The influences on the information/decision process of the constraints on, and components of, these acts of communication forms the subject matter of Chapter 5. Whilst within Chapter 3 reference was made to the human constraints on the verbal and numerical communication of uncertainty measures, Chapter 5 deals with a broader range of issues related to communication.

A model contrasting the theoretical view of producers' interaction with their decision environment (the statistical man) and the holistic view of man's constrained interaction with their decision environment (mortal man) is described in Chapter 6. This holistic model of the utilisation of information in agricultural decision making is based on a contingency view of the progression of data/information between the domains (environment, semantic memory and decision structure) proposed in the Humpreys and Berkeley (1983)(Figure 2.1) structuring of decision making.

In chapter 7 are presented two examples of the theoretical application of the model developed. The first example deals with the externalisation of parts of the information/decision process. The second example discusses the question of aiding human inferencing in view of its relationship to the overall information/decision process.

A producer survey was conducted in an attempt to illustrate the interpretation of some observed behaviours using the model developed. The survey method, results and analysis of results are reported in Chapter 8. Chapter 9 presents general discussion of the degree to which the results validate the hypothesised contingency model. This work is of a limited nature in comparison to the breadth of the model developed, and as such can only been seen to provide limited substantiation of the model.

The tenth chapter concludes this work with a general discussion of the contingency approach to the examination of the data/information/decision chain and the possible future direction of research in this area.

Chapter 2

INFORMATION AND THE DECISION PROCESS

2.1 Introduction

The initial phase of this study into the requirements for, and the processing of, information in the agricultural management context is addressed in three segments. In this chapter the bounds of the data sets required for the application of several decision structures are delineated. The processes involved with, and the constraints on, the acquisition and incorporation of information about the decision environment into the semantic memory of the decision maker will be addressed in later chapters.

The conceptual linkages between this and following chapters will be developed utilising a modification of Humphreys' and Berkeley's 1983 modeling of the interfaces between the decision process, the decision maker's semantic memory and the decision environment. The positioning of the subject matter of this chapter within this model can be seen in Figure 2.1.

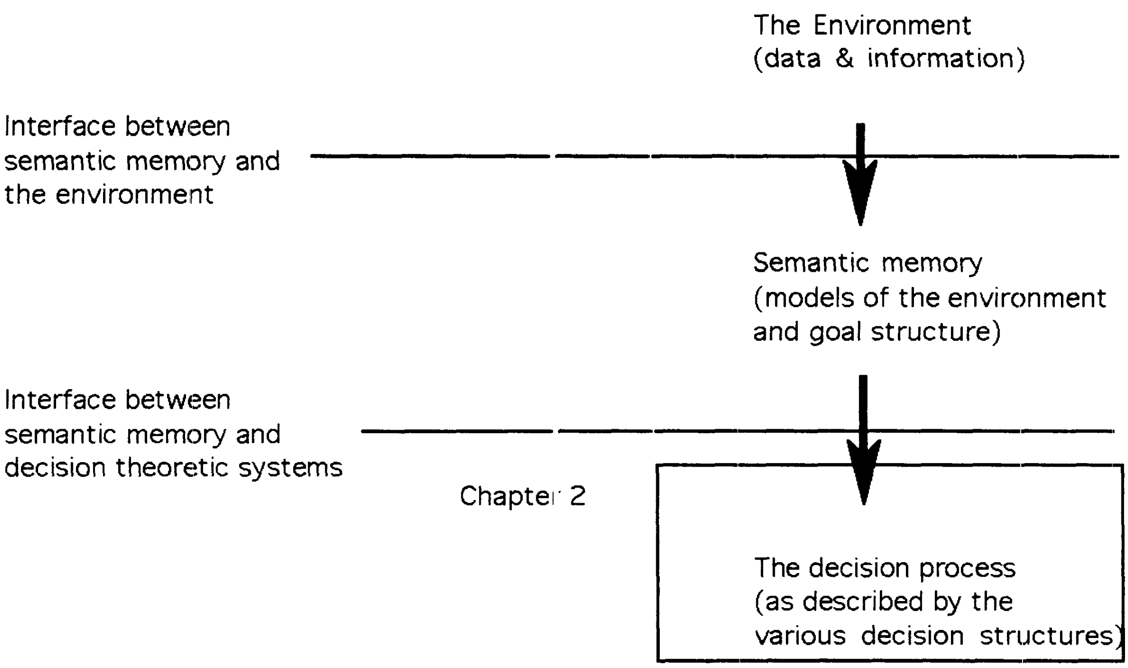


Figure 2.1 The Environment - Memory - Decision Process Interfaces
(adapted from Humpreys and Berkeley 1983)

Alternatively, this chapter can be seen as an attempt to describe the scope of the demand for information inherent in the various descriptions of the decision process, with the focal question being the data set requirements for various types of decisions.

Barnett (1967) identified seven steps in the managerial process: (1) observation; (2) problem awareness; (3) problem identification; (4) analysis; (5) decision making; (6) action taking; and (7) responsibility bearing. An alternative six stage description of the management process is described by Makeham and Malcolm (1988): (1) getting ideas and recognising problems; (2) making observations, collecting facts; (3) analysing observations, and testing alternatives; (4) making the decision; (5) acting on the decision; and (6) taking responsibility for the decision.

Our concern here is to consider the data demands of the decision stage of management. Initially, open loop decision theories and models will be considered (ex ante decision making). Whilst such an approach is applicable in the short term, where the scope for alterations subsequent to the finalisation of the production decision is very limited, it is a simplification of the real world where the majority of management decisions involve a temporal feedback of data from the evaluation of actions taken (closed loop). However, any consideration of the significance of a producer's ability to exercise "adaptive control" (Mauldon 1973, p. 34) and its impact on the acquisition of information, the application of various decision calculi and risk avoidance techniques would necessitate the evaluation of the ability of various decision structures to accommodate temporal flows of information. This latter question is often neglected on the assumption of serial application of open loop decision structures.

2.2 Decision Taxonomies

The boundless diversity of decision activities in any business organisation, held to be fact apparent by Davis and Olson (1985), results in a corresponding diversity of information needs. Such needs extend to requirements for information "about the following: (1) physical input-output relationships, (2) price and price relationships, (3) technological change, (4) political, economic and social institutions, and (5) individuals" (Thomas 1955, p. 1117). To aid in the delineation of data set boundaries it is useful to employ a classification of decision types.

Various decision taxonomies have been proposed based on a number of criteria such as the analytical characteristics of the tasks, the substantive nature of the problem addressed and the levels of conceptualisation (abstraction) required in structuring the problem. While the central concern in this dissertation is the processes involved in internalisation of market information, defined variously as "data on the demand, supply and prices of factors and products" by Barnard (1975, p. 317) and as information about supply, demand, prices, policies and matters affecting them, which could influence farmers in their production and marketing decisions (Hunt 1974), it is suggested that producers are confronted with a range of decisions for which certain data sets and analytical methods will be more or less appropriate.

Davis and Olson (1985) provide an example of a decision taxonomy based on the analytical complexities and duration of impact of the questions addressed. Decisions are differentiated as being strategic, tactical and technical on a continuum ranging from the mundanely routine and highly programmable decision through to the unprecedented and unprogrammable. This type of classification allows for the recognition of the fact that the decision making process (hence information acquisition and incorporation of expectations into decisions) may at times have determinable points of closure while at other times involve an ongoing process of enactment and revision (Thorton 1962, Ortiz 1980).

Alternatively, a decision taxonomy based on the level of abstraction inherent in the problem addressed is described by Humphreys and Berkeley (1983) in their multi-level scheme for conceptualising decision problems.

Within this scheme, Level 1 decisions are "those involved in seriation and the inter-connected postulates of transitivity and conservation" (Humphreys and Berkeley 1983, p. 135). Such decisions would relate to concrete operational tasks requiring the "estimation of values at nodes within a fixed structure". The selection of fertilizer supply source, on the basis of price quotations, would be illustrative of this type of decision.

The second level (Level 2) of problem conceptualisation entails the "manipulation of data on one variable at a time within a fixed structure". A sensitivity analysis based on variations in wool price in a gross margins analysis of a wether operation would be indicative of this level of decision. The manipulation of hypotheses (what-ifs) rather than facts is a recognition of the probabilistic nature of future states.

Decisions requiring the manipulation of two or more variables, which if handled in isolation comprise level two decisions, would be classified as level three decisions (Level 3). Decisions at this level may involve the restructuring of a problem within a generalized decision theoretic system. The manipulation of variables and variable correlations within farm cash flow budgets, linear programming analysis or portfolio analysis would be indicative of decisions requiring this level of abstraction. It is the structural elements of the problem rather than the facts that are of concern at this level.

The fourth level (Level 4) of conceptualisation involves the selection of specific problem-solving structures to handle a generalised class of problems. A producer dealing with a problem at this level attempts to conceptualise the mechanisms by which the type or class of decision may be handled rather than deal with a specific problem. This is seen as superordinate to the routine application of problem solving codes or the manipulation of variables within a decision model, such that the form of the models used in level three problems and below become the content of the questions addressed at the fourth level of conceptualisation.

The fifth level (Level 5) of the schema is concerned with the limitation or conditional closing of "an open system (the unbounded 'grand world' of possible views of the future) into the small world within which an individual's problem structuring activities take place" (Humphreys and Berkeley 1983).

Higher levels of abstraction requiring social rather than personal decision making were proposed by the authors. However, these go beyond the context of this thesis.

In viewing any decision taxonomy as the basis of the development of a framework to aid in the analysis of information systems it is necessary to recognise that the boundaries of the categories described will often be unclear or fuzzy (Anthony 1965). The difficulty in delineating boundaries between decision types is recognised in the literature originating from the study of management information systems (MIS) in large corporate entities, where inherent management control levels and task specialisation has assisted in the delineation of decision categories. This differentiation problem can be expected to be increased by the singular (or near-singular; the average farm employs 1.5 persons Schapper (1979)) operator status of the majority of Australian agricultural enterprises, within which there is no division of responsibility or power.

2.3 Theories and Models of Decision Making

A selection of the literature relating to agricultural decision making has been reviewed. A comprehensive review is precluded by the sheer volume published and the space limitations of the dissertation. The purpose of this review is to identify the mechanisms by which information (particularly market information) is incorporated into a range of normative and descriptive decision theories and various decision aids (collectively referred to as "decision structures"). The aim is to illustrate the information set requirements of the various decision theories and aids and to consider the influence of the availability of information on the selection of decision handling procedures as, ultimately, the acceptance and effectiveness of any decision aid (model or theory) is limited by the ease of attainment of the data set required for its application (Mill and Longworth 1975).

This review of decision structures is formatted such that the decision structures are reviewed in groups relating to their ability to be applied at the levels of problem conceptualisation described in the Humphreys and Berkeley (1983) taxonomy of decisions. The theories and models will be grouped in accordance with the highest level of abstraction with which they deal. It is necessary to recognise that they may or may not be applicable at lower levels of abstraction and that decision structures at successively higher levels may use as content the outcomes (results) of structures belonging to a lower level of conceptualisation. This is illustrated by the manipulation of activity gross margins within a linear programming structure.

The approach adopted allows the tracing of the expansion of the restricted data set required for the application of the lower level decision structures as the degree of problem abstraction moves to higher levels of conceptualisation.

2.3.1 Level 1 decisions

Humphreys and Berkeley (1983) characterise level one problems (tasks) as being "concrete operational, limited to tasks concretely and physically at hand"(p. 133) with an inherent time span of less than three months. (This inherent time span may not apply to agricultural contexts; see below.) The problem structuring capacity requirements of this level are limited to the estimation of values at nodes within a fixed structure.

Attempts to improve decision making at this level have concentrated around the accuracy of the decision maker's assessments of the state of the world. Data accuracy is critical to the efficiency of decision making while, in situations where objective measurement is difficult, the decision maker's ability to estimate the most likely value of the parameter, given some data describing its distribution, is a major determinant of the effectiveness of decision making at this level.

Service manuals

The adherence to a structured service program for a tractor, where designated actions are prescribed on the basis of elapsed operating hours, could be considered to be a level 1 decision. The service manual structures both the decision process and actions required. The decision maker is required to input information, in the form of an estimate of hours operated. The levels of resource allocations (litres of oil, filters and grease) is prescribed by the manual and thus removed from the decision maker's problem world.

In this case the data set required is composed of the single estimate of hours operated since last service. As such, the decision structure (the service manual) can be seen as demanding the input of a single point estimate of a single parameter of the decision maker's small world, to be used as content for incorporation at a single node in a fixed problem structure.

Gross margins

Activity gross margins are one of the most commonly used farm analysis and planning aids. The generally accepted definition of an activity gross margin is the residual of gross income earned by the activity less the variable costs associated with that activity, where an activity is defined as the production of a specific crop or livestock product by a particular production method (Rickards and McConnell 1967, Makeham and Malcolm 1988).

