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Computerised analysis of netball

by

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A thesis submitted to the Council for National Academic awards in partial fulfilment of the requirements for the degree of Master of Philosophy.

August 1992

Sponsoring Establishment: School of Leisure & Food Management, Sheffield City Polytechnic.

Collaborating Establishment: All England Netball Association, Hitchin, Hertfordshire.

ABSTRACT

Computerised performance analysis of netball

This research stemmed from the observation that much netball coaching is based on relatively superficial and subjective observations of a team's performance and a lack of longer term coaching strategy or recognised 'benchmarks' for relevant aspects of technical and strategic play. A review of the netball literature revealed prolific advice about how to perform technical skills, but little strategic information and even less evidence of relevant 'benchmarks' for judging the quality of technical or tactical aspects of performance at given levels of play.

The findings of the literature review, combined with discussions with the national coach for netball, led to the development of two main aims for this project. The first aim was to develop a means of providing netball coaches and players with useful post-game feedback from individual matches, which of itself could be accumulated into individual and squad performance statistics over periods of time. The second aim was to investigate the possibility of developing a model of 'winning' netball performance which coaches might use as an aid to coaching. In order to pursue these aims it was decided to take an inductive approach based on the national coach's expert opinion as to what parameters of netball performance should be analysed and to analyse play at the highest level. A microcomputer-based match analysis system utilising purpose-designed software and a specially built keyboard was developed and tested for acceptable reliability. The analysis process was based on the concept of a team's possession of the ball: data was recorded concerning how a possession started, which players were involved, through which areas of the court the possession moved the ball and how the possession ended, including the scoring of goals. Data were abstracted and recorded from video-recordings of 28 matches taken from two international tournaments.

In terms of providing short term feedback, the system analysed the pattern of goal scoring across quarters, the rate and efficiency of shooting technique, the outcome of centre plays in terms of turnovers, creation of goal scoring chances and goals scored, loss of possession and whether such loss resulted in opponents scoring, together with player profiles of positive and negative aspects of technical performance. It was concluded that this system met the first aim of the project, the national coach using the system during one of the tournaments to analyse both her own team's performance and to 'scout' that of future opponents. Whilst the system did provide relevant information for coach and players in usable form there still exists the major limitation that there exist no 'benchmarks' against which to judge whether the rates of success, error or efficiency recorded for individual players or squads on selected aspects of performance represent relatively 'high' or 'low' levels of play.

After further consultation with the national coach, aspects of shooting & scoring, the ability of teams to score from their own and from their opponents' centre plays, and, the area of the court in which teams lost possession, were selected for further analysis in order to pursue the project's second aim of developing a model of 'winning' performance at netball. The database was split into three sets: data derived from teams which won their match; data from teams which lost their match; data from teams who were judged to have 'drawn' their match. The 'drawers' category was based on a statistically defined goal difference between teams of less than 5: ie, matches in which the probability of chance rather than skillfulness determining the outcome was greater than 5%. This investigation led to development of a 'profile' of winning performance which is statistically different from losing performance and which is based on nine performance characteristics. The results of this analysis suggested that winners and drawers have quite similar performance characteristics, both differing from losers: hence a close/equal score line probably results from a meeting between two teams who both display winning characteristics. Winners create more scoring opportunities from both their own and their opponents' centre plays than do losers: they also shoot more efficiently, penetrate the circle better and tend to utilise Goal Attack more effectively for shooting than do losers. Losers also lose possession more frequently and further from goal than do winners. Whilst these observations might seem obvious to the informed reader, the model has allowed a quantification of the level and scale of difference of these performance characteristics for international play, and hence has established 'benchmarks' against which coaches can assess the performance of their own teams, set targets for improvements and consider the coaching strategies required to achieve them. Difficulties were experienced in finding appropriate inferential statistical tests for the kind of data produced by this match analysis system, suggesting a need for further enquiry in this aspect of sports science.

This project has demonstrated that it is possible to develop an ecologically valid match analysis system for elite level netball which can provide coaches with both a model of winning performance and a means of profiling team and individual players' performance over a set of matches, such as a tournament or a season. The limited model developed in this thesis should be critically evaluated by the netball coaching community both as an aid to the coaching process in its own right and as a stimulus for the development of better ways of evaluating performance and informing future coaching practice.

Acknowledgements

I would particularly like to thank the following people for their assistance throughout this research project:

Heather Crouch (National netball coach), who helped advise during the early stages of the project and who was willing to 'experiment' with the system during the 1987 World Netball Tournament.

The technical staff at Sheffield City Polytechnic who, over the years, have given valuable assistance when required; Neil Donovan, Joan Butt. The two HND students on placement to the research laboratory; Craig and Spike who developed the computer software which made the whole project possible.

The All England Netball Association for their financial support during the early stages of the research.

My supervisors, Dr John Alderson and Mr Malcolm Brewer for their encouragement, perseverance and considerable expertise which has helped to guide me through this work.

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CHAPTER 1

INTRODUCTION

The role of coaching

The relationship between athlete and coach has long been recognised as an important feature for sporting success; Harris (1966) reports that "by the fifth century B.C. it seems to have been normal for every athlete with any pretensions to be trained by a professional". However, the relationship between athlete and trainer in the 5th century B.C. would have been very different from that of today's coach-athlete partnership, the difference is largely accounted for by the approach taken to develop athletic potential. The techniques used by trainers in the 5th century BC tended to be draconian and lacked the necessary understanding of athletic performance needed to develop talent. Historic accounts of athletic training in ancient Greece often portray the picture of a trainer, rod in hand, ready to reinforce his instruction with a well placed blow if necessary (Harris 1966). These first professional Greek trainers were known as 'paidotribes' and employed as disciplinarians rather than as experts in developing athletic potential.

As the cultural importance of athletics grew in Greek society and the need for skilled instructors was recognised, the professional paidotribe was gradually replaced by more

knowledgeable 'gymnastes'. Unlike the paidotribe who was primarily responsible for disciplining athletes, the gymnaste's role was to instruct athletes in the best techniques for their sport and to develop training programmes to maintain skills and physical condition (Harris 1966). It is this latter role that we would today recognise as **coaching**.

The development of coaching expertise over the past century has been somewhat hindered by the distinction between amateurism and professionalism in competitive sport (Bennet, Howell & Simri 1972). At the turn of this century the majority of Britain's athletes were educated persons of comfortable financial means. The notion of a coach to help improve performance was seen as "professional" and a contradiction to an athlete's amateur status (Bennet, Howell & Simri 1972). In Britain, at least, coaching was confined to the needs of professional competitors and therefore deemed an activity for the lower classes. Around the late nineteenth and early twentieth Century the organisation of sports in Britain began to take on a more formal and structured approach with the emergence of National Governing Bodies. National Governing Bodies took the responsibility for developing their respective sports which included coaching. However, the development of coaching practice through informed debate and published literature was slow. Access to information regarding human performance was in the main, reserved for those in formal education and therefore excluded the large majority of working class coaches. Academic research and development of **direct** value to coaches has also been slow to develop, initially

because those working in areas of potential value to coaching practice were unaware of the needs of coaches.

Latterly however, the economic, social and political importance of sport has had a pragmatic influence on the quest for sporting excellence. Attention given to performance preparation has highlighted the often complex nature of coaching and the necessity of relevant information to assist in the process of preparation for sports competition. Whereas in the past it was common practice to appoint former athletes as coaches on the basis of "experience" and with little or no formal training, out of necessity, today's learning process for coaches has become more formalised and structured.

Whilst the National Governing Bodies of most sports offer courses leading to competency awards for coaches, the formation of organisations such as the National Coaching Foundation and the British Institute of Sports Coaches reflect increasing recognition of the need to provide specialist agencies offering information and skills to support the work of coaches.

The nature of the coaching process

Most coaching practice, whether associated with elite competitors or recreational novices, is concerned with the preparation necessary to enable performers to take part in an appropriate level of sport. According to the National Coaching Foundation (1986) this takes place through the preparation and

refinement of performer skills and the evaluation and analysis of competitive performances. By definition, refinement and development of performer skill implies improvement and hence coaching is associated with improvements of performance. As increased importance is placed on the outcomes of sporting competitions, the demand for better preparation grows, and with it, the need for well-informed coaches.

Increasingly, academics and some commercial agencies have joined coaches in the pursuit of better sport performances. Whilst they share a similar purpose, that of better understanding the nature and problems of human performance, the approach taken by different agencies, has varied with their 'motive' and involvement in sport.

For example, coaches are required to operate in a continuous cycle of performer preparation followed by competition. Their direct involvement in this process and immediate concern for the next competition limits the approaches that they can take to improve on previous performances. Their involvement in performance analysis is of necessity highly specific to the performer(s) in their care and they must operate to fixed time schedules. Sport academics, by contrast, rarely have direct responsibility for improving a given performance and are able to take an approach that is applicable to performances in general and are less constrained by time.

Successful performances in many sports are reliant upon a combination of physical and mental abilities, both prior to and during competition. These abilities might include levels of physical fitness, motivation, concentration, technical skill and tactical awareness. Therefore agencies concerned with improving performances must aim to understand these physical and psychological aspects of behaviour relevant to successful performances within a specific sport.

The coach's role is not therefore as straight-forward as might first appear; for example, to affect a performance positively coaches may first have to assess a combination of the physical and mental abilities identified above, before a decision can be made regarding performance modifications. Hence, diverse skills and wide knowledge are necessary to motivate, discipline, physically train and tactically advise performers.

Approaches to performance development

In the recent past, coaches have been offered help by academics operating in a number of sport-related disciplines such as exercise physiology, psychology and biomechanics. However, according to Davids (1988), the academic approach to studying sport has tended to develop through traditional academic disciplines by 'borrowing' accepted research methods and techniques and applying them to sports' settings. For example, exercise physiology, sports psychology and biomechanics have all been born of the formal roots of their parent discipline. The

information produced by these approaches is commonly taught in both academic and coaching courses concerned with sport and human movement and is well documented in a wide range of specialist journals. Each particular discipline has its own methods of enquiry and research techniques which may be sport-related but seldom sport-derived. What is more, the bulk of discipline-based enquiry is performed by academics working in what is essentially a 'laboratory' situation.

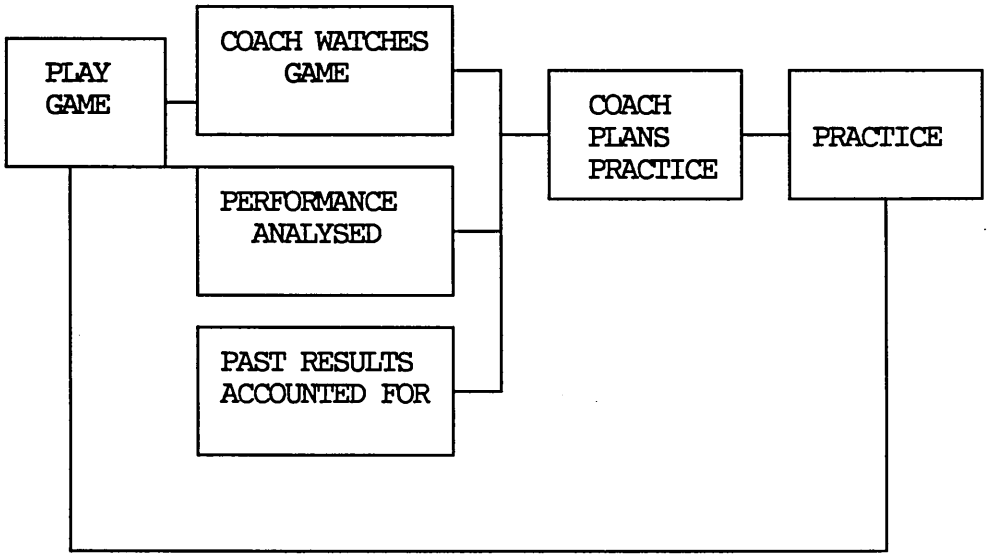
By contrast the coach is committed to operating in a 'field setting' and is recognised as the central figure, directly responsible for modifying behaviour and making decisions about preparation for competition (Franks et al 1983, 1984, 1986; Hughes, 1985, 1986; Brackenridge & Alderson 1985).

The coaching process of performance evaluation and subsequent modification should not be simply viewed as a series of isolated assessments and modifications, but rather as an ongoing cyclic process over a given period of time (a season, or tournament involving a series of matches). This view of coaching, exemplified by Franks et al (1983), portrays a competitive situation yielding information about performance which the coach uses critically, and in conjunction with knowledge from previous performances, in an effort to prepare performers for the next competition (see Figure 1.1). The information gained from the analysis of competitive performance can take different forms and is generally made manifest through performance preparation and practices planned by the coach. The cyclic model is in itself

straightforward and logical; however the quality of the end result, that is the preparation and resultant future performances of the participant(s), are dependant on the coach's ability to function efficiently within it.

Figure 1.1 Scheme of the coaching process

(adapted from Franks et al 1983)



It therefore seems logical that if applied research is to be of maximum value to the development of sport performance it is essential that coaches be involved in its design. A major problem for this process of integration derives from the way in which the academic world has required sports research to be published. The language used for academic writing is not always easily assimilated by 'non-academics'; nor is it always easy to apply the tenets of academic research in the practical sports setting (White & Brackenridge 1983). Silva and Parkhouse (1982) comment on this point when they suggest;

> "sport related fields cannot advance at a reasonable pace and be recognised as academically viable unless there is a balance between basic and applied research."

The relationship between 'pure' and 'applied' approaches to sport research is a contentious one and has highlighted the need to look at the value of research methodologies for investigating sport behaviour (Martens, 1979, 1987; Davids, 1988; Silva & Parkhouse, 1982). The dialectic between the two approaches has arisen through trying to `maintain` scientific rigour by controlling variables and providing internal validity on the one hand, whilst on the other, attempting to conduct 'ecologically' valid research capable of generating information that is directly applicable to the 'live' sports setting. According to Davids (1988), the latter approach has become more `fashionable` within many of the sub-disciplines involved in the academic study of sport as researchers and scientists attempt to make experimentation and investigation more realistic and orientated towards the 'live' event.

Although gradually becoming more 'field' orientated, sports science tends to employ quantitative methods of investigation while coaches make qualitative decisions based almost entirely on subjective perceptions of competitive performances. Traditionally, and of necessity, the coaching fraternity have developed their own approaches to improving performance based on common sense, 'tried and tested' theories and past results. However, more objective approaches have started to find their way into coaching programmes in recent years. The gradual

development of integration between academic researchers and sport practitioners is largely due to the impact generated by contributions to the sports literature from the three established 'sciences'; exercise physiology, biomechanics and motor/ sports psychology. Of these disciplines it appears that exercise physiology has made the greatest impact in the development of objective preparation and coaching programmes (Sharp, 1989). As an established science dealing with the 'physical' aspects of performance, research findings have been well received by coaches. Biomechanics, in comparison, is a relatively new discipline and its full potential for performance analysis has not yet been realised. The contribution of psychology to the preparation of sport performers has frequently been met with scepticism by coaches and athletes. However, the value of mental preparation for physical performances is gradually being taken more seriously by coaches trying to achieve a more holistic approach to preparation for competition (Sharp 1989).

Each of the sports science sub-disciplines has undoubtedly helped to increase coaches' general awareness of the variables that might affect performances in their particular sport. This in turn has certainly assisted in the preparation stages for certain sports events, through the inclusion of relevant material in coaching publications. However, Bate (1987) suggests that high level sport decisions and the competition results consequent upon them are, in large measure, still based on coaches' and managers' subjective opinions. Bate goes on to

recommend that whilst such opinions may be both respected and valid, much more in the way of objectivity is necessary in mapping out future strategies for success.

The need for alternative investigative techniques.

> "In order for both basic and applied sport research to grow and have impact, alternate techniques of inquiry must be recognised... Non-experimental designs often provide a viable approach to help a researcher answer questions worth asking!"
>
> Silva and Parkhouse (1982)

However, to date, the majority of sport performance investigative activity has been kept strictly within the confines of the academic discipline in which it is grounded. Studies are usually conducted by scrutinising sport behaviour in respect of certain physical laws, physiological systems or mental states, providing only a partial analysis of the 'whole' performance. By contrast, Brackenridge & Alderson (1982) assert that 'sport is not simply an isolated number of events governed by certain scientific principles, or the performer simply a site for chemical reactions, social interactions and power dissipation'. The competitive situation provides the means for an assessment of the extent to which individual coaching/ training programmes have contributed to the complete performance. Fuller & Alderson (1990) go further and suggest:

> The coach needs to identify the parameters of performance decrement, and/or the variables likely to affect future performance gain, by reference both to the performance itself and to those aspects of sports science, either singly or in combination, which are relevant to the perceived performance problem."

The nature of sport and methods of analysis

The continuing cyclic evaluation process, shown in figure 1.1 above, is an approach used by most sports coaches, but the focus of the coach's attention and the operational difficulties in evaluation will vary according to the sport. Clearly some sports place greater stress on observation than do others. For example in team games, the coach is faced with large numbers of interacting variables at any given point, as compared with the coach of a single performer in a predetermined activity such as a gymnastic routine.

Game sports in particular involve a high degree of variability through performer interactions which the coach is unable to predict, in detail, prior to competition. The continuing cycle then demands that the coach is able to identify and remember those variables significant to performance outcome in order to modify behaviour appropriately for the next competition.

In order to identify those sports that present the coach with greater observation and analysis difficulties it is necessary to look at the nature of different types of sport activity. Brackenridge & Alderson (1982) have identified three main sport

categories according to the nature of the problem dictated by sports' rule frameworks. Briefly, the three divisions within the classification system comprise gymnastic, athletic and game activities; they are differentiated from one another in the following way;

gymnastic sports; those in which the winner is the one whose movements are deemed 'the best' in qualitative terms as assessed against a predetermined set of criteria (eg, the BAGA code of points);

athletic sports; those in which the winner is the one whose performance is the fastest, longest, highest or strongest as measured against a physical scale such as time or distance;

game sports; those in which the winner is the player/ team achieving real or symbolic territorial domination through the scoring of goals, runs, touch-downs etc.

The focus of this study is the game category of sport. The rule structures of games necessitate a constant struggle between opposing sides often using a ball (or its equivalent) as the means by which territorial domination is registered. The psycho-motor component of achieving success in such games consists of coincidence anticipation and avoidance skills

involving the prediction of motion of a ball in flight, anticipation of the movement of other players and making judgements about time and distance to targets (Brackenridge & Alderson, 1982).