The basic structure of an activity gross margins analysis is portrayed in figure 2.2.

Activity Gross Margin

Inventory Changes	Value (s)		
Opening stock (number of units x valuation)	$-S_1-$		
Closing stock (number of units x valuation)	$-S_2-$		
Change in inventory $(S_2 - S_1 = \Delta I)$		ΔI	
Cash income from sales Σ(units sold $[Y_i]$ x product price$[P_{yi}]$)		$\Sigma_{i=n}(Y_i \times P_{yi})$	
Gross Income $(\Sigma_{i=n}(Y_i \times P_{yi}) + \Delta I = \$_i)$			$\$_i$
Variable Costs $\Sigma_{i=n}$(units of inputs $[X_i]$ x cost of inputs $[P_{xi}]$) = \$c			\$c
Gross Margin $(\$GM = \$_i - \$c)$			\$GM

Fig 2.2 Activity Gross Margin Structure

The decision procedure (the maximising function) utilised is based on the selection of the activity with the highest gross margin per unit of the most limiting production factor (resource). This activity is to be undertaken at the maximum level attainable under the identified resource constraint. Additional activities are then introduced in order of decreasing gross margins per unit of the most limited residual resource until all resources are utilised or increases in total gross margin can not be achieved (Rickards and McConnell 1967, Makeham and Malcolm 1988).

The generalised decision structure utilising gross margins is depicted in Figure 2.3.

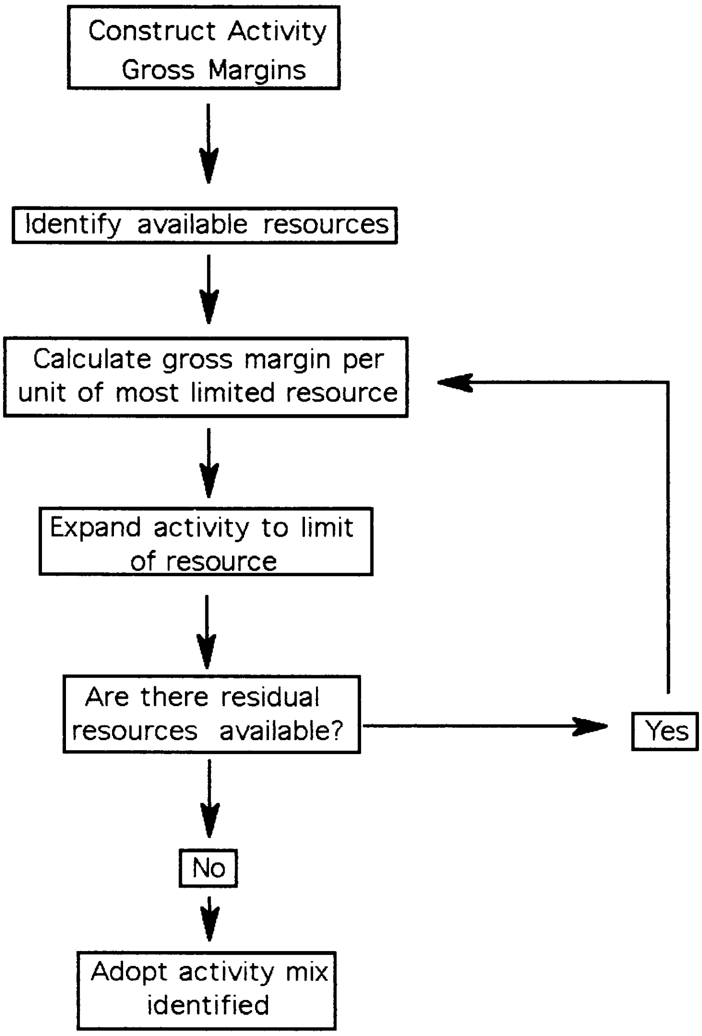


Figure 2.3 Decision Structure Using Activity Gross Margins

This structure requires the input of information in the form of point estimates of: the number of units consumed; the relevant input-output conversion ratios; input and output; prices; and inventory quantities and valuations.

The simplification inherent in point estimates has been termed the "perfect certainty assumption" (Doll and Orazem 1984, p. 26). Such structures are incapable of conceiving error or uncertainty in the inputted data, such that the data is considered to be known with "perfect certainty". The prevalence of random errors within objectively measured data, even those emanating from carefully conducted scientific experiments, means that such assumptions as to perfect certainty can result in major disparity between model predictions and achieved results (Hall and Keynes 1974).

The structure limits the data demand through several mechanisms. First, the arbitrary restriction to the consideration of a single activity, or a limited range of activities, excludes all data relevant to a large range of alternate activities. Second, fixed costs (costs unaffected by activity size) do not enter into the analysis while, third, the structure through its requirement for point estimate entry of data inhibits any recognition of variation in input-output conversion ratios (technology uncertainty) or input and output prices (market uncertainty).

The time span addressed in this type of analysis structure is normally one production cycle. With such activities as vegetable growing the production period will fall within the three months described by Humphreys and Berkeley (1983). With annual crops or the majority of livestock activities the production period may be considerably longer. However, it is suggested that within an agricultural decision classification the adoption of the classification of "short term decisions" (where resource fixity, biological constraints and production lags limit the manager's ability to alter production plans after commitment of resources) may be more appropriate than the stricter time constraint. This constraint on the time span under consideration significantly reduces the size of the data set required to facilitate the application ofactivity gross margins analysis as data relating to costs and prices in future states of the world, beyond the production cycle under consideration, can not be incorporated into the decision structure.

Cash flow budgets

"Net cash flow" is defined as the difference between total receipts and payments within a specified period. As a managerial aid cash flows are utilised for planning (budgeting) and financial control within a budget period (Makeham and Malcolm 1988).

There has been a rise in popularity (in Australian agriculture) of cash flow budgeting applications during the last decade, coincident with the poliferation of micro computers and the demands for increased financial control and accountability. The latter appears to have been linked to the demands of financial institutions associated with increases in farm indebtedness (personal observation).

The orientation of cash flow budgeting towards financial control has led to the imposition of time constraints correlating to relevant accounting or reporting periods. In general, most cash flow budgets are constructed on a monthly, quarterly or annual basis. Budgets may also be constructed for extended periods relating to the period of execution of a proposed development program.

As a decision aid, cash flow budgets are considered to assist farmers in the appraisal of proposed physical plans and to allow continuous feedback and monitoring during the implementation of the plan (Makeham and Malcolm 1988). The limitations of such "error-actuated feedback control", induced by production lags and response recognition delays, is discussed by Mauldon (1973). The pertinent decision structure suggested is as described in Figure 2.4.

Whilst cash flow budgeting does not provide a maximising or decision function for choice between physical plans, the requirement for a plan to generate an adequate cash flow can be considered a criterion on which plans are accepted or rejected. "The cash flow budget just tests whether the physical plan is financially feasible" (Makeham and Malcolm 1988, p. 85). Such mechanisms, that is choice on the basis of "elimination by aspect" (Tversky 1972), will be addressed during the consideration of type three decisions.

Constraints on the data set required for the construction of a cash flow budget arise from: the prior selection of a physical plan (the physical plan should input all factor/product relationships as point estimates); and factor prices as required for only those inputs detailed in the plan, while the forecasting of future product prices is constrained to the budgeted period (usually 12 months ahead).

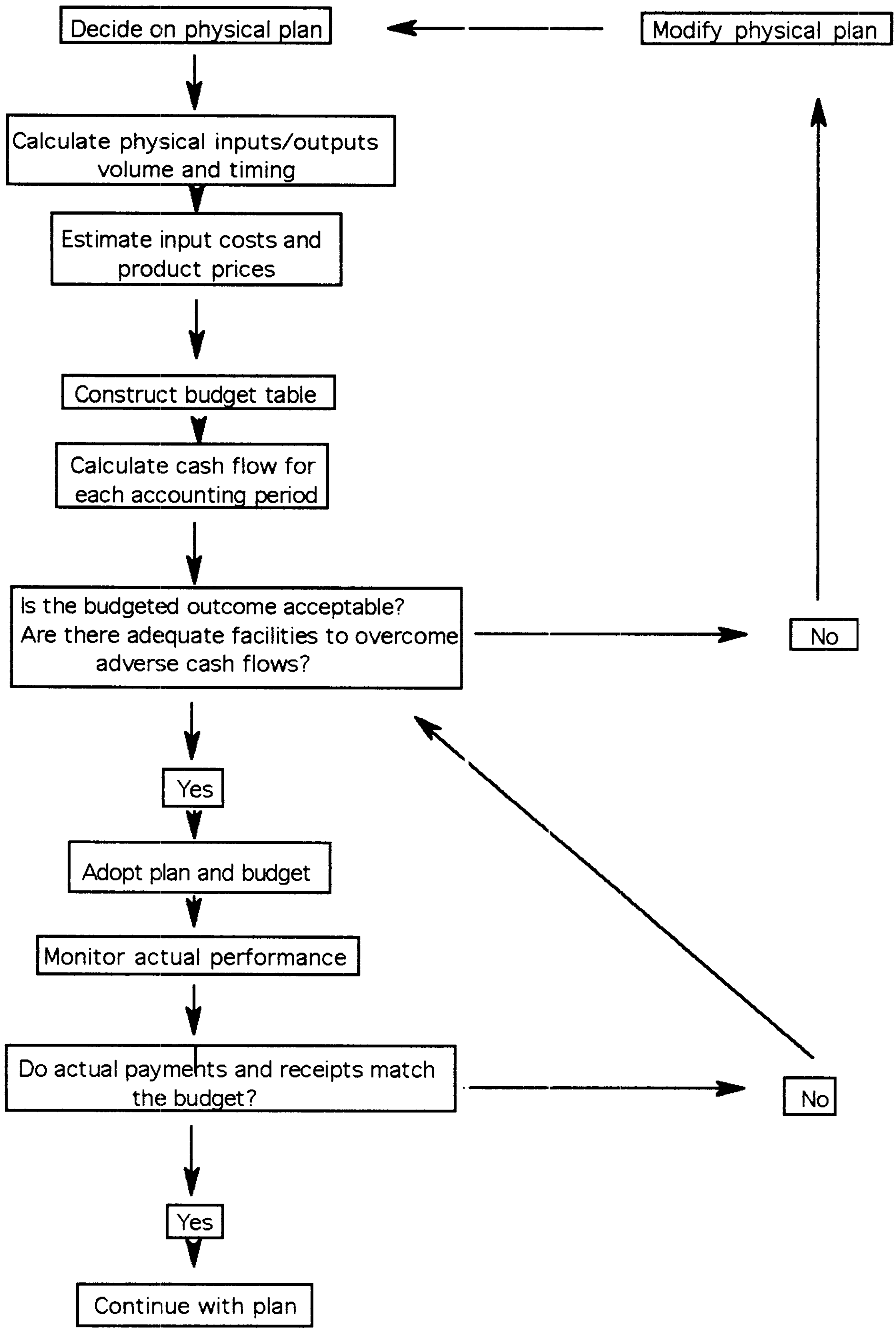


Figure 2.4 Decision Structure Using Cash Flow Budgets

As with gross margins analysis, cash flow budgeting, through its point estimate restriction (perfect certainty) on the inputting of data, excludes from consideration any data describing technology, and market, uncertainty. Hillier (1963, p. 443) describes this simplifying procedure as amounting to the reduction of "the estimates of the possible values of the prospective cash flow during each period to a single expected value, in either an intuitive or statistical sense, and then analyzing the problem as if each of these expected values were certain to occur" .

2.3.2 Level 2 decisions

The inclusion of the principles of inversion, negation, reciprocity and correlation in the consideration of a problems is seen by Humphreys and Berkeley (1983) to be characteristic of the second level of problem abstraction. Such tasks are described as having a typical time span of three months to one year, being formal in their operational status, with the ability to anticipate changes in task resulting from variations in one of: demand, object, production resources or production pathways.

Sensitivity (what if) analysis based on the manipulation of values inputted to a single node within a prestructured decision frame, leaving all other nodes within the structure undisturbed, typifies the decision structures applicable to this level.

Parametric budgeting

Parametric budgeting as a planning aid extends the basic gross margins analysis approach to enable the decision maker to include in his or her conceptualisation of resource allocation decisions the potential for variations in factors (parameters) such as output prices, input-output relationships and resource availability (Rickards and McConnell 1967, Makeham and Malcolm 1988).

The decision structure can be viewed as an extension of the process used to generate activity gross margins. The decision maker, having compiled the relevant activity gross margin analysis, constructs a revenue equation incorporating as variables the parameters which he views as being the most critical to the profitability of the enterprise. Different values of the parameters are then inputted to develop a range of solutions to the equation. For ease of presentation it is often suggested that the results obtained be presented as a monogram or graph (Rickards and McConnell 1967). However, the model is silent on the question as to how parameters are to be selected as either variables or constraints in the revenue equation.