Supporting Brackenridge and Alderson's notion, Patrick & McKenna (1987) refer to games as 'non-deterministic' sports, meaning they comprise a large number of events with a high degree of player choice of action, combined with a relatively high uncertainty of other players' actions. These games are largely performed in open (as opposed to closed) environments. For example, target games like golf are towards the closed end of the 'deterministic' continuum whereby opponents play the course in parallel and are able to perform without interference of other players. Franks, Wilberg & Fishbourne (1982) identify three basic 'playing' processes confronting games players in the 'open' environment:

i) perception of the changing environment; ie, the movement of players and the ball;

ii) formation of appropriate decisions based on these perceptions; ie, where to go/ what to do with the ball;

iii) selection and execution of action/s appropriate to the decisions made; eg, 'feint' left, make long through pass to open space on right.

By necessity, these processes require a high degree of efficient decision-making to secure performance success. An analysis of the cognitive demands involved in sport performance suggests that the relative importance of decision-making in games is much greater than in other sports, usually because of their highly interactive nature. Gymnastic and athletic sports, for example, are relatively simple in decision-making terms, since the 'what' to do and 'when' to do it are largely decided prior to the competitive situation. When observing performances in these activities the coach is faced with a relatively discrete and well defined set of variables against which to make a critical evaluation. Hence an analysis of the efficiency with which players make performance decisions is most crucial in 'game' activities, specifically in those that take place in an 'open' environment and involve participants in some form of interaction with their opponent/s.

Whilst natural psycho-motor ability, physiological condition and mental states all contribute in determining sport competition results, it is the discerning way in which a performer applies their talents in the game context of the activity that has the greatest influence. In other words, the footballer who shows great mastery of technical skills in practice must also be capable of applying these to advantage in the match situation.

Strategy, tactics and techniques in games

The importance of both technical ability and strategic/ tactical

decision-making skill for success in games cannot be over-emphasised. As suggested by Brackenridge and Alderson (1982);

Strategy — refers to the overall plan of attack/ defence to be employed by a games player/ team: eg, the 'Serve & Volley' strategy in tennis.

Tactic — refers to a moment by moment decision made during the run of play. It normally occurs in the context of the overall game strategy but is directly influenced by the game events of the moment; eg, the decision to play the ball deep to the back-hand court in response to a weak forehand cross-court return of service.

Technique — refers to psycho-motor skill, used either singly or in combination, in order to enact a tactical decision; eg, the preparatory movement and volley action required to despatch the ball in accordance with the tactical decision.

Dewhurst-Hands (1980) stresses the crucial importance of strategic/ tactical skill by suggesting that if the technical skill factor is negated by equality between two performers/ teams then the effective application of tactics should be decisive in determining which side wins.

Considering the importance of strategic planning, tactical decision-making and technical proficiency it is surprising to find that a review of academic and sporting literature reveals little objective information on the coaching of strategies/ tactics, or their analysis and evaluation. Information regarding technique development and execution is well documented in sport-specific books and journals, though the evaluation of the efficiency of such techniques is uncommon.

Strategies are, of course, very much governed by the rule structure of a particular game. In football, for example, it is pointless to plan a strategy for forwards to 'hover' in the penalty area ready to receive a long ball forward since they are likely to break the off-side rule. LaRose (1982) defines a strategy as "the art of distributing and applying the means placed at one's disposal for the fulfilment of the objectives of a policy". A strategy is therefore a cognitive plan made in relation to a number of variables such as performer's skill level, fitness, opposition, weather conditions, etc.

Once a strategy has been selected players will face a variety of competitive situations in which they must make tactical decisions about the appropriate skills to fulfil it. These 'in-game' tactical decisions are totally dependant on a performer's ability to interpret and select an effective response to a given game situation. Strategies and tactics thus refer to cognitive processes that can not be directly analysed since they are covert mental operations. Since techniques are

the psycho-motor skills used to carry out chosen tactics, tactical decisions only become apparent through an attempt to apply technical skills. In principle at least, it is therefore possible to assess the tactical efficiency of a performer, albeit indirectly, through the analysis of technical outcomes. Fuller & Alderson (1990) maintain that many sport text books describe in explicit detail 'ideal' game technique in terms of standard movement patterns. They go on to suggest that while 'model' movements may serve as patterns for the novice to try to emulate, any meaningful analysis of technical effectiveness in games must rely on the outcome of the technique. For example, a tennis player may correctly anticipate the service return and subsequent court movement of an opponent and base an appropriate tactical decision to volley to the back-hand side on such information. But in an attempt to implement the cognitive plan the player may not 'play' the volley sufficiently well to achieve the desired tactical end. Hence a correct tactical decision may well result in a ball in the net; hardly an effective tactic when viewed in technical terms!

As mentioned earlier, the interest in strategic and tactical problems facing performers has received little attention in either the academic, or the coaching literature (Smith, Nettleton & Briggs, 1982; Smith, 1984; Franks et al, 1982; Brackenridge & Alderson 1985) although Schutz (1981) maintains that questions regarding performance decisions are constantly asked by coaches who want to know the effectiveness of certain tactics for winning. Schutz goes on to argue that not only do

answers to tactical questions provide immediate benefit for the coach but they also give a fuller understanding of the inherent structure of sport and the interplay between chance and skill.

Smith et al (1982) summarise the importance of decision-making for the games player and its relationship to coaching.

> "...it is clear that an important, integral part of the demands made upon the player is constant, high speed and complex decision making. If this is accepted, then equally clear is the fact that the art and science of coaching team games must encompass ways of improving the quality of the decision made by the players."

That is, the evaluation aspect of the cyclic coaching process must include an analysis of technical/ tactical performance as the basis for coach intervention and subsequent modification of playing behaviour.

Accurate observation and recall

The quality of the observation stage is crucial to the success of subsequent stages of performance analysis. Yet it is problematic, if for no other reason than the enormous number of performance events that occur in any one game. For example, typically there are up to 1000 passes made and 180 shots attempted during 60 minutes of international netball play (Fuller 1987). Franks & Goodman (1986) suggest that inferences for sports observation can be drawn from research carried out in the area of eyewitness accuracy in criminal situations. They

have identified several factors that affect accurate observations in such experiments.

i) The focus of attention of the observer is known to limit observation accuracy. If the observer's attention is focused on peripheral events those features of central importance are not noted, likewise if attention is focused on critical features, then those on the periphery are not assimilated. This has implications, for example, for 'following the ball' and monitoring 'off the ball' play in team games.

ii) The length of time and conditions under which observations take place can affect the quality of observations. Generally the longer an observer is required to attend to a particular event the poorer the observation. Furthermore, conditions such as lighting, distance, fast movements and crowd presence can all interfere with the efficient operation of the attention process. All these are recognisable features of top class games played in front of audiences, when the coach is confined to the side-line and may have a poor angle of vision of the play.

iii) Individual characteristics such as stress, arousal levels and emotional states all contribute to the quality of observation. Importantly, the perceived seriousness that observers attach to an event ultimately influences their accuracy. The more important the event is perceived as

being, the greater the attention of the observer. The results of all competitive games, especially at the top level of both amateur and professional play, are perceived to be important; consequently coaches tend to be in high arousal states, if not actually stressed, during the game.

iv) Prior conditioning, 'set' views and prejudices can cause inaccurate observations. In other words biases that are carried to a situation distort the perception of related events. The subjectivity of match observation, coupled with coach expectations of a particular player/s against particular opponent/s in particular game situations, all mean that the coach is going to be prone to making inaccurate observations/ evaluations of match events.

Research carried out to investigate the accuracy of coach observation and recall is limited (Franks & Goodman, 1986; Hughes C, 1984), but the work that has been done suggests that the accuracy of recalling game information is low. Some initial research by Hughes (1984) at the Football Association found coaches to be only 12% correct in post-game assessments from video-tape of events leading to the creation of scoring chances. The subjects were asked to watch a video of some football action, following the viewing the coaches were asked questions about the play they had watched on film, in order to assess their powers of observation. In a similar study Franks & Goodman (1986; cited in Mackinnon 1986) tested 40 of Canada's top football coaches together with a group of 40 physical education

students on the accurate observation of a football video-tape. The results suggested that the coaches were only marginally better at accurately recalling events than were the students. Furthermore, the accuracy of post-game assessments were as low as 10% and never fared better than 40%.

Collation and analysis of appropriate information.

During a competitive game a coach will be faced with a daunting number of match events, on which s/he might need to concentrate. This is especially true of team games which, as suggested earlier, generate large amounts of information potentially of value to the coach. The amount of information obviously increases with the number of players involved, making observation more difficult for the coach of team games. What is more, accurate observation and recall of match facts alone may not be enough. The sequential dependency of events and their significance to other events may be crucial to the coach's understanding of a particular 'slice' of game action. The significance of a given event may not always be apparent at the time of its occurrence (Franks & Goodman 1986). For example, the implications of a missed interception may only be recognised when the team retaining possession subsequently creates a shooting opportunity. For a coach to attempt to 'back-track' game events from memory is simply impractical.

The human memory system is not unlimited and it would be virtually impossible to remember all the important events of a match in sequential order, let alone collate them and relate them to relevant information from previous games (Franks & Goodman 1983). Whilst memory capacity may vary between individuals, it is not surprising that rapid forgetting occurs amongst everyone. It is inevitable that coaches watching a live performance will tend to be selective in their focus of attention (Lieppe, Wells & Ostrom 1978). They will accurately analyse and recall only a proportion of match events, some of which will be of peripheral significance to the game outcome. Hence the coach's evaluation of the game is of necessity going to be subjective and incomplete if no 'system' is available to help in the organisation of relevant performance information.

The above points demonstrate that the human eye-brain system, commonly relied upon by most coaches, is an inefficient method for evaluating games play over an entire match. A system specifically designed to provide 'appropriate' information for coaching is clearly needed. It is the coach who must decide what it is appropriate to analyse in order that the information gained may inform his/her future coaching intervention with the player(s).

In an attempt to improve on the quality of performance analysis, various methods of recording match events have been tried; for example, video-recording and the collection of selected match 'statistics' (initially using pen and paper). The latter has

become increasingly common during television coverage of sport. In the United States it is now standard practice for television stations to offer tennis, baseball and American football statistics during a coverage. Even in the UK, televised sport is increasingly accompanied by supporting facts and figures displayed on screen. In tennis for example, player statistics are shown for successful first services, service winners and double faults, presented either as raw figures or percentages. More recently, during television coverage of Rugby union, the amount of territorial advantage achieved by a team is shown by an oscillating marker moving along a graded band at the top of the screen.

Although these methods of recording aspects of match performance may be objective, they provide different kinds and varying amounts of information which may or may not be specifically relevant to the coach's needs. Videos constitute a blanket visual record of the game (as seen by the camera, and subject to operator effectiveness) and necessarily contain much information which the coach does not need. Furthermore, although a video constitutes a 'hard' record of a match, the coach still faces problems associated with extracting the relevant information from observation of a fast moving, dynamic sport environment. Hence its use can involve coaches in a time-consuming search for the detail they require. At the other extreme, simple match statistics, regarding turnovers and percentage errors for example, may well provide insufficient or inappropriate information for the coach's needs.

A suggested solution to unreliable observation during 'live' matches and the inadequacy of blanket video-recordings or simple statistics for providing relevant facts, lies in the adoption of systematic, quantitative methods of noting and analysing carefully selected game performance events (Franks et al 1982; Sanderson 1982; Brackenridge & Alderson 1985; McKenzie et al 1989). The specific coaching requirement is access to relevant and precise match facts, capable of informing the coaching process. A means of achieving more objective analysis of performance is to record the selected events in a 'hard' form capable of subsequent collation and analysis. It is argued here that the game-record should provide the coach with information relating to those aspects of play that appear to contribute to success or failure.

The recording of performance events during a game is generally known as 'notation'. The transitional and fast moving nature of games, coupled with the limited speed with which a notator can scribe, necessitates the use of coding in order to simplify the recording of the required performance information. Notation is by no means a new approach to recording human movement, probably the first forms of modern notation were those used in dance (Laban, 1953; Benesh, 1956; Eshkol, 1958, cited in Curl, 1966). However, it is debatable that modern forms of game notation have evolved from these original systems; rather they have developed

in parallel since their purpose and functions are quite different.

Dance notation is used as a method for recording precise movement patterns for each body part together with the timing of each movement in order that choreographed dances can be replicated exactly as originally intended. Game notation has a distinctly different purpose from that of dance. It is not intended to provide a record of a game so that the play might later be reproduced; rather a selective record is made of those elements of play whose incidence and/or effectiveness the coach wishes to investigate. The dynamic, interactive nature of games would render a performance 'script' as useless, since play consists of a series of performance actions to which opponents reply with counter-actions.

In a critical review of research methodologies and techniques commonly applied to sport, Parry (1984) implies that game notation is of the same ilk as dance notation in terms of its potential for understanding players' behaviour. He maintains that;

> "...you could measure the positions of all players on a football pitch, when a certain variety of good pass is made, the speed and direction of movement of players and ball and so on. Let us say that this will be a scientific description of defence-splitting passes. Much may be learned of a scientific description of defence-splitting passes but one thing for certain will not be learned: and that is <u>why</u> it is a good pass."

Parry argues that we are already able to identify "good passes" so we can measure them, therefore measurement does not help our knowledge of them rather it presupposes them. From this reasoning Parry asserts that objectively measuring certain game occurrences will not help us to appreciate **why** they are good.

However, it is not intended that match analysis simply **measure** the details of a particular pass in order that it be identified as 'good' or exactly reproduced. Recording passes (both good and bad) enables an assessment of their 'goodness'/ 'badness', based on the technical delivery and tactical awareness of performers. A good technical pass may result in a bad tactical move and likewise a potentially good tactical move may be marred by poor technique. The type of information offered through match analysis is useful for coaches attempting to improve on previous performances and provide constructive feedback for their player's good and bad technical and tactical performances.

Match analysis can certainly help to explain **what** sorts of circumstances precede, say, a defence-splitting pass. It is true that coaches can identify a 'good' pass when they see one; however, presumably they would like to know, and in more detail, with what frequency they occur, the quality of the 'goodness', who makes them, what game circumstances precede them and how to coach players to create these features of play consistently. **When** and **why** players <u>don't</u> make good passes in situations where they might reasonably be expected to is crucial information for the coaching process. Such information could provide the coach

with details of individual or team performances that could be used to enable future improvements.

On the other hand the academic researcher is concerned with investigating the nature of defence-splitting passes and their relevance to the game as a whole and other facets of play. Further, by 'measuring' the positions of players during certain events, over a series of games, the researcher can perhaps find answers to questions such as 'Why do winners win'? and 'Why do losers lose'?

The coaching cycle demonstrates the necessity of appropriate game preparation in order to improve upon previous performances. As suggested earlier, the quality and objectivity of performance evaluation could benefit from the systematic recording of relevant match facts. Analysis of such facts can then provide the coach with necessary detail to establish a valid practice. Smith, Nettleton & Briggs (1982) stress the point that the coach is required to be selective in choosing the match information to be recorded. A comprehensive account of the information in any game would require more statisticians than players. If only for practical reasons, the coach must decide which game features are essential to providing valuable performance information.

Coaches clearly need more detailed pictures of certain game events, particularly those related to winning and losing performances. Armed with such information, the coach would then be able to assist players by developing a series of principles

of play that can be used as a guide during play and as a basis for post-match evaluation.

Game modelling

The idea of 'models' of good practice are not new to the coaching world. Many coaches attempt to 'mould' their team's play on that of another which is known to be successful. What is new to the sporting world, and to coaching in particular, is the notion of working to precise models of good play that are developed through objective collection of relevant match facts. The purpose of analysing good and bad passes is to achieve more accurate pictures of say, the attacking play preceding shots in football. Furthermore, such 'pictures' should then offer coaches a guide against which they can evaluate their own players' performances.

Parry's original point that objective methods can not tell us, or help us to appreciate, all aspects of performance may well be correct. The claim of match analysis is not to provide information for all aspects of performance rather; it is to record selected performance events in an objective and systematic manner, so that their performance can be reliably evaluated.

Game models have in the past been formed through the collation of key performance factors recorded during competition. Observable performance actions are collected over a series of

matches until regular game features are distilled out. Investigations of game models have taken place in a number of different sports over the past two decades or so (Hughes 1984; Potter 1985; MacKinnon 1986; Reep & Benjamin 1968). In the main these projects have been initiated by academics; the methodology involved has often been labour intensive in terms of recording performance data over a series of matches and subsequently analysing information in a search for game models. The process involves the use of statistical analysis and, through necessity, a computer to ease the manipulation of large data sets.

The purpose and application of Match Analysis

The systems developed by academics are usually unsuitable tools for the coach who faces difficulties inherent in the cyclic nature of their work, as summarised below:

i. Coaches are usually required to operate within set time limits determined by the next competition. This necessarily limits the range of methods available to help them in their work.

ii. The coaching cycle requires observation and analysis of performance in order to set up valid post-game coaching points. Observation and recall reliant on the human eye-brain system is in itself intrinsically unreliable.

iii. Team games in particular place heavy demands on observation, due to the sheer volume of information available during a game. Undoubtedly this results in inaccuracies in assessing performance.

iv. There is a lack of tried and tested information regarding successful tactics and techniques that coaches can use for establishing models of good practice for;
a) evaluating team and individual player performances and
b) preparing coaching programmes.

Whilst academic research has attempted to help coaches with many aspects of their work they have not made a significant impact on the game performance analysis problems noted above. The reason for this has largely been due to the ways in which sport research has taken place, as summarised below.

i. Academic sport research, through its historical development, has tended to be sport-related but not sport-derived; the bulk of traditional investigations seem to take place in non sporting, laboratory environments. Whilst this approach enables the maintenance of 'scientific' rigour, it is often 'short' on relevance to the coach operating in a 'field setting' and of necessity concerned with live action.

ii. Researchers do not always take account of coaches' expertise and requirements. Coaches are directly

responsible for working with performers and therefore developing new methods of trying to enhance performance; moreover, many coaches have an experience of specific performance 'problems' and performance requirements. It seems logical therefore that coaches should be involved in the design of research projects if they are to be of maximum value to the coaching process (see page 8).

iii. Integration between researcher and coach has been further hindered through the way in which findings have been published. Because of academic style, publications of research findings, potentially valuable to coaches, are not easily assimilated by 'non-academics', or easily applied due to the complicated language often required for published work **(see page 7)**.

Defining the "limits" of the project

This study attempts to investigate the development of a performance analysis system for netball to aid coaches working specifically with elite netball teams. Most match analysis systems are based on common principles, which have been adopted to form the basis of this study (Franks and Goodman; 1984). However, the demands imposed by the rule structure of particular sports will influence the specific nature of data identified for collection and the sequence in which it is recorded, in this case the particular requirements of netball have been taken into account. Liaison with coaches was important during the initial

stages of developing the system when deciding which match events are perceived as most relevant to winning and should therefore be recorded by the system.

It is intended that the netball system developed here will be an objective and systematic method of recording selected match details in order to derive a record of events that will be appropriate to coaching needs. In an attempt to improve on the quality of performance analysis, this study aims to build on the work previously developed using pen and paper systems of coding match events (Brackenridge & Alderson 1985; Smith, Nettleton & Briggs 1982; Sanderson 1982; Franks, Goodman & Miller 1982). A complete match record, in its raw recorded form, is of little use to a coach since it merely mirrors the details of play that the coach has seen live. However, subsequent analysis of the match record should provide useful information for coaches by abstracting and collating particular types of game events to give frequencies and summaries. These can then be compared or related in a way which is tied to performance outcome (MacKinnon 1985). After match details have been recorded it should be possible to pick out those player actions that contribute positively and negatively to the realisation of a coaching plan. If the data does not produce information that helps the coach to do this they should influence the 'details' recorded until it does.

The introduction of computerised notation systems has enabled this problem to be tackled since data can be collected and

stored sequentially in a computer's memory and accessed immediately for post-event feedback. The development of technology in match analysis and its consequent efficiency has improved on manual methods in several ways;

i. speed with which analysis is completed,

ii. enhanced presentation of analysis data,

iii. versatility in enabling coaches to select specific analysis programmes to meet their varying needs.

The match data recorded in this project will be used for two main functions:

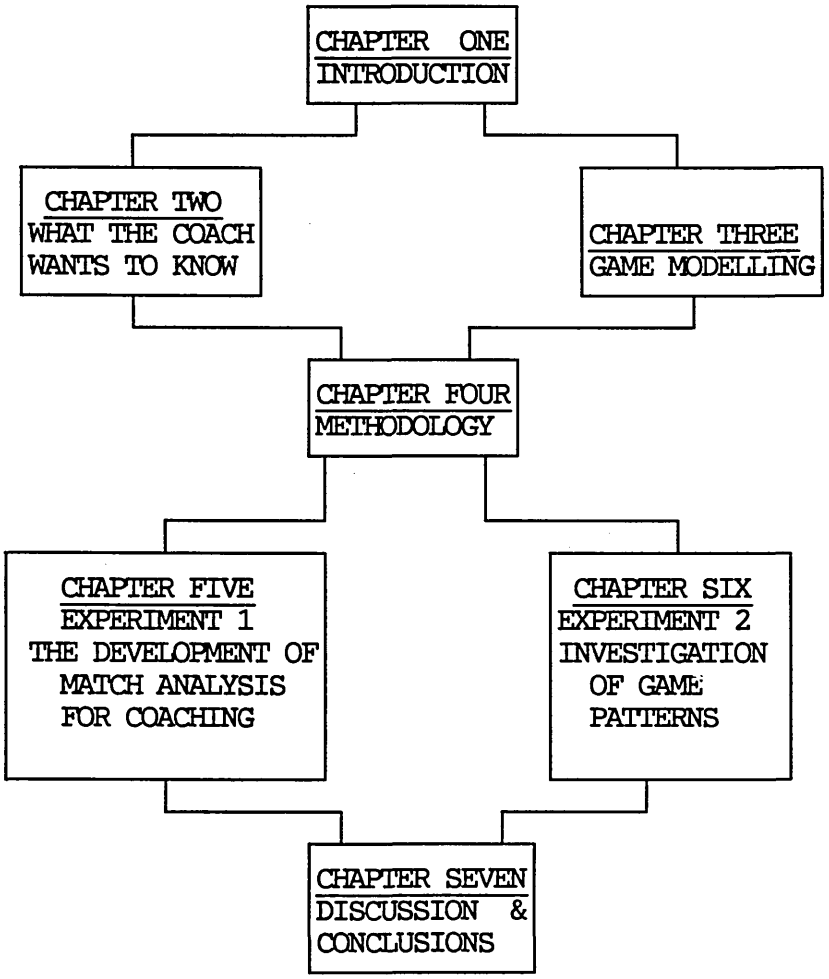
i. To provide netball coaches and players with post-game feedback from individual matches. This is an immediate function of the netball system and of match analysis in general.

ii. To search for models of performance against which future play could be evaluated and which influence the content of practice sessions. This is a relatively long term function of match analysis since the literature suggests models do not develop from data of a single game (Hughes 1986).

The structure of the project reflects the development of these two aspects of match analysis. The methodological procedure

taken to develop a computerised notation and analysis system was designed to serve the needs of both research areas. However, the investigation of **game models** is reported separately from the development of a **post game evaluation tool** since they serve different purposes. Figure 1.2 illustrates the approach taken to the research project and the way in which it is structured in the following report.

Figure 1.2 : Outline project structure.



Summary

* By definition coaching is concerned with the improvement of performances.

* Coaching in competitive sport has long been recognised as an important feature for success. The coach's objective is to prepare performers for future competition by modifying current behaviour in a positive manner. To be an effective coach the individual must be well informed and well organised to meet specific needs and targets. The development of national organisations such as the NCF and BISC, and the increasing amount of literature and publications specific to coaching appear to support this notion.

* The coach is not alone in their quest to enhance performance; academics, and commercial developers have an interest too but they have differing motives for the enhancement of performance and have a different relationship with performers.

* Sport performances often involve a combination of different factors. This might include physical ability, motivation, discipline, technical skill and tactical awareness.

* Hence, the coach's role is often diverse and can include that of; motivator, trainer, disciplinarian.

* In the past coaches have been offered help by academics operating in a number of sport related disciplines eg. exercise physiology, psychology, biomechanics etc, however, their approaches have not always been ecologically valid.

* By contrast the coach is committed to operating in a 'field setting' with fixed time limits in which to modify players' behaviour.

* The model of coaching on which this project will focus is that proposed by Franks et al (1983) who suggests the coach operates in a cycle.

* Within the cycle the coach is limited to casual observation and the capacity of the human memory. The coaching cycle and its efficiency is therefore limited by these features.

* These problems are particularly difficult in situations where there is more than one performer to observe and the environment in which they perform is fast and variable.

* This is particularly true of games where there are many interactions between performers/ competitors any of which can be significant to performance outcome.

* Improved evaluation and analysis of performances will be of immediate value to coaches operating in the coaching cycle.

* A more detailed picture of winning performances may help coaches develop long-term coaching plans based on objective models of the game.

CHAPTER 2

What the coach wants to know

What is known about netball.

Netball is an invasive team game and as such it involves two opposing teams, of seven players, striving for ascendency within an agreed rule framework. It is a passing game in which attacking players move the ball towards the shooting circle, from within which a shot can be attempted. Running/ stepping when in possession of the ball is not allowed and likewise dribbling of the ball is illegal. On reception of a pass players have only three seconds in which to pass to another player or take a shot at goal, this ruling can make for fast attacking moves in teams with good skills. The measure of success is the number of goals scored, the winning team being the one to score the most within the defined period of play. This may seem such an obvious statement that it does not warrant a mention; however, it is the legitimate starting point for further investigation into the nature of winning and losing in netball.

Every netball game commences with a centre play from which the team in possession will eventually attempt to pass the ball to a shooting player, within the bounds of the shooting circle. The rule structure provides competing teams with a near-equal number

of centre plays, and hence a near-equal number of opportunities to work the ball to a goal scoring position, by alternately awarding possession at centre plays irrespective of which team scored from the previous centre play. Each centre play ends with a goal or the end of a playing period. After either of these events the game re-starts with a new centre play.

Netball differs from many other team games such as football, hockey, rugby and so on, since players are not able to dispossess an opponent by tackling or stealing. A non-contact rule ensures players can not be directly interfered with, which suggests that there is far less opportunity to dispossess a team in netball than exists in 'contact' games like rugby, or stealing games such as basketball where the rules allow the ball to be 'snatched' from a players hands. A netball team can only be dispossessed through the interception of a pass or the rebound of a missed shot, although possession may be lost through rule infringements or playing errors. Hence, the structure provides for a fast flowing, high scoring and highly interactive game at the elite end of the playing spectrum.

The combined factors of possession being alternately awarded to teams following a goal and the non-contact rule which ensures that players can not be directly dispossessed, would suggest that the task of goal scoring is a seemingly unchallenged one and therefore theoretically straightforward!

From this simple hypothesis of goal scoring there appears to be an emphasis on two features of performance necessary for success. The first involves working the ball to a shooter in a shooting position (within the bounds of the shooting circle) and is defined here as the 'creation of a goal opportunity'. The other involves the technical ability of shooters to score goals once a goal opportunity has been created and is defined here as 'shooting efficiency'. Goal scoring is therefore a result of teams creating a shooting opportunity and successfully converting that opportunity to a goal.

The theoretical analysis of netball presented above would suggest reasonably high success rates in scoring from a team's own centre plays. However, analysis shows that in practice this is certainly not the case. Teams frequently lose possession when attempting to work the ball to a shooting position and the average efficiency rate for international shooters at the 1987 World Netball Tournament was 66%.

Technical and tactical demands of netball

Match preparation, suggested by Frank's et al (1982) cyclic coaching model (see page 7), would seem essential for teams attempting to meet the demands involved in successfully 'working the ball' to a shooting position and scoring. The 'skills' necessary for achieving these ends can be divided into the two distinct categories previously identified in chapter 1: One

category involves the physical movements and psycho-motor skills required for actions such as catching, throwing, dodging, marking, shooting etc, and are referred to as techniques. The other category of skill involves the decision-making process necessary for the selection and application of appropriate techniques or combinations of techniques and are generally referred to as tactics. In any given game situation players are required to make decisions regarding appropriate courses of action, which will largely be determined by the individual's interpretation of the game situation.

The choice of techniques during a game may be influenced by a number of factors such as previous experience, habit and coaching influence. By definition, coaching should play a major role in shaping a player's performance since its purpose is to prepare and direct players towards successful performances (see Chapter 1 pages 3-7 for a more detailed account of the role of the coach). This function should of course involve the coach in the development of both technical playing skills and tactical decision making.

Traditionally, coaching literature and playing guides in general have provided abundant detail on the technical skills needed to meet the demands of a particular sport. Each technique tends to be reviewed independently and reported as a discrete skill that is applied in the course of a game. It is common to hear commentators referring to game techniques as being played in

'text book' style after the observation of what appears to be a well executed skill. The relative ease of 'studying' individual techniques in isolation from other aspects of performance has lead to their extensive investigation and development in those sports where success is determined by technical proficiency such as gymnastic sports and some athletic sports such as throwing and jumping events (see chapter 1 pages 11-13 for details of sport types).

Bedingfield, Machiori & Gervais (1982) point out that; scientists working in biomechanics have perfected research methods that enable them to dissect individual skill executions into minute parts and to describe the motion in each of those parts through the determination of angular displacements, velocities and the forces responsible for motion. Volumes of information have accrued through biomechanical investigation of sport techniques which have enabled researchers to seek minute changes in movement patterns which have had large effects on gymnastic and athletic success or failure. Attempts are then made to feed this information back to the coach in more practical terms.

Attempts have also been made to apply biomechanical research to investigate techniques within games. The difficulty of using these methods for a given game technique is that the technique is likely to vary in accordance to the game situation in which it is played. Furthermore, there is so much variability within

and between games that the coincidence of a technique being performed under exactly the same conditions on more than one occasion is highly unlikely. Game techniques tend to refer to 'norms' of performance that have expected variations rather than absolute performance techniques where minimal variation is expected.

However, 'text book' techniques are well established for most games, although they tend to be based on tradition rather than detailed scientific enquiry. Those techniques that, over the years, have shown to be consistently effective tend to become a part of the skill vocabulary deemed necessary for performance.

A review of netball coaching texts (Crouch 1983, Campbell 1984, Wheeler 1978) reveals a consistent pattern of descriptions illustrating **how**, for example, a shoulder pass should be performed, or the position a defender should take when marking a player in possession of the ball. While such technical information focuses on the precise action required to perform certain techniques, Thomas (1982) maintains that the technique used for a given skill, such as a chest pass, varies so greatly within a game that;

> "...during intensive video observation of a single netball match a "copy book" version of a chest pass was observed on only one occasion."

Thomas (1982) maintains that during a game it is the tactical situation which dictates the techniques to be used and how they will be performed. This seems to suggest that in games, where players perform in highly variable situations, the precision with which a technique is executed is relatively unimportant compared to the consistency with which it meets its desired end. This observation supports that of Brackenridge & Alderson's (1982) notion of sport categorisation which suggests the focus of game sports is the outcome of technical performance under variable conditions, rather than the technical performance per se (see page 13).

Despite the abundance of literature relating to technique there is a lack of information relating to levels of consistency with which techniques are performed, or target parameters which various levels of performers should be aiming for. Numerous texts explain the technique of shooting in terms of body positioning and action, but none offer guidelines for shooting efficiency rates at different levels of performance, or under different conditions such as penalty shots. If shooting 'success' is evaluated by the number of goals scored against the number of shots attempted it is important that coaches and players have some form of quantifiable guideline against which to make performance assessments, other than technical style. When success rates are deemed to be low it is then appropriate for a coach to focus on the precise nature of the technique in order to assess if it is the cause of the problem.

Despite La Rose's (1984) argument that games offer limitless possibilities for strategic development, there is surprisingly little published information compared to that of technical information. Netball is no exception to this imbalance as highlighted by Embrey (1978) when she suggested;

> "There is a paucity of material to describe what actually happens in a game..."

Thirteen years after making this comment, Embrey still has a strong case. With the exception of several post-graduate studies (Potter 1985, Jones & Treadwell 1988 (cited in Alderson Ed. 1990)), few publications have made a contribution towards the better understanding of strategic performances in netball. However, that is not to say that tactical and strategic possibilities have not been explored; specialist netball magazines frequently publish coaching articles concerned with the application of new tactics. Such articles are often the published opinion of highly regarded/ successful coaches who, during their career, have coached successful teams. Other publications of this nature tend to comprise comments on observations of those tactical elements that appear to distinguish successful teams from their opponents. However, few, if any of these publications, make use of quantifiable match data to substantiate the tactical/ strategic hypotheses made.

Such opinion rarely finds its way into formal coaching and playing publications in the same way that information regarding

technical skill does. Game strategies and tactics are by their nature dynamic and need to adapt or, even change to counteract opposing strategies and tactics. Hence their description and explanation are complex and perhaps difficult to document beyond simple attacking pathways suggested in some texts.

Match analysis in netball

A paucity of research in netball in general and specifically regarding the kind of tactical and strategic information of value to the coach suggests the onus for developing successful playing strategies and tactics appears to lie very much with individual coaches. Through personal observation of netball performances or, through publication of highly regarded opinion, coaches must develop coaching ideas to guide players toward successful performances.

However, a limited number of match analysis studies have been published concerning the evaluation of fitness levels and effort expenditure demanded by netball (Alison 1978, Otago 1980). These studies used video tapes of netball matches and methods of recording energy expenditure similar to those designed by Reilly & Thomas (1978) in their evaluation of football players' movement. While these studies have been acknowledged by coaches as valuable to the design and preparation of appropriate fitness sessions, Embrey (1978) insists that planned investigations of wider aspects of netball performances should also develop in

order to validate what is/ has been written in texts. Embrey's suggestion for investigation was to develop an analysis system that could record specific information regarding the skills demonstrated, the game structure used, the various successes of individuals, the combinations of players used by both teams during any one spell of netball play.

Developing Embrey's ideas, Barham (1980) suggests that match analysis systems could be developed to assist netball coaches in three main areas;

> "immediate information for court side use by a coach during a match and for the following week's coaching session.
> Information to show need for the appropriate types of conditioning.
> Identification of the success of planned strategies."

Barham (1980) went on to illustrate the value of a system developed to assist coaches in the first of the three areas identified above. The system entailed the use of 'live' pen and paper notation that recorded; technical infringements, personal infringements, shooting records, throw-up results, passing and catching errors and rebounds and interceptions won. The potential speed of events within play necessitated that the recorder should be experienced as a player, coach or umpire. Pre-printed recording sheets were used to help in the notation and fast evaluation of information at the conclusion of each playing period (see figure 2.1 for examples). In an example of notation collected for a particular game Barham suggests how the

record could be used for strategic decision making during playing breaks. She shows how a summary of the recorded information could be used to highlight features of play that would require practice in future coaching sessions.

The system records discrete technical information which is simply totalled at the end of each playing period to show the performance of individuals and the team as a whole. Barham suggests coaches can modify the basic system by adding/ subtracting performance variables to suit their needs. However, to maintain the original aim of the analysis, ie provide information for immediate feedback, the system must remain simple in order to record 'live' information and for the analysis to be performed quickly. One of the most important features of such a system is that it enables recorded, raw data to be speedily condensed for interpretation by coaches and hence fed back to players. Interpretation of the recorded information obviously has implications for the coach intending to use this kind of system for strategic decision making.

It is important that coaches are firstly, able to evaluate the information they gain against some previously established record. To suggest, as Barham does, that twelve 'obstruction' penalties in the opposition's goal circle, warrants a change of defending players or strategy, is possible only if the figure can be evaluated against a 'known' level of 'obstruction' acceptability. For those coaches who have never been exposed to

Figure 2.1 Barham's pen and paper notation analysis system.

Table 1 **(a) Master sheet for recording observations**
(b) List of symbols

(a) NAME OF CLUB (COUNTY, etc) OBSERVED .....

GAME OBSERVED .....

DATE.....VENUE .....

	GS	GA	WA	C	WD	GD	GK	COMMENTS
1st Quarter								
2nd Quarter								
3rd Quarter								
4th Quarter								

(b) LEGEND

S = Stepping
M = All other technical infringements
C = Contact outside goal circles
[C] = Contact inside goal circles
O = Obstruction outside goal circles
[O] = Obstruction inside goal circles
T✓ = Throw-up won
Tx = Throw-up lost

✓ = Successful shot from play
X = Unsuccessful shot from play
P✓ = Successful penalty shot
Px = Unsuccessful penalty shot
Ⓧ = Pass or catch not successful
R = Rebound caught
I = Interception (ball caught)
↖ = Deflection (ball tipped or batted)

playing statistics this figure is likely to be meaningless. Perhaps the first stage of using a system like Barham's should involve collecting data over a series of games. This would help to establish acceptable parameters of error for the variables to be recorded and provide some form of benchmark against which future data can be compared.