The maximising function used to select between alternate activities remains the same as that employed in the gross margins structure. The inclusion of variable parameters has the effect of increasing the number of activities and activity levels available for selection.

Conceptualising the problem of activity selection at this level expands the data set required for solution of the problem beyond that required by gross margins analysis, to include information on the sensitivity of activity profitability to variations in the parameters considered in the revenue equation. For the selected variable parameters, point estimates of their values are replaced by a range of values, providing a partial description of any observed or expected variability in the parameter.

Such a decision structure requires the inputting of data which identify the conceived upper and lower limits to parameter ranges. However, it is incapable of handling data on the likely distribution of parameter outcomes within the specified range.

Cash flow sensitivity analysis

Analogous with the construction of parametric budgets based on the introduction of a variable into activity gross margins, the variation of point estimate values within a data cell of a cash flow budget provides an analytical structure for conceptualising the impact of such variations on net cash flow. Such a cash flow sensitivity analysis involves a limited relaxation of the perfect certainty assumption to the extent that the potential for variation is conceived, requiring the decision maker to input estimates of the range of a single parameter within the budget structure. As with parametric budgeting, the data set describing the decision world required is expanded to include information on which the decision maker can subjectively assess the importance of variability in factor-production transformation ratios, factor costs and product prices. The consideration of single parameter variations limits the need for data to those required for the description of the conceivable range of that factor; for example, the possible values that wool prices may take. Again, there is no capacity within this structure to consider the expected distribution of values within this range.

Hillier (1963, p. 444) also notes the usefulness of "sensitivity analysis" as a means of considering risk. However, he concludes that "there is a limit to the information that this can convey (for example, for statistical reasons)" as "it would be misleading to consider the case where all the estimates are too optimistic or where all are too pessimistic." The latter comment refers to multiple variables and hence is more appropriate where problems are considered at the third level of abstraction in the schema (Humphreys and Berkeley 1983).

Production functions

A production function portrays an input-output relationship, describing the transformation rates at which resources are converted into products. In a symbolic form the function can be written as

$$Y = f\,(X_1, X_2, X_3, X_4, \ldots\ldots\ldots\ldots X_{n-1}, \mid X_n.)$$

The differentiation between fixed inputs (factors which are fixed for the duration of the production period) and variable inputs (factors whose level of allocation is determined at the beginning of the production period) is achieved in the symbolic representation of the production function by the inclusion of the former to the right of the vertical line (Doll and Orazem 1984).

Examples of production functions (factor-product relationships) with a single variable parameter (one input to the left of the vertical line) would be consistent with a classification of level two decisions (Humphreys and Berkeley 1983). An example is the classical production function of yield responses to fertilizer applications based on point estimates of yield relative to known levels of the controlled variable (in this case fertilizer). Measured yield responses, derived from experimental work, are normally graphed, with an algebraic equation describing the line of best fit used as an estimate of the actual production function. This involves adoption of the added assumptions of "perfect divisibility" of inputs and outputs along with the assumption of "homogeneity" of inputs and outputs (Doll and Orazem 1984).

Producers whose goal (choice indicator) is assumed to be the maximisation of net returns or profit from variable inputs and who are operating in accordance with the decision structure described in production theory, as predicted by the theory, are expected to allocate resources to production at a level such that the marginal cost of the last unit of resource committed to production equals the marginal return of additional production achieved (given that production is being carried out in the region of the production function where the elasticity of production is equal to, or greater than, zero and equal to, or less than, one (stage II)) (Doll and Orazem 1984). This analysis structure requires the decision maker to input data, under the perfect certainty assumption, on prices and input-output transformation rates, along with the construction of the production function, for the variable input. This limited relaxation of the perfect certainty assumption necessitates a data set expansion to include the information (in the form of a response function) describing the nature of the production response to variations in the selected parameter, for at least stage II of the derived production function.

The application of production analysis in short term resource allocation to a specified activity, that is a problem in which only one parameter is variable (or example, the rate of fertilizer application to corn crop), contracts significantly the boundaries of the data set required. Even so, it is questionable whether producers will have available to them reliable data on which to construct response functions or whether agricultural researchers can ever hope to enumerate all factor-product response functions (Doll and Orazem, 1984).

2.3.3 Level 3 decisions

The essence of decision making as perceived by Dardanoni (1988) is seen to be the notion of trade-offs within economic constraints, while Doll and Orazem (1984, p. 179) state that:

> The art of farm management centres around a knowledge of the competitive, complementary and supplementary relationships among

> farm enterprises. The farm manager tries to combine enterprises to take maximum advantage of supplementary and complementary relationships. This becomes complicated because the relationships between enterprises differ depending on the input considered.

These insights describing the complexity of the decision world faced by farmers (the perceived need to account for a range of competitive, complementary and supplementary relationships) is consistent with the conceptualisation of the farm management problems at the third level of the Humphreys and Berkeley (1983) taxonomy. The third level of problem abstraction encompasses the reformulation of decision structures within a single decision aid, model or theory. This involves the processes of criteria identification, the definition of the relationships between parameters considered and multiple parameter manipulations in the analysis phase. The task of reformulating decision structures given alterations to factor-factor or market relationships would also be classed as a level three decision under this system. A one or two year time span is seen as characteristic of the problem addressed at this level in the corporate sense, as described by Humphreys and Berkeley (1983). In an agricultural context it may be more appropriate to consider the time characteristics as being aligned to "medium term" decision problems where the producer has the flexibility to alter a range of input levels and input-output relationships.

Clarification of the goals (choice indicators) and the development of coherent composition rules to explore the relative desirability of the options under consideration has been the basic intent of the great majority of work in the field of decision theoretics. There are many competing postulates as to how decisions are or should be made which have been developed at this level of abstraction. The various aids, models and theories provide a predetermined structure for the decision process, with major variations in the assumptions they make, choice indicators adopted, the information processing patterns used and the nature of the composition rules used. Characteristic of work at this level of abstraction is its inability to handle questions relating to the mechanisms by which a decision maker should choose between alternate representations of the problem addressed. That is, the models and theories contain an assumption that "they" describe the only rational representation of the problem.

This dissertation is not concerned with arbitrating the often conflicting claims to validity of the various models and theories. Rather, a cross-section will be examined to ascertain their data demands and processing procedures. The size of the data set demanded is significantly influenced by both the number of input-output relationships considered and the means, if any at all, by which risk and uncertainty is accounted for within the specification of the problem. As risk and uncertainty is such an important characteristic of agricultural decision making (Freebairn 1978, Anderson 1982, March and Shapira 1987, Timko and Loyns 1989) specific reference will be made to the conceptualisation of risk, its specification and the means of risk data manipulation employed by the various models and theories examined.

<u>Production function with two variable inputs</u>

Production functions of the general structure

$$Y = f\ (X_1, X_2, \mid X_3, X_4, \ldots\ldots\ldots\ldots X_n)$$

can be developed to describe the complementarity, substitution or competition inherent in the interaction between two variable inputs and the output of a productive system (Doll and Orazem 1984).

This extension of the concepts underlying single input variable production functions expands the data set requirements in that it becomes necessary to be able to depict, in graphical terms, a three-dimensional production surface. This is a composite of the predicted production from all feasible combinations of the two variable inputs, given the holding constant of all other production factor levels. Such a production surface may describe, for example, the expected production (tonnes of grain) from a crop sown at different seeding rates (that is, with different plant population densities) and receiving varying amounts of fertilizer.

The line or curve depicting all observations of equivalence in production outcomes achieved by various combinations of inputs (for example, higher plant populations with lower fertilizer applications may produce the same amount of grain as lower plant populations with higher applications of fertilizer on the same area of land) is called an "isoquant" (Doll and Orazem 1984). Drawn in two dimensions or expressed algebraically, isoquants summarize the yield data (observed or predicted) for the various combinations of the two controlled variables (plant populations and fertilizer rates in the previous example). Again, this involves adoption of the assumptions of "perfect divisibility" of inputs and outputs along with the assumption of "homogeneity" of inputs and outputs (Doll and Orazem 1984). The ability of one variable to compensate for successive reductions in the other variable ($\Delta x_1/\Delta x_2$), whilst maintaining the level of production depicted by the isoquant, is termed the input's "marginal rate of substitution"(MRS). This equals the slope of the tangent drawn to a point on the isoquant.

The nature of the relationship between technical substitutes (inputs which may be expanded or contracted relative to each other whilst maintaining total production) can be ascertained from changes in the observed marginal rates of substitution at points along the isoquant. Characteristic of many agricultural production relationships is a need to substitute increasing amounts of a factor for successive decreases in its technical substitute, often termed the law of diminishing returns. Such a production function would exhibit decreasing marginal rates of substitution (in an absolute sense) as movement occurred along its isoquants. A constant marginal rate of substitution indicates constant rates of factor substitution, while complementarity is exhibited by inputs that are required in fixed proportions such as the elements of hydrogen and oxygen in a molecule of water. In the latter case the isoquant degenerates to a dot (Doll and Orazem 1984).

To aid in the manipulation of the information describing the changes in the rate at which technical substitutes may replace each other, the concept of elasticity of input substitution is introduced. This is traditionally defined as "the proportionate change in the ratio of the input amounts divided by the proportionate change in the MRS" (Doll and Orazem 1984, p. 107). This assumes either a convex or linear isoquant; that is, operation within stage II.

The impact of the cost relationships between the variables (x_1 and x_2) is incorporated in this decision structuring approach through the computation of "isocost lines". On the basis that input costs are assumed to be known (perfect certainty) and constant, a linear total variable cost surface can be constructed, being the composite of the costs associated with each possible combination of the inputs. Points on this surface of equal costs can be described by isocost lines the equation of which can be found by solving the total variable cost equation ($TVC = Px_1 X_1 + Px_2 X_2$) for X_1 as an explicit function of X_2 (Doll and

Orazem 1984).

The minimisation of the cost of producing a given amount is adopted as the choice criterion for the selection of alternative input combinations on a given isoquant. By the combination of data on the physical production relationships, and input cost data transformed into isoquants and isocost lines respectively, the least-cost combination can be calculated to "occur at the point where the isocost line is tangent to the isoquant, given the isoquant is convex to the origin" (Doll and Orazem 1984, p. 114).

Having identified the points of least cost of production on each isoquant, by the above method, it is possible to trace the expansion path, that is the isocline (the curves transecting the isoquants at points of equal marginal rates of substitution) passing through the points identified. Hence, the "expansion path traces out the least cost combination of inputs for every possible output level" (Doll and Orazem 1984, p. 122). A firm with a profit maximisation choice indicator will expand production along the expansion path until the marginal cost of the last unit of output equals the marginal revenue from its sale (Doll and Orazem 1984). To achieve this step the data set requires expansion to include point estimates (perfect certainty estimates) of product price.

The calculation of the profit maximising level of production, using this decision structure, for a firm engaged in a productive enterprise in which there are only two variable inputs requires a data set inclusive of the data describing the production levels resultant from all feasible combinations of the two variables, perfect certainty data on the level of all other inputs and perfect certainty data on the costs of all inputs (fixed or variable). Even within single product entities, an agricultural rarity in themselves, management decisions involving the manipulation of single or dual inputs (technical substitutes) are normally restricted to short-term planning. The basic derivations used in the exploration of the two input case can be expanded to cover decisions relating to the allocation of three or more variable inputs. However, the data set required expands rapidly, especially that relating to the description of the production surface.

The application to the solution of a crop-culturing problem involving factors such as plant density, phosphatic fertilizer applications, nitrogen applications, soil moisture and weed suppression gives a production function of the following nature.

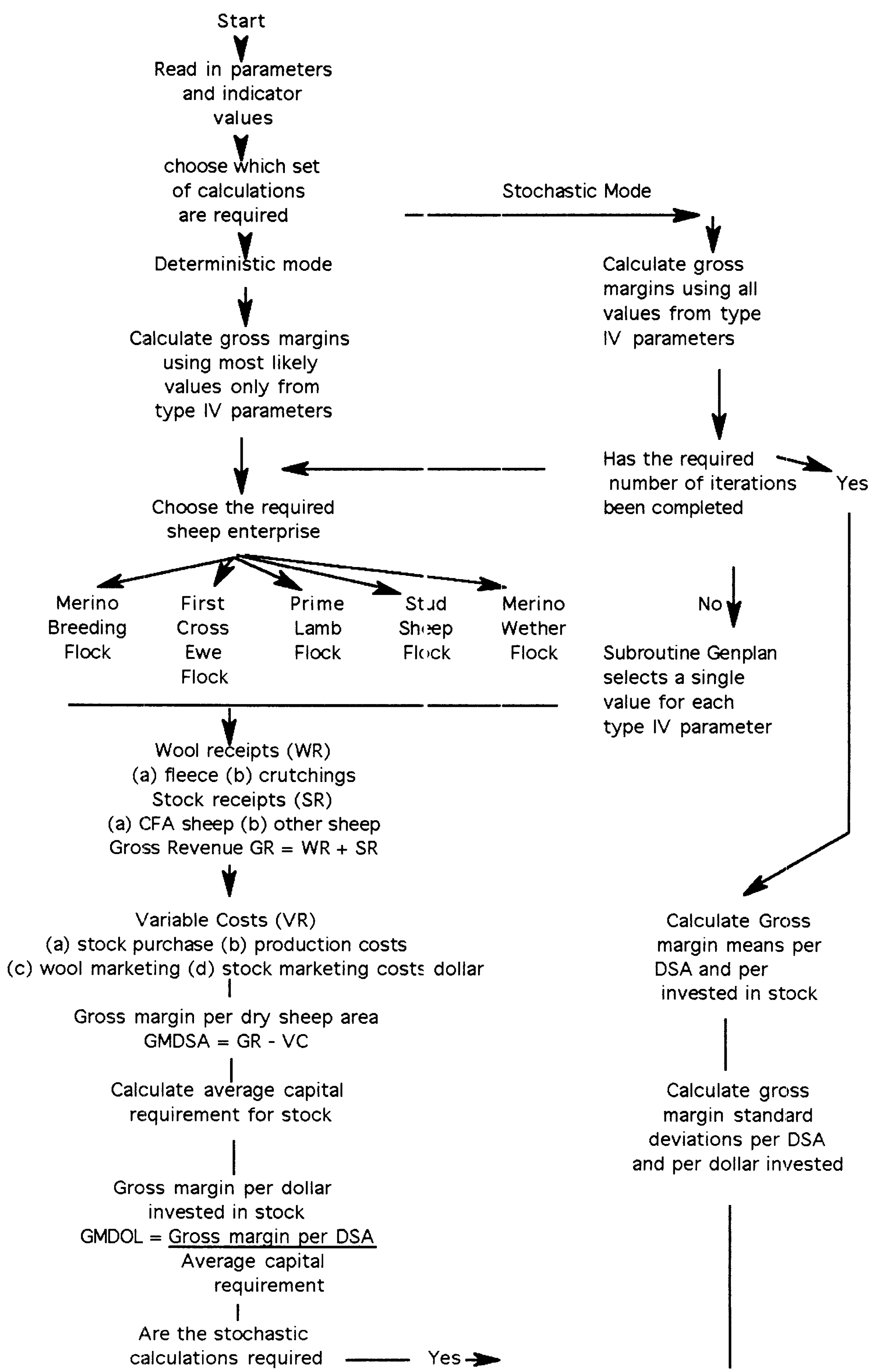
$$Y = f\,(X_1, X_2, X_3, X_4, X_5 | X_6, \ldots\ldots\ldots\ldots X_{n.})$$

Assuming only five feasible input levels for each of the variable inputs, the tracing of the production surface requires 3,125 point estimates of production. This, along with the need for replication within experimental design, can be expected to quickly exclude any objective measurement of such surfaces.

Stochastic computerised activity budgeting (SCAB)

The computerisation and the addition of a measure of risk to the activity budgeting and gross margins analysis is seen in this extension of these decision aids (Mill and Longworth 1975). This decision aid allows for the calculation of gross margins in a deterministic way, with parameter values entered into the decision structure at their average or modal value (point estimates), while in its stochastic mode the decision structure accepts, as data inputs, subjective probability measures for the major uncertain parameters (type IV parameters)(Mill and Longworth 1975).

Mill and Longworth developed a series of computer programmes for the comparison of various activities using the SCAB principles. Characteristic of the decision structure adopted is that described for selection between five sheep activities (Figure 2.5).


Start
Read in parameters and indicator values
choose which set of calculations are required
Stochastic Mode
Deterministic mode
Calculate gross margins using all values from type IV parameters
Calculate gross margins using most likely values only from type IV parameters
Has the required number of iterations been completed
Yes
Choose the required sheep enterprise
Merino Breeding Flock
First Cross Ewe Flock
Prime Lamb Flock
Stud Sheep Flock
Merino Wether Flock
No
Subroutine Genplan selects a single value for each type IV parameter
Wool receipts (WR)
(a) fleece (b) crutchings
Stock receipts (SR)
(a) CFA sheep (b) other sheep
Gross Revenue GR = WR + SR
Variable Costs (VR)
(a) stock purchase (b) production costs
(c) wool marketing (d) stock marketing costs
Calculate Gross margin means per DSA and per dollar invested in stock
Gross margin per dry sheep area
GMDSA = GR - VC
Calculate average capital requirement for stock
Calculate gross margin standard deviations per DSA and per dollar invested
Gross margin per dollar invested in stock
GMDOL = Gross margin per DSA / Average capital requirement
Are the stochastic calculations required
Yes

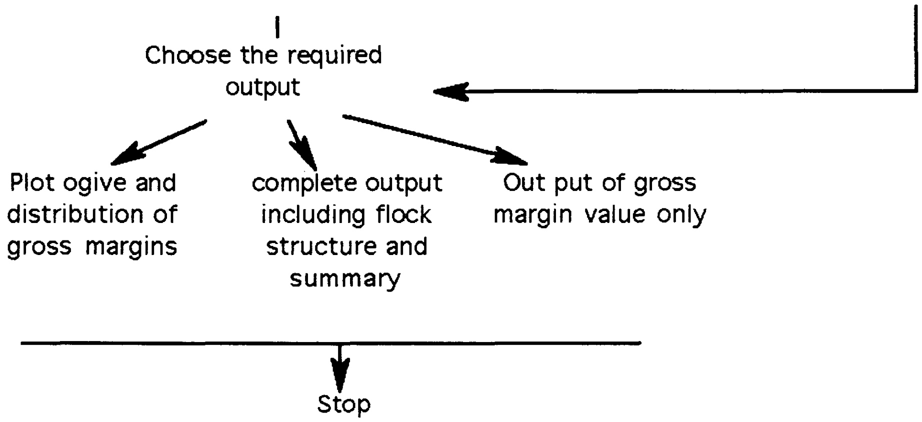


Figure 2.5 Decision Structure Using SCAB
Source: Mill and Longworth (1975).

This decision structure requires the segregation of the parameters involved in the calculation of the activity budgets into four groups. Those fixed parameters written into the computer program are referred to as "type I" parameters. Parameters with a geographic region constancy, referred to as "type II", are varied only when the computer program is intended for use in alternate districts. Of the parameters known to be variable in nature, a subset are considered to be deterministic on the basis that they are either "known with comparative accuracy" or are of minimal significance in the overall calculation. Such variables are referred to as "type III" parameters. Parameters for which there is uncertainty as to their likely value and significance in the budget calculations are labeled "type IV" parameters (Mill and Longworth 1975).

The application of this decision structure in its stochastic mode requires a dimensional expansion of the data set in excess of that required by the deterministic mode (traditional activity analysis), as the absolute certainty assumption inherent in point estimates is relaxed to allow the recognition of risk. Initially, the decision maker needs data (or information) on the stability of all of the parameters under consideration sufficient to allow parameter typing. The adoption of triangular distributions to describe the spread of the stochastic parameters (type IV), and the subjective estimation approach of Cassidy et al; (1970) utilised by this decision structure, necessitates the incorporation of the producer's estimates of the parameter's lowest value anticipated, the most likely values and the highest values anticipated (Mill and Longworth 1975).

The mechanisms utilised to reduce the size of the data set required by this structure include the subjective typing of parameters to limit the number requiring distribution estimates, and the use of subjective probability distributions. The acceptance of the decision maker's subjective estimates, rather than objective measurement of type IV parameter's distributions, significantly reduces the data set requirements, assuming that the former may be derived in the absence of objective data describing the distribution of the parameter. However, whilst such mechanisms reduce the need for objectively derived data, they substantially increase the cognitive load on the decision maker, with excessive cognitive load representing a major constraint on the application of decision structures.

Mill and Longworth (1975) note the limitation of the approach in that it assumes zero covariance between type IV parameters. While this results in a downward biasing of the measure of risk calculated, it does allow the application of the approach in the absence of any measure of the inter-correlation of stochastic variables.

Again, as with conventional activity budgeting, the restriction of the approach to medium term decision problems not only restricts the number of parameters (fixed costs can be excluded from the analysis) but also allows a greater number of parameters to be treated as deterministic (for example, input costs may be viewed as being ascertainable with an acceptable degree of accuracy in the short-to-medium term).

The choice procedure utilised in the stochastic mode remains the same as that employed in the deterministic mode, except that the choice indicator includes a measure of the standard deviation of the expected activity gross margin as well as its mean value (the latter equating to the point estimate of activity gross margin in the deterministic mode).

Subjective expected utility theory

The basis of all utility models is the calculation of the expected utility of consequences of the decision alternatives from a compilation of the individual's utility function and the probability distribution of all possible outcomes, the choice criterion being the maximisation of expected utility.

Freebairn (1975, p. 154) supports the adoption of utility as a choice indicator, with producers' decision problems being characterised as "maximising utility (of which profit is a special case) subject to technical and resource constraints and to market prices". The approach, in its subjective format, is seen as an advance in that it allows for the recognition of individual variations in the strengths of decision makers' "convictions about the occurrence of uncertain events" and "attitudes to risk" (Dillon and Trebeck 1987, p. 5) . Dillon (1977, p. 103) adopts "the view that risky or uncertain outcomes can always be described by a probability distribution and that this distribution is necessarily subjective".

The subjective aspect of the theory impacts on the data set required for its application, in that it relieves the operator of the requirement to obtain objective measures of the probability of the occurrence of outcomes. However, it requires the producer to formulate subjective estimates of the probability distributions of all possible outcomes of the alternatives under consideration. This can demand significant cognitive effort of the producer becoming a disincentive to the application of such decision structures.

An insight as to the elements of the data set required for the formation of such probability distributions is provided by Dillon (1971, 1977) who considered it natural that a decision maker would take account of past frequencies, predictions and additional relevant information including the following:

1- the probability distribution of profit corresponds directly to the probability distribution of possible utility outcomes for a particular choice

2 - each possible setting of the decision variables will have a corresponding probability distribution of profit

3 - each profit distribution is a function of whatever random or risky variables enter the profit equation - in general the risky variables will be product price and yield

4 - generally the profit distribution will correspond to a joint price and yield distribution. Price and yield normally independent for an individual decision maker

5 - if it exists, product price risk will be pertinent through its influence on gross revenue

6 - yield risk arising from uncertain uncontrolled input factors will only be relevant if there is interaction between these uncertain factors and the decision variables. If the probability distribution of yield is not conditional on the decision variables, yield risk has no influence on best operating conditions (Dillon 1977, p. 134).

Bessler (1984, p. 34), commenting on the formation of subjective probabilities, suggests that "any set of information that is relevant to the question at hand - including but not necessarily limited to historical frequencies" will condition a decision maker's estimation of the probability of the occurrence of a particular outcome.

The difficulty in defining the data set applicable to the application of this decision structure is further complicated by the observations of instability in subjective probability estimates over time and between individuals (Young 1984). This suggests that the scope of the data set considered relevant may be influenced by current knowledge and experience along with individual and temporal factors.

The theory is silent on the mechanisms by which the producer should formulate these probability estimates, the impact of inaccuracy in such estimates on decision quality and the ambiguity associated with such estimates. However, the emphasis placed on Bayes's theorem by decision theorists is attributed by Hardaker (1979, p. 210) to the desire that subjective probabilities should (given adequate data) "conform closely with the relative frequency embodied in those data", comply with the rules of probability calculus and be consistent with the individual's beliefs. In fact, the problems and costs associated with the acquisition of data, its transformation into subjective probabilities and their elicitation are seen by Fox (1984) as major impediments to the application of statistical decision technology in the real world.

Critical to the acceptance of expected utility theory is the simultaneous acceptance of the three basic axioms of ordering, continuity and independence. Decision behaviour which violates any of these axioms is considered to be irrational. However, the systematic violation of the axioms has been described by several authors (Simon 1959, Sugden 1986, Beach, Vlek and Wagener 1988) implying the exclusion, by the theory, of several factors impacting on decisions under uncertainty, hence reducing the data set considered necessary for analysis.

With utility, being described as a personal valuation of consequences (Dillon 1971), and the maximsation of expected utility being adopted as the logical choice criterion, ther is a need to expand the data set required for the application of the theory, to accommodte this personalised valuation system. Four methods for the elicitation of an individual's utility functions have been described (Dillon 1971). Such a function associates a risky prospect faced by the decision maker with a single real number or utility index. In general, the procedures rely on the transformation of monetary values and certainty equivalents of probabilistic returns.

It is necessary to recognise the implications of instability in personal preferences even over short periods of time. In fact, Anand (1982) suggests that an individual may vary his or her preferences as the decision process takes place. This leads to questions as to the stability of utility functions (Herath 1982) implying a need for constant review of this section of the data set utilised in the application of expected utility theory.

Vlek (1984, p. 21) draws attention to the conceptual limitations of decision theory.