Secondly a major criticism of using data from a single match is that it does not take account of the variability occurring naturally in games. (see chapter 3 pages 102-103 for more information regarding value of match analysis systems).

Furthermore, Brewer (1990) asserts some scepticism over the use of match analysis systems designed to provide information for 'live' performances. He discovered that;

> "in some team sports at the highest level, the major purpose of the break, besides the recovery by the participants, was motivational and only in exceptional cases was it about changes in strategy, although minor points were communicated."

Despite the initial values associated with Barham's netball system, it seems that in practice, the benefits are not realised in as simple a manner as originally proposed. Firstly, such systems require the development of acceptable performance standards prior to their use but perhaps a more important issue is the value of information from a single game.

The development of more complex match analysis systems designed to investigate strategic and tactical netball performances has suffered from neglect, with notable exceptions from Potter (1985) and Jones & Treadwell (1988) (cited in Alderson Ed. (1990). Potter's (1985) study of school girl netball investigated the pathway of the ball as it moved towards the goal after each centre play. The court was divided into nine areas and using live or video recorded matches a pen and paper notation system was used to chart the areas through which the ball travelled. At the end of each centre play a comment was added to identify whether the attack was successful in reaching the shooting circle.

The 'model' attacking pathway advocated by most coaching texts is a central route that uses 3 or 4 passes including the centre pass. The results of Potter's study shown in figure 4 reveal that the teams studied do, in fact, make marginally more attacks through the centre of the court. Whilst this is perhaps evidence of the teams attempting to work to a coached model, the interesting point to note is the outcome of the attacks. The right hand attacking route appears almost as popular as the central one, but it has a much better success rate in reaching the shooting circle (69% as compared to 44% for the central route).

Figure 2.2 Analysis of centre pass attacks in netball

Potter (1985)

ROUTE	LEFT	CENTRE	RIGHT	TOTAL
POSITIVE	14	35	52	101
NEGATIVE	15	43	23	81
% SUCCESS	48%	44%	69%	56%

These findings obviously have implications for using the central attacking strategies advocated in many coaching texts. It raises questions whether in fact the central route to goal should be favoured as the right hand side appeared far more successful in school girl netball. Since Potter's study did not record how or where breakdowns occurred it is difficult to surmise why there should be different success rates for right and centre routes. Further research is necessary to gain a more complete picture of the differences found by Potter, perhaps dividing the data for winning and losing teams (see chapter 3 page 93).

Jones & Treadwell (1988, cited in Alderson Ed. 1990) expanded upon Potter's idea using data from international under 21 performances. They developed a computerised system using a Concept keyboard for recording data in conjunction with a BBC microcomputer for subsequent analysis. The system recorded performance details related to three areas of play; centre passes, shots at goal and back line throw-ins. The volume of data collected per match necessitated it be input from video recordings rather than live matches. In accordance with Potter's results, Jones & Treadwell found right sided entries into

the shooting circle marginally more successful than left and centre entries. However, unlike Potter's study Jones & Treadwell looked only at the court position of the final pass made to the attacking circle. The attacking route taken from the centre third was not accounted for in the final analysis. Hence, it is difficult to establish if in fact the complete attack was made through the right hand channel. What does appear consistent for these two studies is the success of passes on the left hand side of the court. An explanation for this finding could be related to defending players' abilities to defend/ intercept on the left side. Right sided passes and attacking pathways would in most cases, be to the left hand side of opposing defence (since they would be facing the oncoming attack), for the majority of right-handed players this is most likely to be their weaker side for catching, throwing and intercepting. Therefore taking an attacking route through the right side of the court, against a predominantly right handed team, may exploit opposing teams' weaknesses and increase the chance of a successful attack to goal.

The analysis procedures of Jones & Treadwell's data concentrated on percentage success rates of shots on goal, first passes from centre play, back line passes and passes into the attacking circle. Since the system was developed to assist the Welsh coach, the data collected was limited to that of the Welsh team. The intended purpose of the analysis system was to provide objective information of immediate use the coach. As such no

attempt was made to investigate patterns of performance beyond the collation of independent techniques such as successful centre passes and shots on goal.

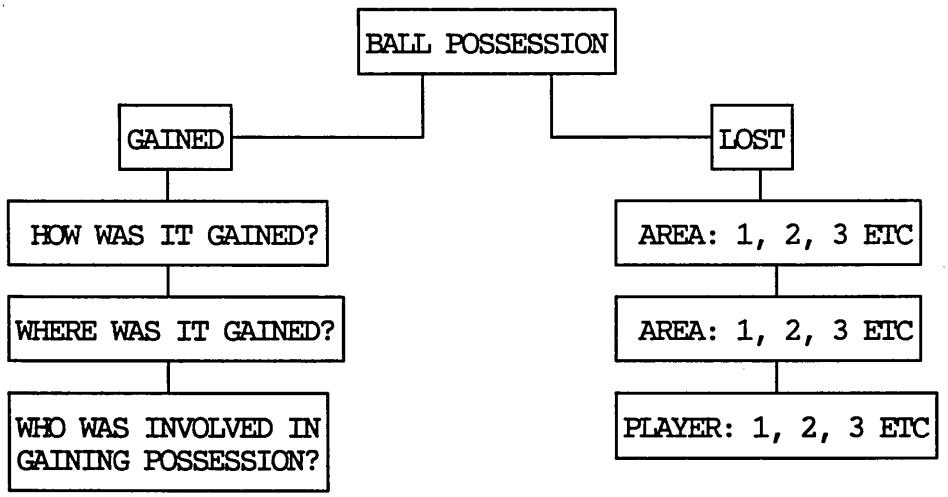
From a review of netball literature it is apparent that there is a sparse base of empirically founded information relating to technical and strategic performances. Given the current climate and thought associated with coach development it seems appropriate to investigate technical and strategic parameters of netball in order to identify critical elements of performance.

Coaching information

According to Franks & Goodman (1984) the initial stage of evaluating any game performance is to determine the structure of the game in question. This begins with a general, two state model which determines if a team is in possession or not, the next level of the model and then begins to probe for information by asking questions regarding the gain or loss of possession, (see figure 2.3 below).

These fundamental features provide a basis on which detailed analysis can evolve. The information available for inclusion in an analysis system is extensive and the selection of essential data is of paramount importance. It is necessary to prioritise key factors of performance so only those events considered relevant are collected and analysed for coaching purposes. It is therefore essential that coaches are involved in the development

Figure 2.3 Hierarchical figure for determining the structure of game events. Franks & Goodman (1984)



of such systems in order to identify the key match events. In this project, liaison with the national netball coach provided expertise and experience.

The key match events selected by the coach as important for making decisions were:

1 Shooting analysis: Providing information for goal shooter and goal attack in the form of a percentage success rate and raw figures. It was also felt important that the analysis should take account of the circle areas from which shots were attempted.

2 Centre play analysis: Success rates of the first pass from a centre play and the success of each centre play reaching a scoring opportunity.

3 Loss of possession analysis: Information explaining how and where possession is lost, the player responsible and whether the opposition score as a result of it.

4 Individual player profiles: To provide performance information for each player over the entire match. The analysis should note positive and negative technical performances.

5 Final ball 'fed' into the shooting circle: To supply information regarding the success of passes into the shooting circle, noting the player and area from which the pass is made.

The kind of coaching information identified above is essentially concerned with technical information that will be of immediate value for player feedback and match post-mortems.

By contrast the researcher will be looking to investigate patterns of play in order to help build a more complete picture of the game in terms of strategic performance. The match information collected and analysed will not necessarily be of immediate value to the coach. In Potter's (1985) investigation of attacking pathways from centre play the information yielded from each match was not of particular use to coaches since the patterns were always apparent. The value of Potter's and similar

sorts of research investigating game strategy lies in longer-term coaching plans and team development. Only when such patterns have shown themselves as reliably associated with successful/ winning strategies could coaches use them as a comparative benchmark with their team's performances.

The manner in which match information is collected may well differ for coaches and researchers. The researcher needs information relating to sequences of attacking passes, the court areas through which they pass and the final outcome of each pass, while the coach may simply need a summary of such information, perhaps the percentage success of centre pass plays or interceptions, rather than the full detail in of every attack.

A conceptual consideration of netball may be used in addition to established coaching theory to help form the research hypothesis related to the investigation of performance patterns. This is particularly relevant in the case of netball where there is a very limited body of coaching knowledge related to strategic performances.

In netball winners are the teams which score most goals, hence it follows that goal scoring is paramount to success, however the rules stipulate that in order to attempt a shot at goal the ball must be passed to either the goal shooter or goal attack within the bounds of the shooting circle. Thus the movement of

the ball to such a position is also critical to winning. Consequently every attack has the potential to provide a team with a goal. On this premise it seems relevant that investigations analyse attacks on goal, especially in relation to centre plays, and a detailed analysis of shooting performances.

Summary

* Netball is a high scoring, fast flowing, non contact game, in which shooting skills and attacking play are important for achieving success.

* Netball coaching literature appears to have an abundance of information associated with technical skills, these appear to be generated through academic research and good practice taking place in the field.

* Most of this technical information relates to the correct physical action involved in carrying out a particular skill but does not specify the efficiency level at which players should perform it. Numerous texts explain the technique of shooting but none offer parameters of efficiency rates within which shooters should aim to operate.

* There is little published information regarding tactics in netball. The information that is available tends to be

published opinion of highly regarded coaches, or information handed down by word of mouth from good practice or success cases.

* Inevitably some coaches will develop their own theories regarding successful playing tactics.

* There is limited research on netball in general and even less on the types of information that may be of value to the coach operating in the cycle described by Franks et al (1983).

* There have been a limited number of match analysis studies concerned with the evaluation of fitness levels and effort expenditure demanded in each of the playing positions, this information is of value to the coach when designing and preparing appropriate fitness sessions.

* There are few studies that have set to test the value of certain playing hypotheses in netball. Potter (1985) designed a study to test a theory suggested in the coaching literature regarding the pathway of an attack from a centre play. The study's findings challenge those in the coaching literature. It has since been repeated by Treadwell & Jones (1988) using a different sample population which has supported the findings of Potter.

* The findings of these studies clearly challenge the value of the published coaching recommendations. However, there has been no explanation of the differences found and coaching recommendations are yet to evolve.

* Due to a lack of empirical information for strategic performances in netball it is necessary to take an evaluation of the game 'model' in order to form some research hypothesis regarding the investigation of game patterns.

CHAPTER 3

Game modelling

The nature of games

To the uninitiated, casual observer, modern team games offer an unpredictable if not almost chaotic picture of complex movement patterns. However, the picture is actually less random and variable than it might at first appear since the highly structured nature of games prescribes goal-directed behaviour and restricts the means by which performers can achieve such goals. Even the casual observer of soccer would soon realise that teams were trying to move the ball 'forwards' and that they can only do so with the use of their feet. More detailed studies have shown that 'patterns' of performance can be identified, being repeated across matches and by different teams. Through the collection and analysis of certain observable game events, such as those leading to attempts on goal, these 'patterns' appear as statistically regular features of play (Reep and Benjamin 1968, soccer; Potter 1985, netball; MacKinnon 1985, squash; Franks & Goodman 1986). In football for example, Reep and Benjamin (1968) and Pollard et al (1977) found that the probability of a team scoring a goal from any given possession decreases as the number of passes increases and that, overall, about one shot in ten (on target) is successful in scoring a goal.

As has been shown, the intensely interactive nature of games necessitate that players become involved in a high degree of decision-making. Each game situation contains many potential cues and stimuli to which performers might attend and respond. The speed and accuracy with which they decide: a) to what they should attend, and b) the response they should initiate, are important determinants of performance in many competitive games (Alain & Proteau 1979). The goal-orientated nature of game situations means that many of the potential stimuli available to players are irrelevant to the task at hand and can be ignored by the performer. 'Good' performances are often determined by a player's ability to make 'good' decisions and select the best course of action. Franks, Wilberg and Fishbourne (1982) suggest that the primary decision any player makes when potentially, or actually involved in a game move depends on whether or not their team is in possession of the ball and hence results in the adoption of an attacking or defending strategy. Further decisions then relate to the objectives of either advancing/ pressing home the attack, or organising an appropriate defence to an attack, or regaining possession in order to mount an attack. From these initial, primary decisions players then become involved in a series of more complex secondary decisions based on more specific attacking and defending tactical ploys.

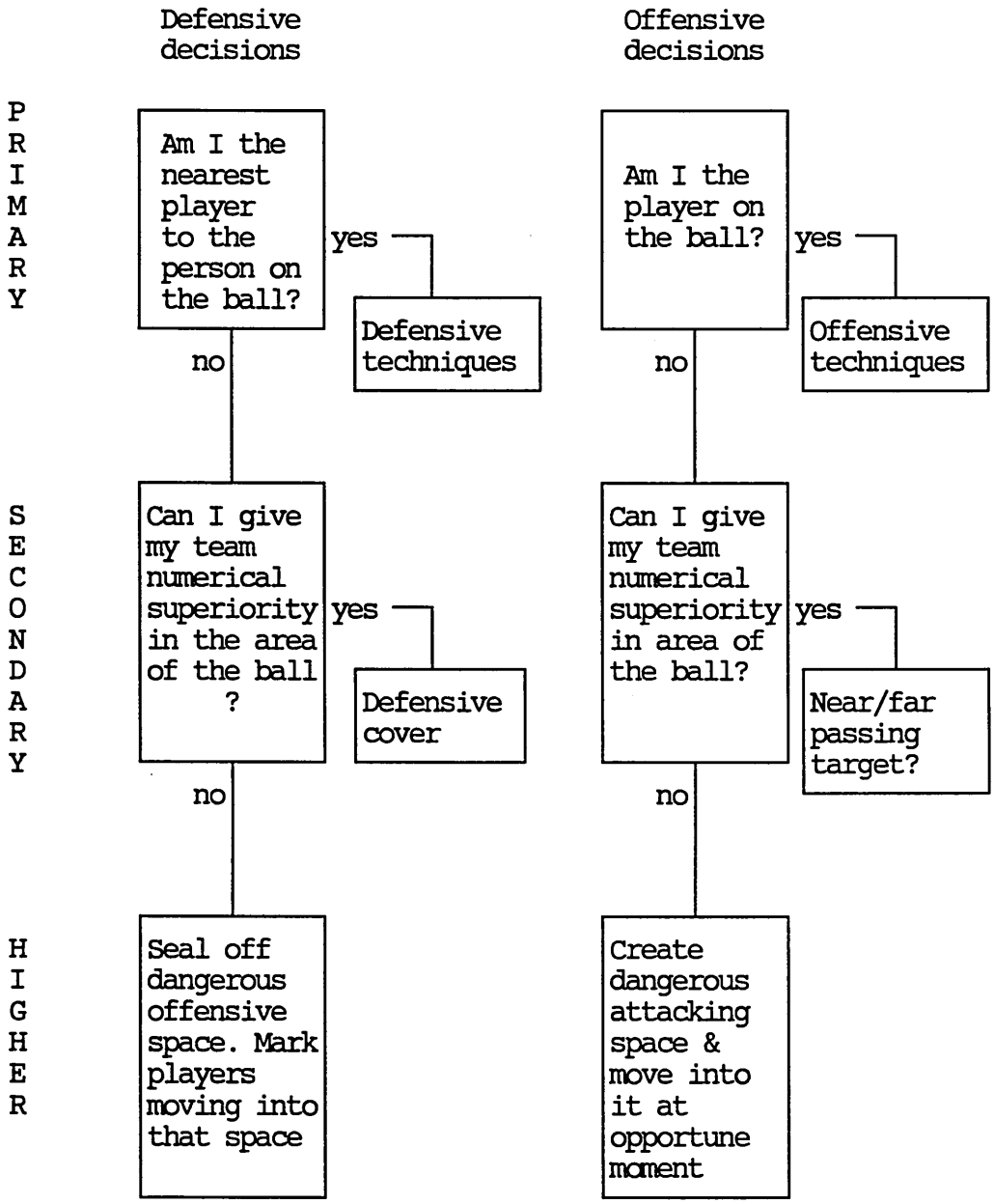
In team games it appears that tactical decision-making is vital for achieving successful performances and should therefore be an integral part of coaching in these sports. (Smith et al 1982,

Smith 1984, Alain & Proteau 1979, Bate 1987). The hierarchical sequence of decision-making suggested by Franks et al (1982), identifies three progressive stages of decisions relating to offensive and defensive games play (see figure 3.1).

At each of the three stages of tactical decision-making proposed by Franks (1982) there are bound to be decision alternatives available because of the 'open' nature of games. It is therefore inevitable that players will respond in different ways if they are not guided by a coaching model or its equivalent. Those coaches who develop their own game plan will attempt to coach/ guide players to play to that model. In such cases, responding to the decision-making stages identified by Franks, players should react with the tactical decisions and concomitant techniques which are designed to facilitate the successful operation of the chosen game plan.

Consistency of good decision-making across matches implies personal skill. 'Patterns' of events, irrespective of skill are the identification of playing syntax, such as Reep & Benjamin's (1968) finding that the increased length of an attacking possession decreases the chances of scoring. Patterns usually begin to emerge after the collection and collation of several matches of data, they are not necessarily of immediate value to the coach in the form that they emerge. A game 'model' tends to be the interpretation/ translation of performance 'patterns' into coaching plans, which should have immediate relevance and

Figure 3.1 The secondary and subsequent decision-making process. Franks et al 1982



value to coaching. Traditionally, statisticians have applied mathematical 'modelling techniques' when investigating the 'fit' of numerical data to certain mathematical properties. If data is found to 'fit' a particular property then a 'model' is said to

be apparent. However, in the context of this project, the emergence of mathematical 'model' will be referred to as a 'pattern' and the translation of that information into a coaching plan will be referred to as a 'model'.

The relevance of game modelling to the coaching process

In attempting to guide performers towards more successful play, coaches will attempt to highlight the game cues that they deem important to tactical decision-making and ignore those that are thought to be irrelevant. A function of game models is to act as a 'blue print' for decision-making'. However, Smith (1984) suggests that while there is a plethora of coaching literature related to technical actions (ie, the motor actions following decisions), information related to the decision-making involved in selecting the appropriate tactic and technique is sparse. Commenting on the poor development of tactical decision-making found in many coaching programmes, Horstwein (1982) maintains that:

> "...in order to reach the required standard of hockey, tactical awareness must be embarked upon with beginners. Since thinking develops automatically with the motor-senses and action develops with thinking, tactical instruction should also be considered when teaching... in order to optimise the children's talents."

There is limited evidence from the literature (Crouch 1984) that some decision-making processes are aided through coaching intervention. When developing certain technical skills it is

common to progress from simple, unopposed skill drills to game-like contexts where the coach is able to highlight those cues that should be noted for the effective delivery of a particular technique. For example, netball goal shooters are commonly coached to watch the pathway of the ball as it advances towards them when their team are attacking to learn how to position themselves favourably in order to 'block' defending opposition players from the most appropriate attacking space. Unlike throwing and catching techniques which can be practised in tactical isolation, the technique of 'blocking' is rarely taught without reference to preceding court play since its significance as a technique is difficult to appreciate outside of the strategic/ tactical context. In theory, a logical means of developing appropriate decision-making skills would be to give players an opportunity to assess the suitability of different tactical solutions in practice situations.

However, in practice, Smith (1984) suggests that the choice of training activities does not always follow the seemingly logical progressions advised. Through observations in a number of sports and from proposed training drills in basketball, tennis, hockey and rugby league, Smith found that technical skills are often practised and repeated in situations that do not offer the range of cues that would normally be available for decision-making in real game situations. This, he maintains, leads to full decision-making by players being replaced by coaching demands such as "run here, do this, then that". Hence the motor skills

learned almost become automated in a 'closed' practice environment, whereas in a match context the situation is largely 'open' and variable.

Developing an inflexible approach, whereby a given technique/ tactic is applied regardless of the suitability of the playing environment, is not recommended (Smith 1984). The 'long-ball', advocated by some football managers and coaches is an example of a playing tactic which is used repeatedly to create penetration in attack. However, it is often used in conditions which are unfavourable; for example, when attacking players are stranded in mid-field and therefore unable to 'run on' to a ball delivered deep into the attacking area, or when attacking team-mates are out-numbered by prepared defenders in the long-ball target area. In situations of this kind, by-passing the decision-making stage associated with the assessment of a situation may lead to missed opportunities where alternative tactics may have been more suitable.

Approaches to developing game strategies

How the coach primes players for different levels of tactical decisions and techniques will largely be influenced by the playing features that individual coaches identify as determinants for success. Through experience, it is inevitable that coaches will develop opinions regarding the contribution of different strategies and tactics. Thomson (1985), maintains that

within a particular sport, opinions will differ regarding the factors that are most relevant to successful performance. Observation of differences in playing 'style' between teams would seem to support this notion. The attacking play of some English football clubs, (Watford, Leeds and Sheffield Wednesday) are characterised by the long ball forward, played from the defending half of the pitch. This produces a playing style quite different from other European football clubs whose attacking strategy is to work the ball forward, hence resulting in longer possessions. In netball, there is differing opinion amongst coaches regarding the effectiveness of a zone defence system as opposed to 'man to man' defence systems. Some coaches identify closing down space as a key factor in successful defending and select zoning as the means of achieving this. Others favour the defending pressure gained through man to man defending and will coach players' tactical decision-making within that strategic framework.

La Rose (1982) suggests that in every game sport situation there are a number of strategic moves that are logically possible. Where strategic opportunities proliferate, it is common for coaches to develop high-level attacking and defending strategies which in turn create identifiable 'styles' of play. These are usually observable from general play throughout a match. In addition specific strategies are also developed for set play situations such as throw-ins, penalties, free passes and so on. These tend not to be recognised as playing 'styles' in the same

way as general defending and attacking strategies are; they are applied in 'dead-ball' situations and do not influence the full game.

Most coaches develop their own strategic models through a mixture of intuition, education and experience; hence these models are highly subjective. Likewise, the evaluation and analysis of decisions inferred through observation of consequent behaviour are largely dependant on the quality of the observation stage of the coaching process (see page 7). However, this observation of player behaviour has many inherent weaknesses, relying heavily on subjectivity to evaluate and verify the relative merits of selected strategies. The problems associated with subjective observation are often magnified when looking at strategies and tactics since the sequential nature of these events places increased stress on the observer.

Strategic/ tactical efficiency is generally inferred from a combination of technical skills, reflecting the point made by Parry (1984) earlier (page 26), that to evaluate single game events does not help us to increase our knowledge of them unless the context of their occurrence is appreciated. It therefore seems logical that strategic models and tactical performances be evaluated in the same objective way as are other performance features such as fitness levels and skill execution. Schutz (1980) supports the notion that objective evaluation should be applied to strategy in sport through 'probability statements

derived from sound assumptions and empirical data' rather than tradition, myth and guess work.

The need for objective approaches to coaching

In general, academic researchers recognise:

a) that through necessity, coaches have had to develop models of play from subjective ideas (Franks & Goodman 1984, Thomson 1985, Reep and Benjamin 1968, Bate 1987).

b) it is quite possible that there are many 'good' and 'bad' features of play that may not, as yet, be part of coaching consciousness.

Furthermore, it may only be through objective and systematic investigation of patterns of match events that we will ever properly appreciate the effect tactics have on game outcomes, and hence derive relevant models of game performance. As a research technique, match analysis has the potential to generate new levels of understanding of **how** games work tactically. At a simple level, for example, in an investigation of tennis, King (1979) found no support for the favoured, conventional 'strong first serve/ weak second serve' tactic, over any other service strategy. Moreover, it was often found that match winning chances actually diminished when adopting the conventional strategy. Shutz (1980) found that a 'weak/ strong' strategy is never optimal, no matter what the probabilities are, but in

accordance with King he found that in some instances a 'strong/ strong strategy, or a weak/ weak strategy to be equivalent to, if not advantageous, over the traditional strong /weak serve. A similar finding has been discovered by MacKinnon (1985) in his analysis of squash. A common belief amongst players and coaches is that service to an opponent's backhand is more favourable than to their forehand, since the former is seen as the weaker side of return. However, Mackinnon found that service to the backhand was actually significantly less often associated with success in winning the rally than service to the forehand. Hence, conventional wisdom is adopted without due consideration of whether the strategy in question really does maximise strengths and negate weaknesses.

Both of the findings above have quite logical explanations and are perhaps less surprising than they first appear. In squash, MacKinnon (1985) pointed out that because of the almost universal adoption of the 'serve to the backhand' strategy, players will get considerably more experience of returns of service on that side. Hence, in a game situation they are probably better prepared to return serves on their backhand, the supposedly weaker side, than they are on their forehand. A slightly different explanation can be offered for Schutz and King's tennis findings. Players are rarely coached to receive weak/ strong, strong/ strong, or weak/ weak combinations of service. In a game situation the use of these 'alternative'

strategies may be such a surprise tactic that they gain an advantage for the server.

Findings of this kind obviously have implications for coaching and for an appraisal of tactics that have been established through subjective analysis.

The development of objective game models

To date game model analysis has tended to be the concern of academic researchers rather than coaches. The major exception to this rule are Downey (1970), who was both coach and academic, and Hughes C (1984), who was director of coaching for the English Football Association.

The analysis process searches for patterns of play from a series of match recordings to distil out regular game features, as opposed to discrete technical statistics. Particular reference is paid to those game events associated with scoring. The implications of these game features can then be included in coaching programmes and used as a basis for monitoring future performances.

The methodology commonly applied in the physical sciences involves the use of deductive methods of research to develop existing theory. This works very well for the well-established sciences since many have a sound foundation of theory which acts

a basis for developing new theoretical propositions and hypotheses. In addition, the laws governing physical phenomena tend not to vary, lending constancy to the theoretical base. However in the social and behavioural sciences there tends to be a less well-developed base of theory, and observable behaviour is subject to significant variation. In such fields of enquiry the deductive method of research is inappropriate.

Inductive research is an alternative methodology and is valuable as a way of allowing patterns of observations to emerge which generate theory where previously none existed. Game modelling has, through necessity, been inductive in nature. A general lack of objective theory in game sports has led to the adoption of inductive research so that new theory emerges from data during analysis.

This inductive approach to research is argued by Glaser & Strauss (1967, cited in White 1982) to offer an opportunity for grounding theory in research and for generating theory from data. Unlike traditional methods the sample size is not predetermined, or at least, it need not be. Match data are collected until patterns emerge and new data fails to evolve different trends or properties.

Despite this essentially atheoretical approach to research proposed by Glaser & Strauss, White suggests that theory discovery should proceed alongside more rational forms of

theorising. In developing game models such an approach is not entirely possible, since most 'theory' relating to successful strategic/ tactical performances have not been objectively established and tend to be based on intuition or hunches. The value of recognised strategic and tactical performances are relatively unknown in most game sports as such and the information that emerges during collation and analysis of data often reveals properties that were not perceived at the start of the research. For example in an investigation of Karate by Genery and Alderson (1985) 1521 technical moves were recorded during an international competition. Of the twelve Karate techniques normally taught, two were not used at all in the competition, a third technique was used only once and a fourth just twice. This finding was not expected prior to the investigation; ie, no hypothesis were established to test this aspect of karate performance. Alderson (1987) reported this finding as particularly interesting since the techniques used so seldom in competition were given as much time, if not more time, in training as the staple techniques.

Similarly, Brackenridge & White (1983) found unexpected patterns emerging in a study examining passing interactions amongst lacrosse players. Frequency matrices, constructed from data collected in eleven matches, revealed 'a remarkable drop in interaction frequency between the attack and the defence units of play, far more marked than expected.' The authors suggested that on the basis of these findings reassessments should be made

of the approach taken to practice sessions. In summary, the 'backs' needed less time on ball handling skills than they currently received and more on other playing skills such as marking and interception.

Sources of game models

From a review of the literature it appears that game models have developed from two different sources of academic enquiry interested in sporting performances; namely sports academics and statisticians with an interest in sports facts. These two interested parties have different motives for investigating game patterns and therefore the resulting data is analysed and applied in different ways.

Statisticians

Statisticians working in this area have collected simple game information and applied sophisticated statistical tools to investigate predictive models, which may or may not be of use to the coaching process; eg Reep & Benjamin (1968), Gale (1971), Carter & Crews (1974), Pollard, Benjamin & Reep (1977), Ryan, Francia & Strawser (1977), Price & Rao (1977), Gould & Gatrell (1979) Gould & Greenwalt (1981) Croucher (1986).

In particular, statistical models have had a bias towards probability theory (Reep & Benjamin 1968; Gale 1971; Carter & Crews 1974; Pollard, Benjamin & Reep 1977; Ryan, Francia & Strawser 1977; Price & Rao 1977; Croucher 1986). The work by Reep & Benjamin (1968) and Pollard et al (1977) investigated the role played by chance in determining winning performances. They examined the frequency distribution of a limited number of discrete performance events such as goals and the passes preceding goals in association football. The null hypothesis of the study assumed that chosen game events (goals) occurred by chance, within and across football games. However, the rate at which they occurred was considered to be influenced by the skill of the performers involved. The researchers made a further assumption that although goals will occur at random, the 'better' team, ie the one with a higher rate of goal scoring over a number of matches, may be beaten by an inferior team due to random fluctuations found in a single game (Pollard et al 1977). The intention of the work was to establish the extent to which skill and chance played a part in the occurrence of selected performance criteria. The statistical modelling technique used by Reep & Benjamin (1968) and Pollard et al (1977) is called the negative binomial distribution.

For each attacking play in football one of two courses of action can take place when the possession is gained; it is

either maintained and possibly passed on to another player of the same team or, it is lost through interception/ tackling, rule infringement or a shot at goal. Reep and Benjamin describe this possibility as "r-pass movement", where having gained possession of the ball, a team has the potential to start a series of r+ successful passes during which, "... there is either a shot at goal by the rth recipient or an infringement, or there is an attempted (r+1)th pass which is intercepted." The investigation involved looking at the probability of possession being maintained beyond r passes. The negative binomial distribution model was used as a stable mathematical structure against which the frequency of the various r - sized movements was compared for mathematical likeness. It was found that possessions with a greater number of passes (> values of r) occurred with reduced frequency (and systematically). The 'fit' or likeness of this data to the negative binomial model was a good one. The distribution of goals in football, touchdowns in American football, runs per half-inning in baseball and goals in hockey have all been shown to fit the negative binomial distribution.

Whilst the negative binomial distribution appears to apply to data involving a team effort such as goals, runs per half innings and so on, similar sorts of events taken from individual player performances in team games do not give close 'fits' to the negative binomial distribution. Pollard

et al (1977) suggests that in these cases player skill may play a more significant part than chance in determining the distribution of given events. Interestingly, when data relating to a selected game variable is collected for just one player, as for example in cricket runs, the data does not appear to 'fit' the negative binomial distribution. However, when data is added for other players involved eg. a second batsman, the closer the data 'fits' the model.

Other examples of probability statistics have been used by; Gale (1971) for tennis; Carter & Crews (1974) for tennis; Ladany & Machol (1977) for baseball; Croucher (1986) for tennis and Ejem (1980) for volleyball. However, these works have largely investigated probabilities of winning/ gaining a point/ scoring goals from given situations that are common within a game. For example, Gale (1971) used a simple probability model to predict optimal serving strategy in tennis from given game points. Croucher (1986) likewise developed a model of conditional probabilities for a player winning a single tennis game from any score line.

Probability statistics

The approaches adopted by statisticians investigating probability models of sport strategies tend to fall into one of two types:

The conceptual approach

This involves the construction of mathematical formulae for predicting the probabilities of success. The formulae develop through reasoning and logic of prior knowledge of rule structures and performance criteria that are thought to influence performance. The collection and collation of raw data is unnecessary for the development of these models. Gale's (1971) probability model for optimal serving strategy in tennis is an example of this type of modelling; serving possibilities were worked out on the basis of known potential of certain strategies and a value was assigned to their 'riskiness' in order to model the most successful serving strategy. Gilchrist (1984) refers to this modelling approach as 'conceptual', whereby the form of the model is derived through an understanding of the situation and 'known theory'. Using this method to evolve more objective and sound approaches to sports strategies is somewhat restricted by the limitations of 'known theory' in this area. As previously mentioned there is a dearth of information in the literature regarding strategies in general, and in particular strategies derived from objective analysis. This begs questions regarding the value of these models in the practical sports setting and their relevance to the coaching process. If conceptual models are not tested/ evaluated

empirically their validity in the applied context must be challenged. For coaches to accept strategies based purely on conceptual models, supported only by subjective evaluation is not enough.

The empirical approach

The other approach to modelling, such as that demonstrated by Reep & Benjamin's (1968) work as previously mentioned, involves the collection and collation of data over a series of matches. The data is then analysed with statistical tools in order to discover whether any patterns of distribution are apparent. Gilchrist (1984) refers to this as the empirical approach to modelling whereby information known prior to the collection of data is totally ignored and only empirical information contained in the data is used. Gilchrist (1984) argues that the same model may result using either empirical or conceptual approach, but goes on to say that in practice we should seek to use prior knowledge and empirical data to model, developing what he terms an eclectic approach.

Additional variations of statistical modelling

Other forms of sophisticated modelling techniques have

been utilised by statisticians investigating player configurations involved in strategic performances (Gatrell & Gould 1979, Gould & Gatrell 1979, Gould & Greenwalt 1981). These studies made use of geographical analysis procedures to define and describe the structure of games (football and basketball). Methodological procedures commonly used in geography were employed to analyse spatial transformations of player configurations. The results of these studies were able to give objective accounts of the games in question, and in the case of Gould & Gatrell (1979), supported intuitive post-game descriptions of team strategies. However, their value to the coaching process and for analysing patterns of player configurations related to successful and unsuccessful performances has not as yet been explored. At this moment in time, they appear to be confined to producing objective descriptions of "the flow of games" with objective reports of associated player configurations on the field of play.

The type of statistical models described above differ markedly from those produced by 'sport academics'. The former are largely developed with the sole intention of investigating statistical properties that 'hold true' within games. The fact that sports behaviour is often less

random than first appears (due to the structured nature of the rule framework and the goal directed behaviour of players), suggests that the context lends itself well to this type of investigation. Collection of sufficiently large amounts of data regarding player actions has indeed supported many of the statistical modelling studies through the appearance of consistent patterns of play associated with successful and unsuccessful performances (Reep & Benjamin 1968, Pollard, Benjamin & Reep 1977).

However, the value of both conceptual and empirical statistical patterns for coaches and performers is questionable. Resulting patterns are often of academic interest only and provide little guidance for coaches working in the field.

Sports academics

Sports academics involved in game modelling have tended to develop match analysis systems capable of producing post-match data of some immediate utilitarian value to coaches whilst also building a data base of information to investigate the nature of games. The data collection systems are often sophisticated in relation to those used by the statisticians and collect data relating to more performance variables; eg Sanderson (1982), Potter (1985),

Hughes C (1985), Hughes M (1986), MacKinnon (1985), Franks & Goodman (1986), Wilkinson (1988).

The models established by sports academics (MacKinnon 1985, Potter 1985, Wilson 1987, Harris & Reilly 1987) have, like statistical models, evolved through the collection of large data sets. However, the nature of the information that is recorded by sports academics generally comprises sequences of game events such as possessions/ rallies. These events tend to be highlighted by practising coaches who are concerned about their impact on performances in a given match, as compared to straight forward statistical modelling which collates match events in order to identify the kinds of stable performance parameters already discussed.

Other differences in the sports academics' research efforts arise through;

i. the statistical methods used to identify significant patterns of performance; ie, conventional parametric/ non-parametric tests,

ii. their intention to investigate game patterns to identify elements of performance that have implications for how the game is played at a variety of levels.

The dual purpose approach to developing game models, discussed above, has clear advantages above the over-simplistic conceptual and empirical examples of straightforward statistical modelling. However, it is still subject to criticism as Harris & Reilly (1987) suggest the research methods adopted by dual theorists, such as Franks & Goodman (1986), tend to be restricted to the production of descriptive data related to tactics. This may be a result of the quantity of information gathered in an attempt to help provide coaches with objective match information on a whole range of performance variables and situations. In contrast, the statisticians have tended to select a few, very discrete variables such as goals, runs etc. Brewer (1990) suggests sports academics face a dilemma when developing match analysis systems to serve both immediate coaching needs and modelling. He suggests that attempting to satisfy both through the development of one data recording system leads to conflicting demands for the researcher. In presenting data for a wide range of performance features the researcher sometimes compromises the development of detailed information concerned with individual features of performance, such as serve and volley strategies in tennis, or centre pass plays in netball (see Mackinnon 1985, Harris and Reilly 1987 as notable exceptions).