> At this point it should be noticed that the expected utility maximization rule has nothing at all to say about the issue of the number of alternative actions. What the rule addresses is the proper way of processing information after the context has been chosen and the array of alternatives has been fixed.

Consequentially subjective expected utility theory excludes from the data set required for a decision made using this structure information on alternate decision structures. Further there is the opportunity for the subjective exclusion of some alternate actions from consideration and hence achieving a further reduction in the range of data required. However, the exclusion of alternate problem solving codes from consideration also excludes subjective expected utility theory from application where problems are conceived at the fourth level of abstraction (or above) within the Humphreys and Berkeley (1983) taxonomy.

Portfolio analysis

Australian primary producers have long recognised the benefits of diversification as a risk avoidance strategy. A producer who is risk averse can reduce the variance of his total returns by selecting a portfolio of production investments for which the prospects are not perfectly correlated (Dillon 1971).

However, it is necessary to recognise that diversification in production may also be a response to other factors. Gladwin (1980) suggests that diversification of production may not only be a response to the desire to avoid risk, but may also come about through the avoidance of the problem of deciding between alternate productive enterprises. Alternatively, biological considerations such as production constraints imposed by crop rotations, related to disease control and fertility, or productivity gains from the mixed grazing of cattle and sheep, may be the motivating factors resulting in diversity in farm production.

Moore and Snyder (1969) are of the opinion that the selection of cropping alternatives with risky prospects can be viewed as being analogous to the selection of a portfolio of marketable securities, and thus be amenable to the application of portfolio analysis, in which the objective is to maximise "long term expected gains". Support for the application of portfolio analysis in such a situation is provided by Dillon (1971). However, he states that the choice criterion should be the maximising of the decision maker's utility. Gillard (1991) observed that the demonstration of a model for crop selection, based on a portfolio approach, had the advantage of illustrating to farmers the costs of alternative portfolios even though they may not choose the optimal portfolio, given a particular choice criterion.

Markowitz (1952, 1959), in developing portfolio analysis, assumed that assets exhibit variations in expected returns that can be described by a probability distribution and that investors are utility maximisers within a decision period who derive diminishing marginal utility from successive increases in wealth. The investor is assumed to equate risk to the variability in expected returns, as measured by the standard deviation of returns. It is further assumed that, for any given level of risk, an investor will prefer an investment with higher expected returns.

Reilly (1989), in reviewing the application of portfolio analysis in the field of securities investments, suggests that the covariance of an individual investment with the market portfolio is the appropriate measure of risk. An asset's covariance (referred to as its systematic risk) is defined as the component of total variance in returns derived from holding an asset that is attributable to variation in the returns from the total market portfolio. In addition, an asset will exhibit unsystematic variance (risk) associated with features unique to the individual asset. This, however, is considered to be unimportant in a large, diversified portfolio.

To calculate the variance of an individual asset, and the correlation between asset returns under consideration for inclusion in the investment portfolio, it is necessary for the data set to contain measures of the potential returns from that investment and estimates or measures of the probability of the occurrence of such returns. The general approach has been to use historic time series data describing actual returns and their distribution as the basis for calculation of such measures. However, the efficiency of selection of future investments, based on such measures, will be critically influenced by the temporal stability of the measures estimated.

The acceptance of standard deviation as the appropriate measure of risk within this decision structure necessitates the computation of the standard deviation for a portfolio of assets. The derivation of the generalised formula for this calculation was developed by Markowitz (1952; 1959). The formula indicates that the standard deviation of a portfolio is derived from the "weighted average of the individual variances (where the weights are squared), plus the weighted covariances between all assets in the portfolio" (Reilly 1989, p. 265).

Having calculated the expected rates of return and the standard deviations of expected returns for a range of investment portfolios, the decision structure then requires the identification of the efficiency frontier representing the set of portfolios that minimise risk for a given return. An individual investor is then assumed to select an investment portfolio from those on the efficiency frontier. A utility maximiser would select the portfolio identified by the point of tangency between his highest obtainable utility curve and the efficiency frontier.

Hence, the application of this decision structure is therefore dependent on the expansion of the data set and the availability of a computational capacity capable of yielding the appropriate measure of risk.

Elimination by aspects

A number of decision theories, of which Elimination by Aspects (Tversky 1972) is one, have been developed from the study of information processing patterns associated with decision making. As a group such theories (models) are referred to as descriptive theories as distinct from prescriptive (normative) theories.

In contrast to those normative theories of choice that revolve around the ranking of alternatives on a scale of the relevant choice indicator, Elimination by Aspect theory (EBA) postulates that choice between alternatives is based on a sequential comparison of the component aspects of each alternative under consideration.

The first step in the decision structure, described by Tversky (1972), requires the identification of the aspects (characteristics) of the alternative actions available to the decision maker. Aspects may be qualitative or quantitative dimensions of alternatives such as price, quality, comfort, labour requirements, capital requirements or arbitrary features which can not be measured using a simple dimensional system.

An aspect is then selected and all alternatives not including this aspect are eliminated from further consideration. Should all alternatives include the selected aspect, no alternative will be eliminated. Hence, aspects common to all alternatives do not affect choice probabilities, such that details of common aspects may be excluded from the data set required for the application of this decision structure. The process of alternative elimination on the basis of the absence of an aspect is repeated until a single alternative remains which becomes the adopted course of action.

The probability of the selection of a particular aspect, in this process of elimination, is said to be proportional to its "weight". The weight of an aspect is a function of the proportional utility ascribed to the particular aspect within the total set of aspects comprising the aspects of all alternatives under consideration . This results in choice probabilities being seen to reflect "not only the utilities of the alternatives in question, but also the difficulties of comparing them" (Tversky 1972, p. 284).

In developing EBA, Tversky (1972, p. 297) observes that the limitations of human computational capacity restrict the application of optimising decision structures, involving "computations based on the weights assigned to various relevant factors, or on the compensation rates associated with the critical variable", in situations were people are faced with multiple complex alternatives to choose between. He is of the view that "people appear to search for an analysis of the situation and a compelling principle of choice .... without relying on estimation of relative weights, or on numerical computations." .

Within this structure there are a number of mechanisms by which the data set required for the application of the decision structure is reduced in size. Absence of data relating to, or the failure to recognize particular aspects associated with, alternatives simply removes the aspect from the set of aspects by which alternatives may be eliminated. Similarly, the occurrence of an aspect in all alternatives under consideration also removes that alternative from further involvement in the selection process. Further, as there is no requirement to evaluate aspects on a common scale (for example, utility), data relating to the valuation of an aspect in a numerically transformable format is not required for the application of this decision structure.

A two-stage disaggregate attribute choice model

Gensch (1987) proposes a two stage disaggregate choice model, in which an initial screening of alternatives is followed by alternative selection based on simultaneous attribute level comparison of alternatives. In contrast to EBA, which assumes alternatives are compared by consideration of their attributes in a hierarchical sequence, this approach in its second stage involves the simultaneous evaluation of attributes and recognizes the potential for trade-offs between attributes.

The use of conjunctive and EBA strategies in the early stages of decision making is seen as a decision-simplifying technique (Payne 1976). Explanation of the desire to quickly eliminate some alternatives is usually couched in terms of the decision maker's need to reduce their computational load. This early stage reduction in the number of alternatives under consideration not only reduces the size of the decision algorithm, it also significantly reduces the data set required in the application of such two stage choice models. Gensch (1987, p. 225) describes the first stage of choice in the following way:

> Individuals will screen down or simplify the amount of information by eliminating alternatives until they reduce the information load sufficiently to deal comprehensively with the final set of information.

The first stage reduction of the set of alternatives in this model is achieved through the application of the "maximum-likelihood-hierarchic model"(MLH) (Gensch and Svestka 1984).

<u>A Theory of Real-Life Choice</u>

Gladwin (1980) proposes a six stage descriptive theory of choice, termed the "theory of real life-choice" (R-LC). The theory is described as an attempt to take into account the "simplifying procedures or heuristics that people use in real life to make their decision making easier"(p. 45).

Alternatives available to the decision maker are described, in R-LC theory, on an aspect system similar to that used by Tversky (1972), with an additional simplification of descriptive data in that aspects representing continuous quantitative dimensions are considered to be summarised by limited numbers of discrete intervals along the continua. Under such a constraint on the incorporation of data, the price of a tractor may be entered into the decision structures as, for example, being above or below $50,000 or within a range (ie.g. ≥ $30,000 ≤ $35,000). This feature of the theory recognises the difficulties in ordering or semi-ordering of alternatives on any given aspect where discernible differences exist or precise ranking data is difficult or expensive to obtain.

Stage one of the decision structure is described as the unconscious or preattentive elimination of alternatives. To obtain a "feasible" subset of alternatives, Gladwin (1980) proposes that this stage follows a pattern similar to that described by Tversky's (1972) "elimination by aspects theory". In contrast to the probabilistic selection of aspects assumed by Tversky (1972), in R-LC theory Gladwin (1980) acknowledges the potential for a deterministic selection process. This initial pruning of the set of available alternatives to a subset of feasible alternatives, relieves the decision maker of the need to acquire data on all available alternatives. In fact, in certain decision situations the lack of appropriate data may be an aspect by which certain alternatives are eliminated.

The second stage of the decision structure is the heuristic elimination of aspects from the dimensional representation of the feasible alternatives under consideration. Gladwin (1980, p. 57) provides a non-exhaustive list of strategies to achieve this condensation of the set of aspects requiring further consideration.

> (a) if an aspect is of little or no subjective worth to the decision maker that aspect is eliminated.
> (b) if there is no noticeable difference between alternatives relating to an aspect, ..., that aspect is eliminated.
> (c) if two aspects are of equal value or equivalent importance, and the order of alternatives on one aspect is the opposite of the order of the alternatives on the other aspect, ..., then both aspects are eliminated.
> (d) if one aspect affects the decision process only through another aspect, and does not have a separate effect, the two aspects are considered as one aspect.

This removal of aspects from the dimensional representation of the feasible alternatives under consideration coincidentally removes the data relating to the aspects from further computation in the decision process. Hence, the process significantly reduces the size of the data set required for the application of this decision structure. The third stage involves the selection of an aspect from the stage two residual set of aspects on which alternatives are ordered. Gladwin (1980) suggests that the selection of the "ordering aspect" may be on the basis of the aspects themselves (for example, the aspect with the greatest utility or subjective worth) or by "means of a function not built up from ordering"(p. 58). This ordering aspect is then applied to the alternatives to generate an ordering or semi-ordering where alternatives are mutually exclusive. In the cases where the alternatives are not mutually exclusive, the decision maker is considered to partially order the alternatives on the ordering aspect (Gladwin 1980).

The fourth stage of the decision structure involves the imposition or formulation of minimal acceptable levels for each of the residual aspects of stage two, excluding the ranking aspect. The level of such constraints may be exogenously imposed or be a decision variable. The setting of the constraint levels will require data on the controls placed on the residual aspects by the decision environment. For example, a farmer considering the production of milk will need to consider the impact of externally-imposed quota constraints.

The alternatives are passed through the identified constraints in their ranked order until an alternative succeeds in passing all constraints, becoming the adopted alternative. This choice procedure has been described as "an algebraic version of maximization subject to constraints"(Gladwin 1980, p. 67). This is the fifth designated stage of the decision process.

The failure of any feasible alternatives to pass all constraints results in the decision process being extended to a sixth stage. The decision maker is expected to follow one of a series of strategies involving options of selection of different ordering aspects, the lowering of constraint thresholds, selection of the highest ranking alternative on the original ranking aspect, deferral of the decision and search for new alternatives.

Image theory

Image Theory (Beach and Mitchell 1987) includes in its description of the structuring of the decision processes both compatibility and profitability selection procedures. In this description the majority of personal decisions, of some importance, are viewed as being made unaided with only a minority being made after deliberate analysis, using such decision structures as expected utility theory.

The differentiation of decision types, within Image theory, is on the basis of the underlying image to which they relate. "Image", there, is taken to be the means of representation of information pertinent to the problem and the decision world under review. Beach and Mitchell (1987) identify four types of images with which various decision procedures interact.

1) The "*Self Image*" consists of "personal beliefs, basic values, morals, ethics, etc," . "*Principles*", the name given to these constituent parts of the self image, act as the choice criterion for the adoption of "*goals*".

2) The "*trajectory image*" is seen as a person's aspirations in life. Specific events and achievements or abstract states of well-being are termed "*goals*" which make up parts of the trajectory image.

3) The "*action image* " consists of the various plans that are in use at any moment for achieving the various goals that the decision maker is pursuing, whilst plans are viewed as programmes for action. Their concrete behavioural manifestations are called "*tactics*".