Harris and Reilly (1987) point out that variables such as goals 'provide few data collection points in complete games' and in

some there may be none at all! They go on to suggest that a more fruitful approach would be to study broader aspects related to success in games. In their own research, the authors investigated attacking configurations, they looked at the number of attacking players in relation to defenders per attacking sequence, the number of passes, type of attacking moves by individual players and the distance of nearest defenders to an attacking player with the ball. Elements of successful attacking configurations were subsequently identified from an analysis of this data.

The research of Franks & Goodman (1986) demonstrates the collection of match data relating to wider aspects of performance, believing that in order to gain relevant information for use in the coaching process, a comprehensive system of analysis should be developed. These authors suggest that all aspects of play should be recorded and analysed in relation to each other so that, for example, physical condition can be related to decision making, skill execution and so on. They note,

> "the interaction of all responses is integral to the completion of any one goal-orientated act, it is necessary to take many simultaneous measures of human endeavour."

In producing such a detailed analysis, it is implied that a conceptual game model will emerge, capable of guiding subsequent coaching practice. This presupposes that a "model of play" is

implicit in all games and that the collection of sufficient match facts together with a systematic search for patterns within the data will distil out regular 'features' of game play.

The apparently holistic, hierarchical approach suggested by Franks & Goodman (1984, 1986), would require an extremely sophisticated and labour intensive analysis system, which is currently beyond the limits of most coaching budgets. Three general assumptions seem to be implicit in these authors' approach to modelling;

i. all games have a model,

ii. the game model will appear if enough performance information is collected,

iii. the method used to search for patterns, develop models and monitor future performances can be applied to a variety of game sports ie. it is of a generic nature.

Whilst it is undoubtedly true that eventually game 'features' will emerge from massive statistical analyses, the all-embracing approach adopted by Franks and his associates attempts to measure as much performance detail as possible. Despite their original intentions to help provide coaches with a reliable means to assess technical and strategic performances of players, the methodological procedures are concurrent with the more

academically orientated research approaches. The development of a system to measure 'everything' does not guarantee that the subsequent analysis will necessarily have value for the coaching process.

The value of game modelling

According to Alderson (1990) the contribution of game models to both coaching and developing theories of how games work is in its infancy. From the literature it seems that in theory at least, models should be capable of providing coaches with markers against which some assessment of their own players' performances can be made. For future developments in the area of game modelling a critical evaluation of their practical worth would be a useful exercise.

Using soccer as a focal point it is possible to explore the values of game modelling mentioned above since more work has been carried out in this game than any other.

Possession in football has traditionally been viewed as the key to success. Only when in possession can a team attack the goal with the aim of scoring and whilst in possession they are able to prevent opponents from doing so. The rule structure of the game means that possession can be gained anywhere on the pitch where the ball is then (usually) moved forward in the opponent's goal direction. Methods of working the ball forward from the

defending half of the pitch have traditionally been of two types; a methodical build-up as most usually displayed by the home countries and Northern European teams, or the fast break where the ball is carried forward quickly by one or two players as often seen with South American and some European teams.

The original research of Reep & Benjamin (1968), and latterly followed by Hughes C (1984) and Bate (1987) has 'charted' the characteristics of possession preceding goals. All three researchers have come to the same conclusion, namely that long possessions rarely result in a goal. This could be explained by the amount of time that long possessions give defenders to organise and effectively close down attacking space (Reep & Benjamin 1968). From their statistical observations all the researchers noted that;

i. most goals come from the attacking third of the pitch,

ii. most goals come from short possessions (four passes or less).

Based on these simple observations Reep & Benjamin devised a principle called the 'reacher theory' which involved the pitch being divided into thirds, the attacking third being the most important scoring area (from the goal mouth to an imaginary 25 yard line). A 'reacher' was defined as a single pass from the defensive third delivered ('reaching') into the attacking third.

Their analysis showed the 'reacher' to be the most probable method of creating a goal scoring opportunity from a possession originating in the defensive third of the field.

The work of Charles Hughes (1984, mentioned earlier), is a classic example of match analysis work that has developed from a pragmatic, coaching viewpoint. From statistical observations of the parameters surrounding goal scoring he formed a model known as the 'domino theory'**(see Figure 3.2 page 98)**.The theory is intended as a practical, strategic plan in which five performance criteria have been identified for winning performances. The performance criteria are sequential in nature and take on a 'domino' effect when applied to a match. <u>All</u> five criteria are intended as progressive steps towards winning, at each stage of the model teams must achieve better results than their opposition in order to secure a win. Undoubtedly, Hughes' theory has affected the practice of many English league football clubs over the last decade or so.

A result of Hughes (1984) model and the previous work of Reep & Benjamin (1968), the 'reacher' has emerged as a third method of attack from possession gained deep in the field. This involves the use of a long ball played from the defending third of the pitch through to the attacking third. However, unlike the previous two methods of attack explained above, implicit in the 'reacher', or long ball attack, is the possibility of losing possession. As such the 'reacher' style of football has been

subject to criticism by some officials as an 'anathema to the popularity of football in Britain' (The Sunday Telegraph 1989).

It appears that the theory generated by the above mentioned researchers has influenced soccer playing style and game tactics. They simply found that the longer the length of an attacking possession the less likelihood there is of scoring a goal; ie, the chances of scoring decrease with every pass that is made.

The popularity of football in Britain seems to be a contributing factor in the continued interest and research of these initial playing 'patterns', as compared to other game sports. Bate (1987), extended the work of the two previous researchers in order to examine the current vogue for 'possession' football. Seemingly contradictory to the findings above, many European and some British football teams have recently had widespread success using possession tactics.

Bates' findings revealed that 98% of all Notts County goals, (1985-1986 season), were scored from four passes or less and 33% of these were a result of set plays in the attacking third. He concluded that the results supported 'long ball' theory and that possession football should be critically assessed as a key to winning football games.

The focus of football analysis work reported to date has been the creation and conversion of scoring opportunities, and related phenomena such as breakdown of possession. However, in most games all teams score whether they win, lose or draw. Hence, data on which the analysis is based, contains all three match outcomes and simply 'averages' data specific to winners or losers. The next logical stage of analysis is to separate data for winners and losers in order to search for differences/ similarities of play preceding goals. Hughes M, Robertson & Nicholson (1987) looked at patterns of goal scoring and preceding passes in order to investigate the existence of differences related specifically to winning and losing teams in the 1986 World Cup. They found that successful teams seemingly played more possession football than unsuccessful teams (measured by the number of touches per possession). The explanation offered for this finding by Hughes et al was that top teams have sufficient players to sustain controlled possession and can afford to wait for an opening to play a quicker or longer 'through ball'. Hughes and Lewis (1986) extended this work by analysing the attacking plays for successful and unsuccessful teams. They identified and recorded 37 playing variables associated with attacking plays and analysed the different frequency counts of each variable for winning and losing sides. The results suggested, amongst other things, that successful teams passed the ball more, particularly out of defence. These findings have been supported in other

minor research projects (Russell 1987, Taylor 1987, Herborn 1987).

Herborn (1987), in particular, compared goal attempts and the use of the long ball in first division English League and international European football. The findings disclosed the use of a combination of attacking tactical styles ie, 'reachers' and possession football, amongst successful sides, especially at international level. 46% of goals scored by successful teams, at international level, were from less than four passes and the remainder from more than four passes. Interestingly, the research revealed that 43% of goals came from set play situations such as free kicks, corners, penalties, throw-ins. The author concluded that these observations had implications for well rehearsed tactical preparation in all these areas of performance.

These latter findings of goal scoring in football appear to provide results that add a new dimension to the original findings of Reep & Benjamin (1968) and Bate (1987). Whilst the latter maintains that 98% of goals are scored from four passes or less, the studies by Herborn (1987) and Hughes et al (1987) seem to suggest that goals scored by winning/ successful teams come from a combination of 4 passes or less and possession play. Reep & Benjamin maintain that while changes in playing style would be expected to affect the parameters of the negative binomial distribution it would not alter its mathematical

character; ie, playing styles do not cause the differences in the mathematical character of the model. Investigating the goal scoring data for winners and losers separately must account for the differences in play preceding goals. Whilst statistical analysis reveals that most goals (98%) are scored from four touches or less (Bate 1987), it appears that winning teams may differ slightly from the overall trend of goal scoring attacks. Herborn's (1987) research would seem to support the notion that winning teams are more discerning in their use of the 'reacher', and/ or that they are able to position a receiver for the 'reacher' more frequently. Interpreting these findings, or at best surmising why winning teams should have a different pattern of goal scoring from the general model, is difficult. However, it would seem logical that better teams are more efficient at speculating when a suitable opportunity exists for a 'reacher', or long ball, as opposed to playing the long ball regardless of opportunities for scoring or maintaining possession. In those situations where the long ball is perceived as 'risky' the alternative would be to maintain possession through build-up play, which might account for winners' successes.

It may be true that winning teams play to different patterns from the general, winner-loser combined pattern, however further research is required in this area of modelling, since the latter studies used smaller sample sizes than the original work of Reep & Benjamin (1968), Hughes C (1984) and Bate (1987).

Enduring performance patterns have been detected by sports academics in a number of other sports, notably; rugby union (Lyons 1988), rugby league (Larder 1988), hockey (Hughes M & Billingham 1986; Wilson 1987; McNamara 1989), karate (Genery & Alderson 1985), lacrosse (Brackenridge & Alderson 1983), netball (Potter 1985) and squash (Sanderson 1982; Hughes M 1984; MacKinnon 1985).

The interpretation of playing models

The information gained in these studies have all offered pictures of performance tendencies, but how the information is used for future preparation of teams is ultimately down to the coach and his/her subjective interpretation of both model and player/ team 'needs'. The supposition is that if the coach is able to identify performance parameters which are reliably associated with success they will be better placed to evaluate future performances and prepare teams in training. Coaching can then be directed towards technical and tactical events which offer an attractive rate (probability) of success.

An interpretation of the early modelling work conducted in football might result in coaches heedlessly subscribing to long-ball tactics from possession gained in defending and mid field areas. However, in light of Hughes' et al (1987) findings of goal scoring, he concluded that for coaches to suggest that teams in the main aim to restrict their possession to 3 passes

or less would be a simplistic approach to winning! In a recent newspaper article reporting the football analysis conducted by George Wilkinson it was argued that "the correct application of the long-ball theory will inevitably bring success" (The Times 1989). Leeds United's successful use of the 'reacher' against recent opposition, is used as support for this claim. However, Wilkinson's (G) interpretation, of the 'correct application' of the reacher is not defined and no example of its incorrect application is offered. The practical value of the reacher seems to be ambiguous and in need of clarification for coaching purposes.

Through MacKinnon's (1986) efforts involved in searching for tactical trends in squash, he asserts that "manipulation of the data in various ways is essential in attempting to produce a clearer picture of the game." In particular, MacKinnon found that data relating to rally winning shots could be misleading if presented as a percentage of all shots. Specifically, he found that over 16% of all winning shots were straight drives, which he suggested may lead individuals to think that the straight drive is used by players as one of the main attacking shots. However, when analysed further it was found that only 3% of all drives result in winners. The fact that drives comprised the most common shot, elevated its ranking in relation to other winning shots that are simply played less frequently.

In the same way that Hughes's et al (1987) research in football distinguished different goal scoring patterns for winners and losers, MacKinnon also found differences when comparing the data for match-winning and match-losing players. He found that trends for winning and losing shot distributions, in relation to court areas, became more apparent when the data was divided into match winners and match losers. This particular tactical pattern of winning and losing play in squash adds support to current coaching theory. The data showed no statistical difference in fore-court usage by winning and losing players but differences were observed in the number of shots played in the rear court and mid-court area; losers playing more from the rear court and winners more from the mid-court area. MacKinnon draws the conclusion that the difference between winning and losing depends on which player is able to dominate the mid-court area and keep his/ her opponent to the rear. This latter point simply reinforces the basic coaching tenet of getting to the 'T' before an opponent and maintaining dominance of that area.

Performance patterns regarding unforced errors and rally winning shots in relation to hand-in (player serving) and hand-out (player receiving service) conditions were also investigated. Again differences only emerged when the data were divided into match winners and match losers.

In addition to the support that MacKinnon (1986) found for current coaching theory he also exposed data that challenged

certain coaching assumptions and practices. As reported earlier the common belief that service to an opponent's backhand is more effective than to the forehand does not hold true (see page 71); more rally winners come from services to an opponent's forehand and hence questions the coaching wisdom behind this tactic. Furthermore, an attempt to gain more objective evaluation of player performance coaches often use the ratio of shot winners divided by shot errors as an indicator of performance. However, statistical analysis of MacKinnon's data showed no difference in winner/ error ratios between match winners and match losers. This result challenges the value of 'simple' match statistics as an indicator of successful performances especially as a guide to winning performances.

The application of statistical models to coaching practice

Few match analysts have been as bold as Hughes C (1984) in making a detailed series of coaching recommendations based entirely on statistical research findings. Hughes developed a sequence of successive playing criteria that he believes leads teams to ascendency. These comprise six playing recommendations that link together the patterns emerging from his research on goal scoring (see figure 3.2). The model is known as the 'domino theory' and is used by Hughes to both guide coaching sessions and evaluate player performance. Such is Hughes' belief in the model that he maintains the criteria for victory rarely varies whenever a team plays to it.

Figure 3.2 Hughes' playing football model - the Domino theory

1 Get more long forward passes than the opposition

and

2 Make the most entries into the attacking third of the field.

and

3 Obtain the most re-possessions in the attacking third of the field

and

4 Have more shots on goal than the opposition

and

5 Get a higher percentage of shots on target than the opposition

According to Hughes when all five criteria are met the chances of winning are 82% and of not being beaten the chances raise to 91%. If all five criteria are met and 14 or more shots are achieved the chances of winning are estimated to be 94%.

The seemingly logical process by which Hughes arrived at this model, involved the collection and subsequent analysis of vast amounts of soccer match data. The trends that emerged from analysis of the data formed the basis of the model of successful play. As yet no other researcher involved in game modelling has taken steps to develop strategic playing recommendations based on statistical models of performance. However, it has been suggested that the very point and purpose of modelling is that;

a) it be used as a guide against which performances may be evaluated for the purpose of post-game feedback, and

b) it may be used to develop objective coaching plans guiding players/ teams toward sound tactical performances (Brackenridge & Alderson 1985).

Although Hughes's (1984) series of playing recommendations appear to be a logical development from the statistical data he collected, an earlier study by Reep & Benjamin (1968) questions the apparently logical process of data collection leading to model development and in turn to the establishment of playing criteria associated with success. They found that although patterns for goal scoring emerge after the collection of data over a number of games the resultant probability model does not necessarily 'fit' a one-off match. Reep & Benjamin's modelling work on goal scoring in football involved recording the number of passes in a possession preceding a shot on goal. The subsequent analysis charted the frequency of possessions of various lengths and the outcome of these possessions in terms of shot attempts/ goals. It was found that when data from a number of matches was collated certain definable features of performance were distilled; for example, the ratio of shots on goal to goals scored was stabilised to nine shots per goal. However, these features did not necessarily hold true for any individual match whose data contributed to the overall analysis. It is unrealistic to assume that a team managing to get 18 shots

on goal will necessarily score 2 goals in any given match! In support of this finding Wilson's (1987) investigation of goal scoring in women's international hockey established a ratio of 5 shots per goal. However, she found that teams with the highest number of shots on goal did not win the greatest number of games; ie, the ratio of 5:1 fluctuated between games but held steady for the entire data set.

This finding warns against apparently simplistic interpretation of match analysis findings. Reep & Benjamin's findings suggest that variability in performance is dominant at the single game level despite the emergence of models over a number of matches. In addition these findings relate to an 'average' performance ie they do not separate winners from losers. They conclude that chance plays a major role in determining football game outcomes, particularly if competing teams are evenly matched in skill and the score is close. Hence a statistical game model is of questionable utilitarian value to the coach concerned with a specific match and suggests that coaches need to take a longer term view of performance characteristics.

This suggestion raises several questions regarding the use of modelling information for post-match evaluation and the value of developing sophisticated models on which to base future coaching practice.

Problems are most likely to arise when a rigid approach is taken to applying set patterns of play in order to achieve a given model. The variability shown in the single game by Reep & Benjamin is enough to demonstrate that players and coaches must be aware of situations that are appropriate to the application of set patterns. Hence, there is a need for flexibility of interpretation within the proposed model framework and as such coaches should be made aware that demanding certain strategies be adhered to in all instances does not and can not always lead to successful performance. In football, for example, much criticism has been aimed at the long ball strategy based on C Hughes' findings (1984). Allen Wade, ex-director of coaching at the English Football Association, believes that the 'hit and hope' strategy governed by statistical findings will be the death of football (The Times 1989). However, Hughes disassociates his model from the hit and hope notion of the long ball and insists that long balls should be quality passes targeted to the back of defences. According to Calvin (1990), Hughes' model should not encourage 'throwing a lot of mud against the wall in the hope that some will stick'. Persistently pursuing a pre-determined strategy such as the long ball without having players with the skill to perform quality passes is almost pointless. Teams require a more flexible approach so that players who are able to play an accurate long ball can effect the strategy when an opportune opening presents itself. Hence game evaluations should make reference to the number of suitable

opportunities to play a particular strategy rather than the number of times it was played per se.

It seems that the interpretation of statistical results into meaningful coaching/ playing models it not as logically straightforward as first appears. But perhaps more problematic is the inclusion of playing models such as C Hughes (1984) into coaching programmes and match strategies.

Whether based on probability theory or developed empirically through the collection and analysis of match data, game models can be either;

i. simple models based on discrete technical skills such as shooting and passing accuracy and

ii. more sophisticated models based on strategic performances.

Simple technical models

Simple technical models are useful for establishing/ defining efficiency levels at which players/ teams should be operating, or aiming towards. For example, if shooting efficiency data is collected from netball performances at different levels, it should be possible to establish a range of performance norms which players at each level should target. Consequently coaches

would then be able to evaluate performances in light of an established benchmark. Brackenridge and Alderson (1985) assert that it is important for coaches to have an idea of what is expected and accepted in certain playing situations. They suggest that whilst it is inevitable that errors will happen as a result of the natural variability of inter-active games play, it is necessary to have knowledge of what level of error is acceptable. For example, the coach of a junior netball side might expect a higher level of shooting errors (missed shots) than would the coach of a senior or representative side. Quantifying what the acceptable level of performance is should be integral to realistic goal setting and post-match feedback .

By the same token, rewarding and promoting players for good performances also necessitates the use of some form of measure against which such performances can be evaluated. For reasons suggested earlier, it may not be appropriate to base coaching decisions on a player's performance in a single match. Keeping a record of performances over a period of several games may be a more realistic method of comparing a team or individual to established 'norms'.