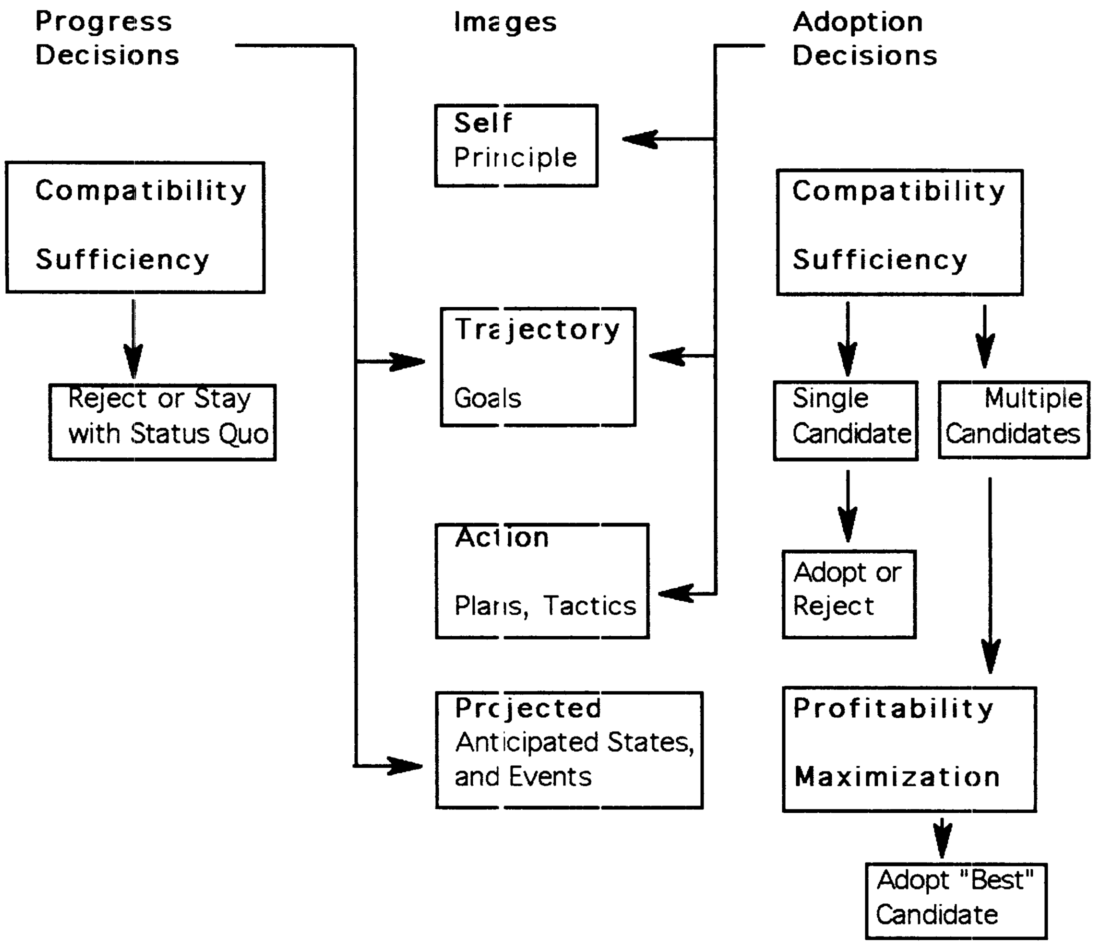
4) The "*projected image*" refers to the mental representation of the decision maker's expectations of the future , given the continuance of the plans already adopted or given the adoption of new or alternate plans. As such, it would be expected that this image would incorporate available data relating to such market expectations and the decision maker's evaluation of such data.

Given this classification of images, Beach and Mitchell (1987, p. 205) continue to describe two types of decisions:

> adoption decisions, which are about rejection or adoption of candidate constituents for images, and progress decisions, which are about whether each plan on the action image is progressing towards attaining its respective goal on the trajectory image.

The choice criterion for adoption and progress decisions is the compatibility of alternatives with existing constituents of the images and profitability. The latter is defined as the "degree to which a candidate offers attractive consequences contingent upon its successful achievement" (Beach and Mitchell 1987, p. 205). Decisions based on compatibility are seen to be non-compensatory, subconsciously undertaken, with the default value being "yes", with rejection requiring the attainment of a threshold of in-compatibility, while the "potential profitability of a candidate for adoption is the sum of the judgements of the profitability of its potential consequences, each discounted by the decision maker's doubt about whether the contingent consequences will occur or about whether it will prove to be as profitable as anticipated" (Beach and Mitchell 1987, p. 207).

This differentiation of decision type and the applicability of decision structures is depicted in Figure 2.6.



Source: Beach and Mitchell (1978, p. 209)

Figure 2.6 A Schematic of Progress and Adoption decisions.

2.3.4 Level 4 decisions

The question of problem comprehension is considered to be a potentially important factor in the determination of which information is utilised and which is ignored (Wallsten 1983). The array of decision structures available and their applicability to various problematic situations has led to the "assertion of diversity" as proposed by Kozielecki (1989, p. 57), which states

> .. that in the volitional acts people use many decision making rules, such as compensatory rules (the linear additive model) and non-compensatory ones (conjunctive and lexicographic rules), analytical (algorithm-like) and non-analytical (heuristic) rules. The selection of the proper rule depends on the structure of the problem, on personal variables, and on fortuitous influences.

The fourth level of abstraction proposed by Humphreys and Berkeley (1983) involves the conceptual task of "choosing the type of problem representation which is requisite at any point in a decision making process"(p.140). This demands of the manager a detachment from specific cases, with problem classes and alternate problem solving structures (problem representations) being the content manipulated within the decision process at this level. Humphreys and Berkeley (1983) suggest that, as a result of the lack of any formal articulation, within decision theory, of the principles involved in decisions at this level, managers revert to the use of natural or learned language in the development and evaluation of alternate problem solving structures. The development of acceptable problem solving systems is viewed in a corporate sense as the function of general management with inherent time spans of five to ten years.

The significance of the need to decide on the format of problem representation is also recognised by Waller and Mitchell (1984), who provide a description of a two stage decomposition of the decision process. The initial stage is concerned with the selection of an appropriate problem representation.

Herath (1982, p.153) has noted that different models may be used in a number of differing circumstances, with time costs being considered significant in partly explaining "why non-quantitative and ad hoc approaches have been developed in certain situations." The development of some measure of the goodness of fit between individual decision structure and the problem facing the decision maker is seen as critical in addressing the "simple but crucial point ..... that we need to be able to make decisions about decisions" (Fox 1984, p. 319).

Beach and Mitchell (1978) (see Waller and Mitchell 1984, p. 399) suggest that decision makers have a portfolio of decision structures from which they select strategies appropriate to the problem at hand having regard to the following.

Decision strategies

Aided analytical strategies- strategies that require the decision maker to apply a prescribed procedure utilizing external decision tools in a guided, systematic attempt to analyze the decision and evaluate its components (e.g. operations analysis, decision trees, 'moral algebra').

Unaided analytical strategies- strategies for which an attempt is made to explore the dimensions of the problem but for which no external tools are used (e.g. approximations to SEU performed entirely in one's head, 'satisficing,' and 'script' processing).

Nonanalytical strategies- simple, preformulated rules that are applied by rote to decision tasks (e.g. flipping a coin, homiletic rules, habits).

Task characteristics

Decision problem characteristics- characteristics that are inherent in the decision problem (abstracted from the decision environment).

Unfamiliarity- the degree to which the decision problem is foreign to the decision maker.

Ambiguity- the degree to which the elements of the problem (e.g., its goals, alternatives, constraints, available information, etc.) are unclear to the decision maker.

Complexity- the number of different components of the decision problem and the degree to which the problem will influence future decisions.

Instability- the degree to which the criteria, goals and constraints of the problem change during and after the decision.

Decision environment characteristics
(characteristics of a more general, situational nature)

Irreversibility- the degree to which the decision maker can make and implement a decision, monitor its effects, and reverse the decision if things go poorly.

Significance- the magnitude of the outcomes and the breadth of the decision's ramifications for other parts of the decision maker's life.

Accountability- the degree to which the decision maker is to be held accountable for the results of the decision.

Time and/or money constraints- upper limits on expendable decision resources.

Decision maker characteristics

Knowledge- the decision maker's knowledge of the available strategies and their relative likelihoods of yielding a 'correct' (in the ex post sense) decision.

Ability- the decision maker's ability to use the strategies.

Motivation- the decision maker's striving to expend the least personal decision resources compatible with the demand of the decision task.

This table is the framework by which decision strategies are chosen with regard to the characteristics of the decision task and the decision maker. (Waller and Mitchell 1984, p. 399).

Subsequently, Mitchell and Beach (1990) expressed some dissatisfaction with their 1978 approach, a result of the observed under-utilisation of some decision theories, especially formal analytical approaches, and the reliance of the "strategy selection model" on maximising theories that selected the best alternatives from a set of alternatives. They go on to pose the question,

> "Surely the mechanism that determines admission to the final set of alternatives is somehow more fundamental to decision making than one that merely selects the best alternative from the set." Mitchell and Beach (1990 , p. 4)

The mechanism alluded to is suggested to be a compatibility test, in which alternatives are initially accepted or rejected on their compatibility with "images" held by the decision maker. This process is described in the initial stages of the decision structure (Image Theory) developed by Beach and Mitchell (1987).

A corollary to the question as to the admissibility of alternatives to a choice set is the question of the admissibility of individual decision structures to the portfolio of decision structures available to the farmer. The relevance of the question of admissibility of decision structures to this portfolio, when problems are considered at the Humphreys and Berkeley (1983) fourth level of abstraction, to the design of management information systems to support farmers in decision making relates to two questions.

First, does the availability of specific information exclude various decision structures from the portfolio of decision structures available to the farmer? For example, given Hillier's (1963, p. 449) comment that "unfortunately, it does not yet appear to be realistic to expect investment analysts to develop reliable estimates of covariances", it is necessary to question whether "portfolio analysis" is in fact a viable option for the structuring of decisions in agriculture.

Second, are there image incompatibilities that exclude certain decision structures from use, hence making the provision of a data set tailored to specific decision structures a futile exercise?

The potential for incompatibility between theoretical decision structures, available data sets and the decision maker's images of self and the environment in which they operate, along with their computational and cognitive capacities, points to the need to address problems at Humphreys and Berkeley's (1983) fourth level of abstraction when studying the adequacy of market information provision. The significance of this problem and the consequence of its avoidance is noted by Johnson (1979, p. 88):

> Thus it is clear that a very high percentage of a problem-solving effort must be devoted to establishing the preconditions for use of a particular maximization rule in reaching prescriptive knowledge about the right action to solve a problem. This makes it extremely easy for economists to err in premature use of their maximisation models and techniques. Failure to resist this temptation accounts for much of the credibility gap economists encounter with both farmers and public decision makers.

Bettman, Johnson and Payne (1990, p. 114) utilised a measure of the computational and cognitive effort associated with the application of various decision structures (strategies) as a preliminary step towards the description of decision structure choice procedures. The metric of cognitive effort developed, Elementary Information Processes (EIPs) is based on the decomposition of decision structures into a sequence of "mental events, such as reading a piece of information into STM (short term memory), multiplying a probability and a payoff, or comparing the values of two alternatives on an attribute." The EIP events used were moves, reads, additions, products, compares, eliminations and differences. Apart from demonstrating that a model based on the weighted summation of these fundamental components (EIPs) of the various decision structures was a good predictor of the reported cognitive effort involved with the application of the particular decision structure, the authors concluded that

> taken together, the present results, plus those reported in Payne et al. (1988), support the hypothesis that decision makers choose strategies as a function of a strategy's demand for mental resources (i.e., the effort required to use a strategy) and the strategy's ability to produce an accurate response. (Bettman, Johnson and Payne 1990, p. 135)

This question of the strategy's ability to generate accurate responses is critical to the development of an alternate view as to the admissibility of decision structures to the portfolio of available decision structures put forward by Heiner (1983) in his development of the concept of "reliability condition". This concept appears to be useful in the understanding of the utilisation or non-utilisation of particular decision structures, of limitations placed on the range of alternate enterprises considered within decision structures by producers and the phenomenon of information filtering exhibited by producers. The tenet of Heiner's (1983, p. 585) argument is based on the observation that uncertainty, defined as the decision maker's inability to "decipher all of the complexity of the decision problems they face", constrains economic agents in their attempts to maximise. The following traces Heiner's development of the theory underlying this conclusion and attempts to apply the theory to the question of producers' acceptance or rejection of decision structures.

First, the concept of a "C-D gap"(competence - difficulty gap) is defined as the difference between the decision maker's competence and the difficulty of the decision problem. Uncertainty in the selection of the preferred alternative from a choice set is viewed as the product of the existence of a C-D gap. The determinants of the C-D gap are classified as being from two classes of variable (1) environmental variable (e) and (2) perceptual variable (p). Environmental variables (e), "including the complexity of environmental situations potentially encountered; the relative likelihood of these situations; and the stability of the relationships that determine possible situations and their relative likelihood" (Heiner 1983, p. 564), determine the complexity of the decision problem confronted by the producer. The producer's ability to decipher the relationships between their actions and the environment is taken to be determined by a range of perceptual variables (p).

Thus the C-D gap is seen as a function of the e and p.

The relationship is

> ... formally represented as a vector-valued function, $U = u(p^{-}, e^{+})$, which describes the structure of uncertainty from a C-D gap characterised by p and e. The signs above p and e signify that uncertainty is negatively related to an agent's perceptual abilities, and positively related to the complexity and instability of the environment. (Heiner 1983, p. 565)

The extrapolation of the argument to the consideration of the constraints leading to fixity in the repertoire (portfolio) of decision structures available to producers revolves around the requirements ("reliability condition") that a new structure must meet prior to admittance to the repertoire.

The likelihood of a new decision structure improving a producer's performance will depend on the probability that it is the right time to select the new decision structure. That is, the application of the new decision structure at a particular time will generate a superior outcome to that expected from the application of decision structures previously contained in the producer's repertoire. This probability is denoted $\pi(e)$ with the probability that the selection of the new decision structure occurring at the wrong time being $1-\pi(e)$. Here the selection of a particular decision structure is considered; however, the argument may be also conducted at the level of the admission of a new alternative to a choice set.

Further, a producer may or may not, in fact, select the new decision structure even if it is the right time. Similarly, they may or may not select the new decision structure at the wrong time. The conditional probability of selecting the new decision structure at the right time is written $r(U)$ and at the wrong time $w(U)$. Such probabilities are dependent on the structure of the uncertainty $U = u(p, e)$. The gain (over and above the utilisation of decision structures in their existing repertoire) from selecting the new decision structure at the right time is written $g(e)$ and the loss associated with the selection of the new decision structure at the wrong time l (e).

The "*reliability* " of selecting a new action is measured by the ratio r/w which decreases as uncertainty (as defined) increases, since the likelihood of mistaken selection increases and the chances of selecting the new decision structure at a time when it would generate favourable outcomes decreases.

It is not assumed that the individual is aware of the levels of $r(U)$ and $w(U)$ as uncertainties. Similarly $\pi(e)$ and $1-\pi(e)$ may also be unknown to the producer.

Given the above elements, Heiner(1983, p. 566) poses the question "when is the selection of a new action sufficiently reliable for an agent to benefit from allowing flexibility to select that action?". The question, transformed to coincide with Humphrey's fourth level of problem abstraction, becomes: when is admittance of an additional decision structure to the portfolio of decision structures available to producers of benefit?

The expected gain and loss from the admittance of a new decision structure are, respectively, $g(e)r(U)\pi(e)$ and $l(e)w(U)(1-\pi(e))$. Hence, for gains to accumulate quicker than losses the requirement is that $g(e)r(U)\pi(e) > l(e)w(U)(1-\pi(e))$.

This inequality can be rearranged to produce what is termed the "Reliability Condition"

$$\frac{r(U)}{w(U)} > \frac{l(e)}{g(e)} \cdot \frac{1-\pi(e)}{\pi(e)}$$

The probability of "correctly " responding under the right circumstances, relative to the probability of "mistakenly" responding under the wrong circumstances, is referred to as the "reliability ratio" (the left-hand side of the inequality $r(U)/w(U)$). The lower limit of the reliability ratio at which a new decision structure would be admitted to the decision maker's portfolio is termed the "tolerance limit" (T(e)) which is defined as the right-hand side of the inequality.

$T(e) = l(e)/g(e) \times (1-\pi(e))/\pi(e))$

Hence, a decision structure should only be admitted to the producer's repertoire for potential use if $r(U)/w(U) > T(e)$.

> We can intuitively interpret the ratio $r(U)/w(U)$ as the 'actual' reliability of selecting an action, in comparison to the minimum "required" reliability specified by the tolerance limit, T(e) (Heiner 1983, p. 566).

Heiner (1983) adopts a notational simplification $r/w > T$, which can be viewed as the reliability condition for the admittance of a decision structure, while $r/w < T$ represents the condition for the removal of a decision structure from consideration. Using this inequality it is possible to consider the impact of changes to the likelihood ($\pi(e)$) that a new action (production activity or decision structure) will generate a superior outcome to that expected from the consideration of actions previously contained in the producer's repertoire. Changes to $\pi(e)$ will influence both the range of activities considered by producers and the range of decision rules utilised by the producer.

For a constant l/g ratio, the T value approaches infinity as π decreases. Hence, for an action or a decision structure capable of identifying actions with a low probability of being the superior action to be admissible to a producer's repertoire (for example, comply with the reliability condition), the required reliability (r/w) of selection rises rapidly. As producer ability to select the right action at the right time is limited by uncertainty,

$U = u(p,e)$, rare or unusual actions are usually ignored. This latter statement may be contradicted if it is possible to demonstrate significant superiority in the reliability of selection (for example, higher r/w ratios) for particular decision structures. However, the absence of any dominant decision structure in agriculture indicates that it is difficult to suggest that any particular decision structure exhibits any major superiority. Similarly, the question of a constant l/g ratio is open to debate. However, over the longer term, competitive pricing of inputs and output would be expected to equalise losses and gains between agricultural activities.

Therefore, alterations to the decision environment which decrease π, that is the probability of any particular decision structure detecting a superior action (or a particular action being superior), will in fact restrict the numbers admissible to the portfolio of decision structures (choice set). Such decreases in π may be brought about by changes to the complexity of the decision environment through increases in the complexity of environmental situations potentially encountered, decreases in the relative likelihood of these situations, and instability in the relationships that determine possible situations and their relative likelihood.

This provides a formal characterisation for the basis of the reversion to rule-governed (heuristic) choice as the complexity of the decision environment increases. This is consistent with personal observation indicating that, as planning horizons increase in agriculture, the number of activities in the choice set decreases and the variety of decision structures utilised also decreases. Producers revert to rules of thumb that cover the majority of common situations and disregard the rare events, in long term planning, for example budgeting for property acquisition.

The reliability constraint ($r/w > T$) may also be contradicted by a reduction in reliability (r/w). As the r/w ratio is inversely related to the level of uncertainty ($U = u(p^-, e^+)$), a decrease in the producer's comprehensiveness of perception of the decision environment associated with an increase in complexity would also be expected to restrict the diversity of actions available to the producer.

In summary, factors such as increased environmental variation or greater perceptual difficulties will result in increased violations of the reliability constraint. This will lead to reductions in the number of decision structures and activities available to the decision maker.

> Therefore, greater uncertainty will cause rule-governed behavior to exhibit increasingly predictable regularities, so that uncertainty becomes the source of predictable behavior. (Heiner 1983, p. 570).

2.3.5 Level 5 decisions

The fifth level of problem abstraction proposed , for which no calculus was identified, involves the

> articulation of principles guiding the conditional closing of an open system (the unbounded 'grand world' of possible views of the future) into the small world within which an individual's problem structuring activities take place. (Humphreys and Berkeley 1983, p. 146)

In a business context this level of problem abstraction would require the structuring capabilities necessary to consider the modification of the boundaries within which the business operates and conceive possible future states of nature. As such, the decision maker is required to address such things as the parameters governing admissibility of production options into the set of alternate enterprises under consideration and the ability of the business to influence the environment within which it operates.

Prior to any consideration of the inclusion of a production alternative in a choice set and the subsequent application of selection procedures, it is necessary to recognise the existence of the alternative. A producer who is unaware of the market for chick peas is unlikely to include the production of chick peas in their set of potential production alternatives. Similarly, producers unaware of the differentiation between the "Korean Steer" market and the "Jap Ox" market will not be in a position to consider the profitability of production specialisation.

As with the inclusion or exclusion of alternatives, the truncation of the decision maker's small world may result in exclusions from the portfolio of available decision structures. For example, a producer lacking information on the correlation between the returns of various enterprise will be prevented from applying "portfolio analysis" (Markowitz 1952, 1959) to the selection of production alternatives.

Hence, the factors influencing the scope (that is, the proportion of the grand world conveyed to producers) of management information systems, and especially that section which purports to convey to producers the structure and nature of the market environment in which they operate, will be critical in the expansion or contraction of the producer's portfolios of decision structures and their set of available alternatives.

2.4 Certainty, Risk, Uncertainty, Ambiguity and Competence

The inadequacy of the perfect certainty assumption as applied to agricultural decision making is widely accepted. The relaxation of this assumption requires descriptors of the variability associated with outcomes of the various alternatives in the decision maker's choice set. Numerous descriptors have been adopted in the various decision structures reviewed. The availability of either particular descriptors or the capacity to generate such descriptors from available basic data, contained in the data set accessible to the decision maker, will be critical in determining the make-up of the portfolio of decision structures from which a farmer may select.

This section will attempt to identify a conceptual hierarchy of descriptions of outcome variability and will attempt to consider their use in the communication of market uncertainty to primary producers, and as descriptors of decision makers' perceptions of the market and their decision world.

2.4.1 Definitions

Numerous definitions of the terms certainty, risk, uncertainty and ambiguity appear in the literature.

Bullock and Logan (1969, p. 109) supply the following definitions.

> Certainty : if each action taken by the decision maker is known to lead invariably to a specific outcome.
>
> Risk: if each action leads to one of a set of possible unknown outcomes, but each outcome occurs with a known probability distribution.
>
> Uncertainty: if each action leads to one of a set of possible outcomes, but the probability of a particular outcome is not known to the decision maker.

The dichotomy of risk and uncertainty is also recognised by Doll and Orazem(1984), with risk being defined as occurring where a random variable exists with a known probability while, in cases where the probability distribution of a recognised variable is unknown, the situation is described as being one of uncertainty. An example of the use of this dichotomy is seen in the description of the strategic class of decisions, which are described as having outcomes that are probabilistic and being associated with some degree of uncertainty (Davis and Cosenza 1985).

Dillon (1971, p. 3), however, describes risky decisions in the following terms.

> Risky choice prevails when a decision maker has to choose between alternatives, some or all of which have consequences that are not certain and can only be described in terms of a probability distribution.

He maintains that all moments (mean, variance, skewness, etc.) of a probability distribution describing risk are encapsulated in expected utility values where the decision maker accepts the principles of Bernoullian choice (Dillon 1971). This view is supported by Sonka and Patrick (1984, p. 96) who assert that "the distinction between risk and uncertainty has focused primarily on objective verses subjective probabilities" and that all probabilities used in decision making are to some extent subjective, hence removing the need to differentiate between risk and uncertainty.

This obviation of the risk-uncertainty distinction in normative analysis is viewed with concern by Cancian (1980) who suggests that, at least in the descriptive analysis of agricultural decision making, the risk-uncertainty distinction is of considerable value. To achieve such a differentiation in an objective sense requires the use of probabilities to convey the "degree of uncertainty surrounding an uncertain event", requiring that the definition of probability be expanded to include measures of belief as well as relative frequencies (Hardaker 1979, p. 210)

The confidence that a decision maker has in their probability estimates is viewed as being important in the decision process (Becker and Brownson 1964, Kahneman and Tversky 1982, Einhorn and Hogarth 1986, Curley and Yates 1989). This assertion is supported by Heath and Tversky (1991, p. 7) who observe that an individual's

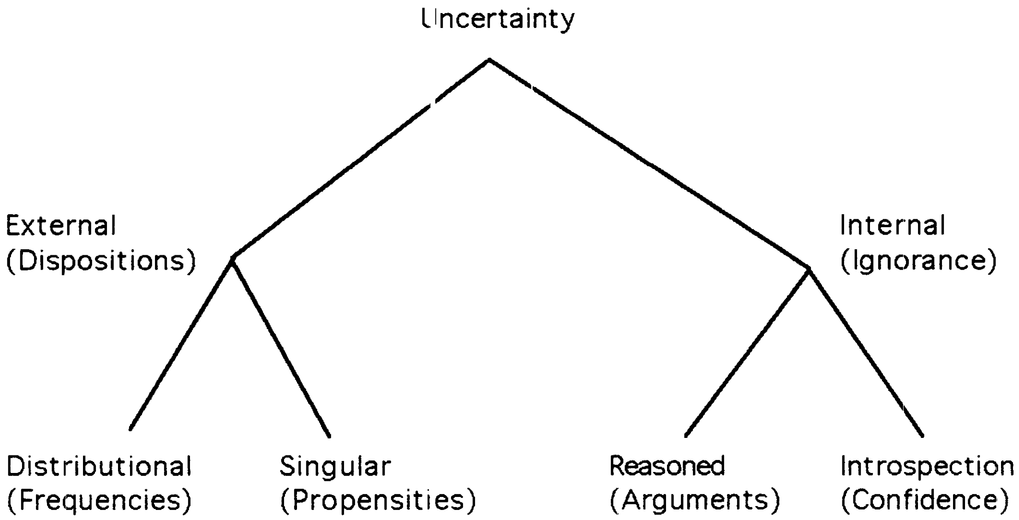
> .... willingness to bet on an uncertain event depends not only on the estimated likelihood of that event and the precision of that estimate; it also depends on one's general knowledge or understanding of the relevant context.