Simple models based on data involving discrete technical performances are perhaps of more immediate appeal to coaches than are more sophisticated models based on strategic/ tactical performances. Evaluation of a player's technical performance such as shooting, rebounds, throwing accuracy, interceptions and

so on are relatively easy to monitor and interpret through simple pen and paper charting. Benched players/ reserves and assistant coaches can be utilised to chart specific events for certain players. Over 4/5 matches coaches are able to develop player profiles and identify aspects of technical performance that fall inside or outside the established, accepted range of technical skill. On the basis of such team or player profiles, meaningful coaching practices can be developed and future performance targets set

Sophisticated models

More sophisticated models are useful for coaching during the preparation stages of the cycle. Coaches are able to develop patterns of play that shape behaviour towards 'known' winning performance criteria. They are more complex than models based on simple, discrete technical data such as the number and type of errors recorded from possessions. They very often record a sequence of technical events in order to determine tactical features that will distinguish successful from unsuccessful performances. For example, Potter's (1985), junior school netball study recorded the passing progress of an attack from each centre play until it reached the shooting circle or possession was lost. From an analysis of the data Potter was able to search for distinguishing patterns that separated successful from unsuccessful centre passes (see chapter 2 page 52 for detail). The correct practical application of such models

and the methods necessary to evaluate a player's or team's efficiency within the model are often labour intensive and necessitate the use of a computer to record/ analyse match performances (Sanderson 1982, Hughes 1983, MacKinnon 1986, Fuller 1987, Sharp 1984).

In addition, the variability of game performances shown at individual match level seems to suggest that sophisticated game models are perhaps not best utilised for immediate post-game evaluation. The value of these models appears to be in developing a better understanding of how games work and identifying the means of achieving successful performances. The information determined by such models may go on to form the basis of a coaching plan, in turn influencing strategic performances and tactical-decision making.

Over a series of matches, a model can be used to evaluate the consistency with which teams/ players attempt to use coached patterns. However, it is quite possible for a coach to utilise a model and monitor its impact/ effect on performance outcomes by using a simple pen and paper charting system. As compared with the more complex system required to collect and analyse the data necessary for developing the model in the first place. In theory, once a model is established it should be possible to identify the performance features that are important to its application in order for a simple data recording and analysing system be established. In many cases this would be a necessary

requirement for acceptance amongst the coaching fraternity since both time and access to computing equipment, necessary for using a sophisticated model, would be a precluding factor for many.

The current state of game modelling

The objective recording of selected performance parameters has enabled the development of models which describe some "characteristics" of winning and losing in a number of sports (MacKinnon 1985, Hughes et al 1987). Once the appropriate systems have been developed the task of differentiating winning and losing characteristics is a relatively straightforward one.

Coaches have been slow to experiment with match analysis techniques, focusing more at the level of technical player analysis than at the tactical game level. In the limited number of sports where models have been developed (see Hughes C 1984, Reep & Benjamin 1968, MacKinnon 1985) it would appear that coaches have been slow to apply the findings which in many cases have often been simplified when put into practice.

According to Alderson (1990) the contribution of game models to both coaching and developing theories of how games work is in its infancy. The existing match analysis literature, supported by the findings of this investigation, demonstrates that models of game play are capable of providing coaches with performance

criteria associated with success and bench-marks against which some assessment of their own player's performances can be made.

Summary

* The 'open' and interactive nature of games characterises their variable and complex performance patterns. The players involved in such games are involved in constant decision-making regarding their next course of action.

* Within the 'open' environment players are influenced in their decision-making by a goal directed structure which is both prescriptive and restrictive.

* Within this pre-defined structure coaches will try to guide players to more successful performances which is presumably related to 'good' decision-making. It is almost inevitable that many coaches have a view of the game and the playing methods that help to achieve success. In many cases coaches may in fact have a model of performance that they will try to get their teams to work towards.

* Traditionally, these self-defined 'models' have been highly subjective in nature.

* As a result of this players are coached to attend certain performance features and ignore others; they are 'trained'

to respond to the areas of play that the coach deems as important with specific actions.

* In the current sports environment where greater expectations are placed on teams and coaches alike there is a need to extend and the information currently available to coaches and to increase objectivity of certain coaching hypothesis based on subjective feelings.

* Patterns have been detected in soccer (Reep & Benjamin 1968, Hughes C 1984), squash (MacKinnon 1986), netball (Potter 1985).

* The collection of sufficiently large amounts of data regarding player actions in certain game situations will almost certainly reveal consistent patterns or play associated with successful performances.

* "Models" or methods of play adopted by coaches should be empirically tested and appropriately refined. In the past researchers, in conjunction with coaches, have tended to define certain performance parameters and investigate.

* The information from these studies can give pictures of performance tendencies, BUT how the information is used for future preparation of teams is ultimately down to the coach

and his/her subjective interpretation of both model and player/ team 'needs'.

* Based on the findings of his soccer research Hughes C (1984) has put forward a series of playing criteria that teams should employ in quest for success, such is his confidence in the established model.

* These 'playing criteria' developed by Hughes, are patterns of play that he linked together to try and achieve a successful model of goal scoring.

* The earlier study of soccer by Reep & Benjamin (1968) has questioned the apparently logical process of data collection, pattern investigation and subsequent coaching model. They found that although patterns for goal scoring emerged after the collation of data from a number of games the resultant probability model does not necessarily 'fit' a one-off match.

* Hence this finding challenges the apparently simplistic interpretation of analysis.

* These findings suggest that variability in performance is dominant at the single game level despite the emergence of models over a number matches.

* This raises several questions regarding the use of such information for coaching and the value of developing sophisticated models on which to base future coaching practice.

* Danger arises when a rigid approach is taken to applying set patterns of play in order to achieve a given model. The variability shown in the single game is enough to demonstrate that players and coaches must be aware of situations appropriate to the application of set models.

* Coaches should be aware of stifling flare and creativity by demanding set patterns be adhered to in all instances. A model that demonstrates 9 shots precede each goal does not necessarily mean that 9 shots will result in a goal.

* Two types of models appear to develop from the literature: Simple models based on discrete technical skills such as shooting and passing accuracy and more sophisticated models based on tactical performances.

* Simple technical models are useful for establishing/ defining efficiency levels at which players/ teams should be operating.

* They may be of immediate use to the coach for post-game evaluation on efficiency criteria.

* More sophisticated models have come from two sources of enquiry, sports academics and statisticians. Both have tackled the problem in different ways using different methods of analysis.

* Their models tend to be of value to coaches in their longer-term plans for performance development.

CHAPTER 4

METHODOLOGY

The review of literature covered in chapters 2 and 3 has identified two distinct functions of match analysis, namely game modelling and the production of relevant match information for coaching purposes. The former function is particularly useful when attempting to discover more about the structure of a game and its specific technical and strategic parameters. The latter function has an applied value and attempts to produce specific information about certain events/ behaviour within the game. It would seem logical that the latter (more applied) match analysis should derive from the former. However, Alderson (1985) suggests that in their enthusiasm for results, coaches are more likely to develop and use an applied system based on their current pool of knowledge. In games like netball where little strategic knowledge has been validated, such systems are often influenced by coach bias when it comes to selecting the key match events to be recorded. Coaches have to rely on their personal opinion in choosing game aspects that they consider to be determinants of good performance. Despite this element of subjectivity associated with coaching decisions, notation is undoubtedly capable of supplying more information than is otherwise available using the human eye-brain method of evaluation.

This project attempts simultaneously to fulfil both functions through the development of a computerised match analysis system. A critical assessment of previous efforts at notation and analysis has enabled the assimilation of their considered strengths in the design of the system developed here.

Essentially, match analysis is a method of data collection from live or video taped performances followed by data manipulation. The design of such systems should be governed by the answers to a series of inter-related questions regarding; what information should be collected, how it is to be collected, who is going to do it, how is it to be processed, for whom and for what purpose? Clearly the coach and researcher have quite different requirements of match analysis and the two 'functions' of the this project.

Developing a system to provide relevant match information for research investigations

As outlined in chapter 3, investigations of strategic performances have tended to emerge from two different sources; namely, statisticians and sports academics. The methods of investigation adopted by these researchers have differed to suit their particular enquiries (see pages **75-83** for details). The analysis process used by both involves searching for patterns of play from a series of match recordings so that regular game features can be distilled, as opposed to the discrete technical statistics normally desired by coaches. The essential

differences in the two research approaches were discussed on pages 68-71. However, in arriving at a suitable methodological procedure for the following project it is worth noting important strengths and weaknesses of previous analysis systems.

Essentially, statisticians collate a limited number of discrete performance variables in order to identify stable parameters. In the past researchers have selected to record and analyse such events as passes preceding goals in soccer (Reep & Benjamin 1968) and the effectiveness of serving strategies in tennis (Gale 1971). Due to the limited number of variables of interest to these researchers, the observation and scribing demands of the notator are relatively low. Hence the adoption of simple pen and paper systems have served their purposes adequately. However, the analysis procedures used to identify patterns within the data tend to involve more complex statistical techniques, and as a result, the patterns detected are often of academic interest only and provide little guidance for coaches working in the field.

In contrast, the sports academic tends to collect sequences of game events such as rallies/ possessions to provide post-match data of some immediate value to coaches and build-up a data base of match information to investigate the nature of games. The match events recorded in these systems are often identified by practising coaches as having an important impact on performance. The intention of these dual purpose systems is to identify elements of performance that have implications for how

the game is played at a variety of levels. The sheer volume of data collected from each match necessitates the use of a sophisticated notation and analysis system in order to produce speedy information for coaches and the manipulation of large data sets during the investigation of patterns.

As with the analysis approach adopted by statisticians, dual purpose systems also receive criticism. Firstly, they tend to be restricted to the production of simple descriptive data related to techniques and tactics eg. Barham (1980). This usually results from an attempt to serve the needs of coaches by presenting data for a wide range of performance variables. Eventually it may compromise the development of detailed information concerned with individual tactics and strategies, such as the serve and volley strategy in tennis. Secondly, some sports academics advocate a comprehensive system of analysis whereby as many performance variables as possible should be recorded eg. Franks et al (1985). However, the development of a system to measure 'everything' does not guarantee that subsequent analysis and emerging patterns will have value for the coaching process.

The most recent and important development of analysis procedures, appears to be the separation of data by winning/ successful performances from losing/ unsuccessful performances (see pages 94-95 for details). It appears that winning and losing teams can reveal differentiated playing characteristics.

As compared with those observed in combined winner-loser data. This is an important consideration for the investigation of patterns, since combined winner-loser data may be a spurious amalgam offering irrelevant performance models.

Developing a system to provide suitable coaching information

For practical purposes the coach requires a system which is easy to operate (user-friendly) and capable of presenting game information in a way that facilitates an understanding of a teams' performance. This suggests that the data collected should firstly identify teams and individual players and secondly be related to the events that are related to match outcome, such as gaining and losing possession and scoring goals. Such demands necessitate a restriction in the amount of data collected and the kinds of analysis performed to produce concise information that is easy for coaches to assimilate.

Once coaches have identified the kinds of performance information they would like abstracted from matches, the method used for data collection and manipulation can be conducted in a variety of ways. The cheapest and by far the most widely used notation and analysis technique is that of pen and paper (NCF 1986). This medium has been employed for many years due to its simplicity and is ideally used to collate and tabulate performance events such as technical skills and success rates into frequency tallies. However, the use of pen and paper

systems involves several limitations; firstly, recording match events can be a labour intensive process, Embrey (1978) suggested that it is often necessary for one person to observe play and call out events, and another to record the verbal commentary. This requirement will of course depend on the volume of data to be recorded and the demands of match observation. Additionally, Brackenridge & Alderson (1985) note that with more sophisticated systems recording sequences of events such as rallies or a series of passes in court/ field games, can cause commentators and notators difficulties in keeping up with the run of live match play. They suggest that in such cases the use of a video or audio recording would enable notation to take place at a slower play back pace after the match has taken place. This technique is still time-consuming however, and can provide difficulties for the analyst if the video recording misses events or loses the sight of play.

Secondly, at the end of the notation, the user has a detailed match record, but no analysis of performance, usually the notated form of data has little or no relevance to the coach until it is sorted and collated in a meaningful way. The subsequent analysis procedures can take hours and even days, depending on the amount of data collected and the nature of the analysis required, Sanderson (1983) quantified the analysis time of his squash system as taking 40-50 hours for one match. As a result, the use of pen and paper systems often limits the amount of data to be recorded and the analysis that can be carried out.

Barham's (1980) pen and paper system is limited to recording technical infringements, interceptions and shots on goal. Whilst recording these events involves a simple process of placing a cross in relevant boxes (see figure 2.1 for example), each event is recorded as an independent entity. Consequently there is no reference to the outcome or importance of such events in the course of the game. For example, a penalty given away in the opposition's shooting circle can be crucial if the score line is close with only a few minutes of play remaining, as compared to a penalty given away in the early stages of play or in a game with a disparate score line. Moreover, Brackenridge & Alderson (1985) suggest that "popular statistics" resulting from over-simplistic analysis can be of use to coaches, but more often than not they give an over-simplified picture which can be misleading.

The use of computers for match analysis

The introduction of computers has greatly alleviated some of the problems identified above. Sydow (1974) notes four advantages of computers over manual methods of notation and analysis:

1 The storage of large quantities of information which is quickly accessible.

2 The ability to perform numerous operations in a very short period of time.

3 Consistent accuracy (once effectively programmed) due to the elimination of boredom and fatigue factors inherent in human calculation.

4 Extreme versatility in terms of analysing various components of performance.

Purdy (1974) maintains that the computer can be used to make more analysis with greater sophistication than could be accomplished by hand, therefore making it possible to work with larger volumes of information more efficiently than in the past. Whilst computers can never replace the decision-making of a coach they can provide a means of organising, analysing and displaying information to the best possible advantage to the coach/ player. The success of any such system for coaching purposes will depend to a large extent upon its simplicity of operation, its perceived value to the coach and the ready availability of both hardware and software.

Computerised match analysis generally tends to comprise computer notation and pre-programmed data analysis. In the past such systems have been developed for use in real-time (Hughes 1985), and due to the problems encountered in keeping up with fast action, lapsed-time (Brackenridge 1984, MacKinnon 1985). In some cases systems designed for pen and paper analysis have simply been transferred to a computer for efficiency purposes, the original system being sound in concept and design but labour

intensive to operate (see for example MacKinnon 1985, Hughes 1983, Sharp 1986).

The structure of computerised match analysis systems

The basic structure of computerised match analysis systems have tended to follow a standard design. The systems comprise hardware (physical components) and software (computer programmes written to operate the computer in a specified manner). The hardware consists of a computer, a monitor (screen), specialist keyboard/ standard qwerty keyboard and a printer. The choice of hardware equipment and the design of software have, however, been varied.

Hardware

In the United Kingdom the BBC microcomputer has been commonly adopted by researchers in this field, in higher education. Over ten years ago most institutions of higher education were limited to use the of mainframe computers, in the mid eighties improvements in micro-engineering meant greater availability and access to microcomputers. In the United Kingdom the government supported a computer literacy scheme which subsidised BBC micro computers for schools and other institutes of education. In the mid eighties the availability of these machines were increasing as a 'home' and educational computer due to low cost. The BBC was selected for this match analysis project on five accounts:

i The relatively low cost

ii The availability

iii The relatively large memory capacity which can be expanded (an important feature if large volumes of data are to be stored).

iv The proven suitability for match analysis in a number of sports; eg squash and tennis (Mackinnon 1984 & 1985, Hughes 1983), Lacrosse (Brackenridge 1985) and badminton (Sharp 1986).

v The availability of programmable data input instruments.

The techniques used for data input (notation) have been varied and include; the traditional 'qwerty' keyboard, the concept keyboard, specially constructed keyboards using microswitch keys and graph pads using a light pen. In a review of match analysis systems Brewer (1990) considers the qwerty keyboard as a poor input device on three accounts; firstly the layout of keys has no direct logic for match analysis, secondly the keys are both small and too close together for fast data entry and thirdly, the operator has the burden of remembering which key is assigned to a particular match event to be recorded. The graph pad is an A4 sized board which can be programmed to define 'key' areas. Inputs are registered through the movement of a special 'light pen' over the specified key area. The major criticisms of this devise include the preciseness with which the light pen must be positioned over the key areas in order for a touch to be registered. It was considered by Brewer (1990) that the use of

the key pad would inhibit the recording of live matches and considerably increase the time taken to record information from video recordings.

By far the most common input devise is that of the concept keyboard. This is an A3/ A4 sized board which plugs into the computer and has a 16 x 8 cell matrix marked on its surface. Each cell is touch sensitive and can be defined or left blank as required. Cells can be 'pre-defined' from the normal computer keyboard with the accompanying software. Hence the match analyst can design a 'keyboard' layout to meet specific data input requirements. Commonly, a paper overlay with appropriately labelled and coloured 'key' areas is used on top of the keyboard to simplify learning. The keyboard is especially good in the developmental stages of analysis systems since it can be quite easily re-programmed to improve operation. However, Brewer (1990) comments on the insensitivity of the touch surface which can cause a small number of inputs to be ignored, potentially this could cause problems if a system is to record live match play.

'Specially constructed' keyboards usually evolve from designs that have been shown to be successful when used with the concept keyboard. The specially constructed keyboard has micro switch keys laid out in the same manner as they would have been on the concept key board. The main advantage of micro switches over the

concept keyboard is the positive action of the switches which are not prone to insensitivity.

Software

As yet there are no commercially available software programmes designed for match analysis. In the UK most existing software has been developed in-house at various institutions of higher education. The function of any match analysis system, be it manual or computerised, is to record relevant match events in a systematic manner in order that retrieval and analysis of the data can take place at some later point in time. Match analysis software is thus designed to allow data input, storage of data, various statistical tabulations and analyses, and presentation of the results of the analyses. In a review of eight match analysis software programmes, Brewer (1990) found that they conformed to the same basic operational paradigm which was felt to be representative of the state of the art of analysis systems in the UK. The following seven operational features were common in the design of these systems:

1 Software is loaded into the computer from a 'floppy disc'.
2 Information to assist the operator run the system is displayed on the monitor.
3 From time to time the operator may need to 'drive' the programme by entering codes or simple instructions on

the standard 'qwerty' keyboard in response to prompts displayed on the monitor. These may include the selection of analysis options from a menu of possibilities displayed on screen at the start of the program.