Wright (1983) raises the possibility that decision makers may have doubts about the accuracy of prior probability estimates of the occurrence of risky variables, referring to this as "felt ambiguity". It is suggested that this lack of confidence in probability estimates ("chance beliefs") may arise from doubts about the estimate of the range ("set beliefs") that a parameter may take and doubts about the constancy of the chance-generating mechanisms ("stability beliefs") that produce the probability distributions under consideration.

Einhorn and Hogarth's (1985) use of the term "ambiguity" to highlight the distinction "between one's lack of knowledge of the process that generates outcomes and the uncertainty of outcomes " appears to be consistent with Wright's (1983) observations on uncertainty surrounding the probability estimates. The irony of the selection of well-defined stochastic processes (for example, coin tossing, random drawings from urns, etc), and their inherent lack of ambiguity, as standard methodology for the investigation of decisions under risk can not be overstated where extrapolation of these results to "real world" decision making is advocated.

A similar initial differentiation is seen in Kahneman and Tversky's (1982) work describing the "variants of uncertainty". They suggest that uncertainty may be attributed to one, or a combination, of four variants of uncertainty (Figure 2.7) relating to either internal or external sources.

Under such a schematic representation of uncertainty, the root cause of uncertainty associated with estimates of market prices held by a producer may be wholly or partially associated with the randomness of the price-generating mechanism which is external to the producer or associated with the producer's own ignorance (state of knowledge) of the factors influencing price.



Source (Kahneman & Tversky 1982 a, p. 151)

Figure 2.7 Variants of Uncertainty

The decision maker's feeling of "competence" will be assumed to describe the level of the decision maker's belief in their comprehension of the decision world. The felt level of competence is taken to be related to the decision maker's general knowledge of, their familiarity with, and their expertise in, the relevant decision world; that is, those "internal" (Kahneman & Tversky 1982 a) factors significant in the generation of ambiguity.

In the further consideration, within this thesis, of the communication of the market environment to a producer, Bullock and Logan's (1969) definitions of certainty, risk and uncertainty are adopted maintaining the risk-uncertainty dichotomy. Further, the term "ambiguity" will be taken to describe a decision maker's lack of confidence in the accuracy of any estimates (e.g. point estimates means, probability distributions, etc). "Competence" will be taken to refer to the decision maker's perception of their own expertise in a particular decision world.

2.4.2 Descriptors

A producer faced with the need to incorporate into a decision structure an estimate of product price (for example, the price of 21 micron best top making fleece, ASW wheat 10% protein, or lambs 18.1 to 24 kg DW (dressed weight) - FS (fat score) 3) will be faced with two constraints: (a) the availability of data and its presentation format; and

(b) the constraints imposed by the decision structure utilised, which will have predetermined both the data format required and boundaries of the appropriate data set.

At Humphreys and Berkeley's (1983) first level of problem abstraction, the inputting of such product prices is assumed to be on the basis of perfect certainty. These point estimates of prices would be plugged into such structures as gross margins analysis and cash flow budgets. For decision makers the problem becomes one of selecting a "price" that they believe to be, with certainty, the price that they will receive for their production. Should producers observe the market for any period of time it is likely that they will record numerous "prices" . The size of this data set will generally grow as the period of observation is extended and as variability of product quality increases within specific market reporting categories. Further, where the estimate of price is required to relate to product for sale at a future date, the data set of "future prices" would be expected to be modified by factors recognised as important in the formation of prices but not currently operating in the market during the period of observation (that is, not in the market-reporting period).

A decision maker who is cognisant of either the risk or uncertainty associated with agricultural markets would be expected to experience significant ambiguity relating to the use of perfect certainty estimates as descriptors of the market.

Replacement of point estimates with assumed perfect certainty with such measures as averages of market prices, weighted averages, risk-discounted actual prices or subjective expected averages, could be considered as ways to achieve a partial mitigation of this felt ambiguity. Such a step would require a higher level of conceptualisation of the market environment while allowing the application of a simplified decision structure consistent with the basic level of problem conceptualisation. The use of such an approximation method would be in line with Tversky and Sattath (1979) observations that people find it difficult to utilise all available information in multidimensional decision worlds and, as a consequence, adopt information-approximating procedures. A complete description of such a decision maker's problem-structuring and information-processing activities would require the use of the conceptual components underlying Humphrey and Berkeley's (1983) higher levels of problem abstraction.

However, in the formation of a point estimate of price, from the observations of the market place (data) a producer may be, through a range of data transformations, attempting to account for a significant number of factors in the market considered relevant to the decision world. Whether such transformations are in fact achieved through the statistical manipulation of objective market data or are the result of an unstructured mental weighting of general market information is relevant to the classification of the data handled by a particular decision structure; that is, as being objective, or alternatively, subjective. However, the adoption of formalised decision structures which require point estimate inputs places restrictions on the presentation format of the data, yet leaves the question of the derivation (subjective or objective estimates) of the data unrestricted. While other decision structures require specific objective descriptors of risk, Young (1984, p. 31) provides the following commentary on this point.

> No necessary theoretical linkage exists between the specific risk concept and sources; however, theoretical relationships may exist between some decision modes and the probability sources.

A range of information processing techniques, both descriptive and normative will be discussed in chapter three.

The major advantages of retaining a relatively low level of problem structuring (implying a low level of problem conceptualisation) appear to lie in the reduced computational load and the avoidance of the cognitive effort required to restructure the decision process. Felt ambiguity arising from the lack of confidence in the applicability of more formal decision structures, or the utilisation of alternate descriptors of risk - uncertainty, may also be a major reason for decision maker reluctance to utilise more conceptually sophisticated decision structures.

Humphreys and Berkeley's (1983) second level of decision conceptualisation entails the recognition of variation in a single parameter. This introduction of variability is a common transformation of models developed under the certainty principle (Dardanoni 1988). Decision structures applicable at this level require a descriptor capable of conveying, to some extent, the variation expressed by that parameter. For example, the decision maker may choose to recalculate a cash flow budget using a number of alternate point estimates, say for lamb prices, or solve a parametric budget over a specific range of values of the chosen variable. In the initial example, the decision maker may select an alternate point value, in an arbitrary manner, or utilise several independently formulated point estimates. This act of identifying numerous point values will invariably generate a range.

Ranges as descriptors require that the decision maker formulates estimates of, or at least be provided with estimates (either objectively-derived or subjectively-formulated) of, the highest and the lowest values that the parameter may express. To estimate the high and low values of market prices applicable to their product, a decision maker will require of their market intelligence systems either actual highs and lows or forecasts of highs and lows. That is, producers require data that allows them to develop a rectangular distribution for the variable.

However, the solution of a revenue equation for the expected highest and the expected lowest value of a parameter gives little in the way of an indication of the distribution of outcomes within this range. The use of averages or means of market prices can be seen as an initial attempt to convey some indication of this distribution to a decision maker. The use of low-medium-high values in stochastic computerised activity budgeting (Mill and Longworth 1975a) to generate triangular probability distributions is illustrative of a decision structure which is capable of incorporation of this descriptive pattern.

Intuitively, the proposition that a variable may exhibit one of three values can be considered rather limiting. Furthermore, a producer who regularly studies the market for their products would observe a continuum of prices for virtually identical products within a range. The communication of such an observation, along with the observation that certain prices occur more often than others, requires the use of descriptors composed of either discrete price intervals and associated probability estimates or representations of continuous probability distributions, such as algebraic equations. Whilst it is possible to conceive of the utilisation of such measures within a decision world containing a single variable, hence implicating Humphreys and Berkeley's (1983) level two conceptualisation of the problem, it is apparent that such market descriptors are more likely associated with the application of multivariate (level 3) decision structures.

In subjective expected utility theory the statistical descriptor "variance" is utilised as the means of risk communication and the method of incorporation of risk in this decision structure (Dillon 1977). Hence, for a producer to incorporate product price as a variable (or as a component of a variable, for example, outcome utilities) in such a decision structure, there is a requirement for the elicitation of a subjective probability distribution of the expected prices (outcomes) from which they then calculate the variance associated with the distribution (Ortiz 1980).

In a review of the concepts of risk, Young (1984) highlights the contrast between the chance of loss and the variance of income. He suggests that this is illustrated in the development of the class of decision structures known as "safety first rules". There are numerous references in the decision psychology literature (Payne 1973, Luce and Weber 1986) to consistent differences in the valuation of unit losses and gains and the need for incorporation of measures of the risk of losing and the risk of winning in decision structures.

Alderfer and Bierman (1970, p. 350) studied the impact of different exposures to potential loss in investment selection. They concluded that, in the choice between alternate investments, "higher moments than the variance (for example the third moment and skewness, the measure using the third moment) are also relevant". Hence, it appears that, in the communication of the risk associated with an agricultural investment, skewness as a descriptor of the distribution of product prices may be of interest to the producer. This differentiation between "up-side" and "down-side" risk by managers was also observed by March and Shapira (1987, p. 1407) who concluded that "most producers do not treat uncertainty about positive outcomes as an important aspect of risk."

Alternatively, risk can be described as a multidimensional concept, which is conceptualised by the decision maker in terms of the amount to win, the probability of winning, the amount to lose and the probability of loss (Payne 1973). Decision structures incorporating this bifurcation of risk are described by Slovic and Lichtenstein (1968) and also by Anderson and Shanteau (1970).

Problems and applicable decision structures that can be related to the third level of Humphreys and Berkeley's (1983) decision taxonomy are described as involving multiple variables. Among these is "portfolio analysis" (Markowitz 1952, 1959) which is dependent as a structure on the calculation of the standard deviation of the portfolios of enterprise (for example, investment opportunities) mixes. Portfolio standard deviations are derived from the "weighted average of the individual variances" of the returns from each enterprise, plus "the weighted covariances between all enterprises in the portfolio" (Reilly 1989, p. 266). As such, the enterprise covariances are used to describe the relationships between the risks associated with alternate enterprises (systematic risk). Such measures, either subjectively or objectively derived, would be required for the application of portfolio analysis to the selection, say, between production programmes where a producer has the capacity to produce various types of grain (wheat, barley, oat, etc) or even for choosing between mixes of beef production targeted towards the "Korean Steer" , the "Jap Ox" and "Domestic Beef" markets.

The fourth level of Humphrey's problem taxonomy involves choices between decision structures. This choice procedure is seen to be influenced by completeness of information available to the decision maker (Svenson 1979). As the amount of information increases, confidence in predictions increases, given that the amount of information is a salient feature. Here, Peterson and Pitz (1988) define "confidence" as the level of beliefs that a given prediction is correct. A lack of " confidence", as defined by Peterson and Pitz (1988), would be expected to result in an increase in the decision maker's felt ambiguity relating to predictions.

While it is possible to suggest that the utilisation of more sophisticated descriptors of price and the risk and uncertainty associated with a market or price predictions may reduce the felt ambiguity, there appears to be no measure of confidence or ambiguity which can be incorporated into a decision structure selection calculus. However, where externally generated forecasts are used by a decision maker to formulate their own price estimates, the forecasting agency may convey to the decision maker, using descriptors such as error estimates or historical predictive accuracy measures, some measure of the confidence that should be placed in the estimate.

Humphreys and Berkeley's (1983) fifth level of decision abstraction deals with the closing or reduction of the "grand world" to delineate the "decision world". The scope of the management information system, inclusive of the market reporting and market intelligence systems accessed by the decision maker will be instrumental in the setting of the decision world boundaries. Alterations to the boundaries of the decision world, for example through the calling to attention of factors in the market which were previously not recognised by the producer, may significantly alter a decison-maker's belief in their own competence. It is suggested that the awareness of the existence of unattainable data (Heath and Tversky 1991), or the availability of data in the absence of either appropriate decision structuring or information processing procedures, would significantly reduce a decision maker's felt competence. As with ambiguity, there appears to be no objective descriptor of felt competence by which a decison-maker's completeness of understanding of the "appropriate" decision world can be measured.

2.5 Summary

The basic aim of this chapter has been to develop a structure which will allow the identification of the scope of the demand for information in agricultural decision making. Humphreys and Berkeley's (1983) taxonomy of decisions is used in an initial classification of various agricultural decisions in terms of their inherent cognitive complexity. Coincident with this, numerous decision aids and structures described in the literature have been classified on the basis of their ability to handle problems at the levels of cognitive complexity previously described.

The data sets required by the various decision aids and structures increase in both volume and complexity as the cognitive complexity of the problem increases. Similarly, as the level at which the stochastic nature of agricultural variables is dealt with by decision structures increases, the nature of the information demanded alters and the volume demanded increases.

Having established the nature of the information demand the following chapter considers the capacities of humans to process data obtained from their economic environment to fulfil this demand. In doing so the movement of data from the environment to the producer's semantic memory and the producer's formation of expectations is considered in some detail.