4 Match data is fed into the computer in the required format via a specialist input device.

5 Normally, the match information is displayed on the monitor as it is entered, allowing a visual check for the operator. This feedback is very useful whilst the operator is learning to use the system, but during fast-moving match play the operator may not have time to monitor it.

6 Analysis of the match data may take place continuously as it is fed in, or at the end of periods of play. In either case the results of the analysis can be displayed on the monitor and/ or printed out on paper.

7 In some cases the data is stored on floppy disc so the analysis can be re-run as a later date.

Presentation of match information

According to Alderson (1987), the acceptance of an analysis system is largely dependent upon the perceived value of the information it produces. In the case of coaches, the information upon which value judgements are based is the final presentation of analysis. MacKinnon (1986) notes that the "academic"

collection and storage of data that provides a comprehensive record of each match is not necessarily relevant for the coach. He maintains that to be attractive to the coach the analysis system should provide immediate results that condense the input information and abstract salient features of performance. Hence the nature of the results output must match coach expectations. Generally, the coach is not interested in pages of detailed match report, consisting of statistical significances and obscure graphs. This is classic computer overkill and the objective of making a match more revealing and interesting is lost. The information must be kept to a minimum, showing the specific facts and figures that the coach has requested and in a 'user-friendly' form that requires no further translation for coaching use. Since it is unlikely that all coaches would require the same information from a match, the inclusion of a menu that offers the opportunity to select appropriate analysis from a number of options should be integral to the design of a system.

Development of the notation and analysis systems

There were three main components to this investigation, namely;

i the development of a notation and analysis system,

ii its use to record performance and provide relevant coaching information,

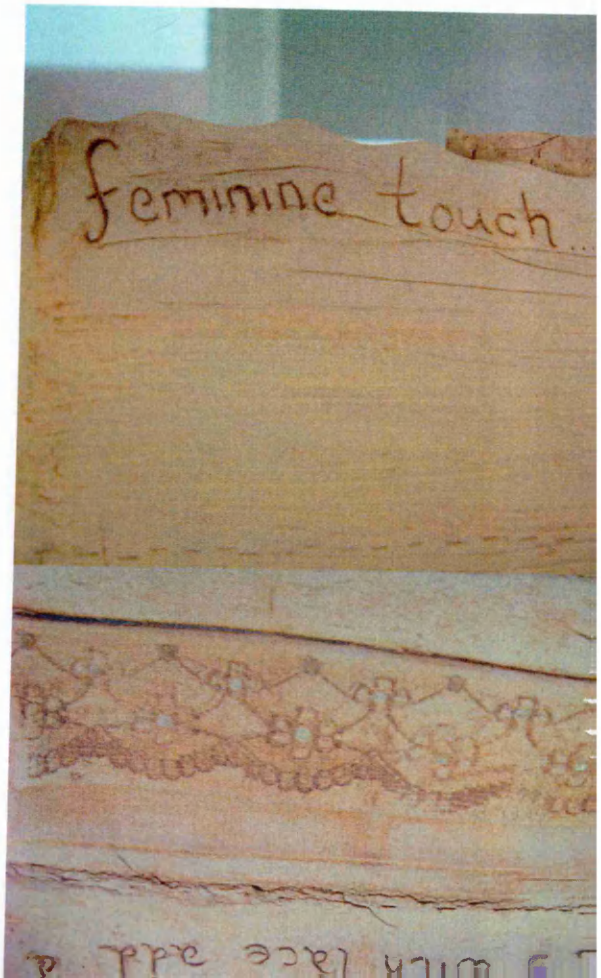
iii the analysis of the data to investigate presence of performance patterns capable of distinguishing winners from losers.

In designing the notation and analysis system, the intention was to develop a pen and paper system which, when operating satisfactorily, could be translated to a computer programme. As with previous dual analysis systems (Brackenridge 1985, MacKinnon 1985, Hughes 1984), it was decided that every possession should be recorded, noting the player and court area involved. At the end of each possession an additional comment was added to identify the reason for the possession end. This notation enables the abstraction of specific match information requested by the national coach (see page 54), in addition to providing information that would enable a more detailed search for performance patterns. Each uninterrupted possession is referred to here as a tactical entity, it is a definable unit of play, beginning with one team gaining possession of the ball and includes the progress of play towards the goal. It is ended with the loss of possession, either through a technical error, dispossession by the opponents or as a result of a goal being scored.

The system notes;

a) how each tactical entity starts,

b) the player involved and the court areas through which the ball travels,


feminine touch...

Martin J (2001) Ergonomics 44
1069 - 1075

" " (2001) JOHS 48/
211 - 225.

Brewer 1990.
Murphy 1995.
Priday 1974.
Potter 1985.

c) the reason for each tactical entity ending,

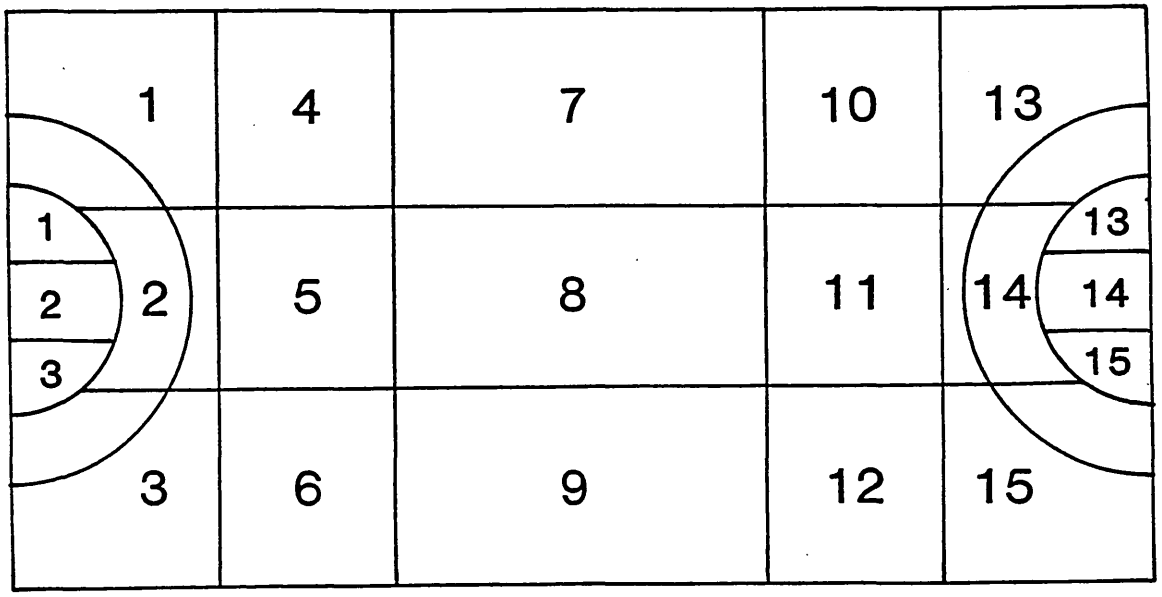
b) an optional comment.

Players

It was necessary to identify each player in possession of the ball so that 'player profiles' could be developed at the end of matches and coaches could correlate individual players with certain match information. In addition, it enables further analysis to investigate differences and possible stereo-typicalities that might exist between playing positions. Each player is identified by their playing position, the notation used is the same as that used on the player' uniform. For example, goal shooter is recorded as GS, goal attack GA and so on.

The court

Figure 4.1



The proposal to record court areas through which a tactical entity travels was largely a result of Potter's (1985) netball study of school girl performance which looked at the channels of attack from centre passes. The study's findings suggested that successful attacks had a strong bias for the wings, hence it was felt that this information might be important in the analysis of performances at senior level. Furthermore, during consultation with the national coach she felt that detail of depth was needed in each of the end thirds of the court, since the specific area from which the ball is fed to the shooting circle is considered to be important to its success.

Thus in this project the court is divided length ways into three channels with five width divisions. The shooting circle is also specified to identify whether the ball is received in a potential scoring position. Further court details distinguish inner and outer areas of the circle, which the coach thought to be important to shooting analysis. Figure 4.1 shows the court divisions. Both teams are recorded as attacking towards area 2, thus if a change of possession occurs in area 5, the new tactical entity will be recorded as starting in area 11 ror the team beginning a fresh attack. This enables the distinction between attacking and defending areas of the court for analysis purposes.

Development of equipment

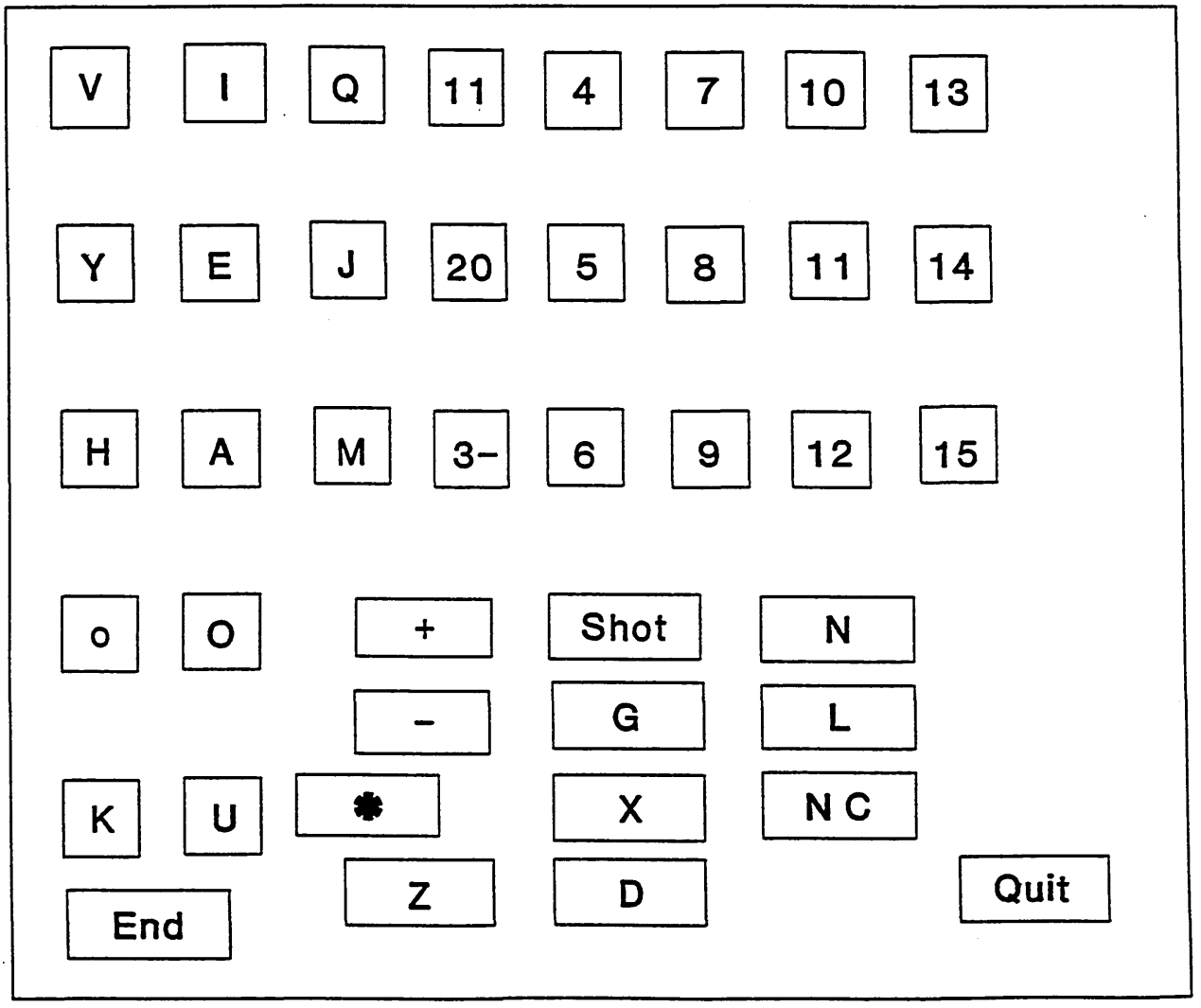
Following satisfactory development of the pen and paper notation

system, a computer program was written to increase the efficiency of recording data and the speed of subsequent analysis. It was hoped that the use of a keyboard would eventually lead to live match notation, with the analyst inputting events in a 'head-up' position thus reducing missed play or misinterpreted actions. This intention demanded that the user adopt skills similar to, but not as sophisticated as that of a touch typist. Hence the development of a user-friendly input system was an essential prerequisite to the system.

The input device initially chosen and used was the concept keyboard(see page 122 for explanation), selected because of its satisfactory use in a number of other computerised match analysis systems (Brackenridge 1985, MacKinnon 1985, Sharp 1986). The major advantage of this equipment was the ease with which the keyboard can be amended during the development stages. Whilst the concept keyboard sufficed as a prototype, the insensitivity of its surface prevented the input of data at speed, ie. live recording. A more reliable input mechanism was found to be a purpose-built keyboard using micro switches laid out in the same configuration as used for the Concept keyboard, this left the operator in no doubt as to whether the input had been accepted by the computer. The keyboard interfaces directly with the BBC microcomputer and circumvents the need for the operator to work with the qwerty keyboard at all. In addition it bears the appropriate notation symbols on its keys and is

protected against irrelevant key presses. Figure 4.2 shows the keyboard layout.

Figure 4.2 Purpose designed keyboard for data recording



CHAPTER 5

The development of a match analysis system for coaching

The primary objective of developing an analysis system for coaches was to aid them in their evaluation of technical and tactical performances.

In netball, break times are usually three minutes, with a maximum of five minutes for half time. These short periods would not be sufficiently long to produce and deliver analysis for coaching purposes. This is perhaps a minor limitation when Brewer's (1990) point is taken into consideration: after discussions with top coaches he maintains that game breaks are used more as motivational periods than for direct technical or tactical coaching. Experience of trying to operate the match analysis system live showed that a high level of 'detached' concentration was required, confirming Barham's (1980) view that it would be impossible for a coach to monitor the run of play in the normal way and to notate for analysis purposes at the same time. It was also found that due to the speed of netball play at international level, the system developed for this study was operated using video recordings of matches rather than live performance.

This system was designed to produce information specific to the stated needs of the national coach and as such produces information deemed suitable for coaches of elite teams, it is acknowledged that the output may not be entirely appropriate for coaches working with teams performing at lower levels.

The value of the system as a coaching aid was assessed during the 1987 World netball tournament where it was used to provide match information for the England netball squad.

Reliability of the notation system was tested to assess the consistency with which the system could be applied by a given user. Having designed the system for objectivity in recording match data it is essential to check that it is used reliably by the operator to 'measure' performance. Potentially, errors could result from four areas of input during the recording of a match;

i. wrong ending to a tactical entity,
ii. wrong court area through which the tactical entity travels,
iii. wrong player identified,
iv. wrong comment.

The reliability test involved recording a match from video via the computerised system and repeating the recording a day later. The two match records were then compared for differences.

The comparison of the two matches is revealed in figure 5.1 below:

Figure 5.1 results of reliability test

Differences	Number	Total number of events	% Difference
Tactical ending differences	4	344	1.2%
Court area differences	25	1528	1.6%
Player differences	2	1528	0.1%
Comment differences	1	344	0.3%

In accordance with normal statistical practice in the behavioural sciences, an error rate of less than 5% was determined as the criterion of acceptability: ie, if the comparison error rate is less than 5 in 100 ($p<0.05$) the incidence of sampling error is significantly low, hence confirming operator reliability.

Table 5.1 shows that four differences were found in the recording of tactical endings; this figure represents less than 2% of the 344 tactical endings recorded. As expected, court areas provided the largest number of errors since all area divisions are not visibly marked on the court surface and hence some subjective judgement has to be made; however, the 25 differences noted represent only 1.6% of the 1,528 court areas recorded. Likewise player and comment differences are less than 1% of the total of the respective recorded events and hence fall within an acceptable error range. These results suggest that the system

can be accepted as a reliable tool for recording match data at the 5% criterion adopted.

Notation

All tactical entities hold information regarding attacking moves, since only 'on the ball' play is recorded. Defensive organisation is not therefore directly recorded, although all attacking play is made in relation to the defending strategy being employed. Hence, if loss of possession analysis shows that a majority of possession is being lost in the centre third of the court it may imply that the opposition are particularly strong at defending in that area.

Areas 1, 2, 3, 13, 14 and 15 are areas in which the shooting circle lay. It was therefore necessary to add a further notation symbol in those areas to indicate whether possession is in the inner regions of the circle (I), outer regions (O) or outside of the circle (-) (see figure 5.2).

Notation symbols

Match events are recorded as single letter symbols for ease of data entry and storage. The symbols used for notating game events are shown in figure 5.2; they are divided into those that start a tactical entity those that end or interrupt the flow of a tactical entity. The symbols that indicate how play ends can

be further supplemented by an explanatory comment if required.

Figure 5.2 Start and end notation symbols

START OF PLAY SYMBOLS:

F - Free pass
T - Throw-in
W - Toss-up won
R - Rebound
P - Penalty pass/shot
p - Penalty Pass
C - Centre pass
L - Loose ball retrieval

END OF PLAY SYMBOLS:

V - Foot fault
H - Held Ball
K - Contact
O - Obstruction
I - Interception
J - Pass too close
A - Tip by opposition
S - Shot
D - Dropped pass
Z - Loose ball retrieved by the team in possession
- - Rebound to defence
Y - Replaying
O - Over a third
U - Toss-up
E - Off-side
Q - Out of court
+ - Rebound to shooters
M - Out of court, throw in by same
G - Goal

Comments

X - Inaccurate pass

_ - Loss of possession

* - Team in possession are fouled

The notation is displayed in a horizontal string of characters (see figure 5.3), with a new string for each new tactical entity. The start of each tactical entity identifies the team in possession, the score and how play started (eg; free pass, interception, throw in, etc). This information is then followed by the area through which the ball travels and the player to possess the ball in that particular court area. The string of entries continues until play is broken or interrupted. At this point the event causing the break or interruption and, if necessary, the area and player responsible, is recorded. Following symbols ending a tactical entity denoting; out of court, interception/ tip and dropped pass it is possible to add a supplementary comment regarding the nature of the error ie whether it was caused by an inaccurate pass or not.

Figure 5.3 shows an example of match notation. At the start of the recording it shows there are four periods of play and that England are team 'A' and Scotland are team 'B'. Scotland have possession (B) and the score is 0-0. Play starts with 'C' (centre pass), in area 8 by 'C' (centre), the centre then makes a pass to the 'GA' who receives the ball in area 9 the string of

characters continue until the 'GS' in area 3 0 (left hand, outer region of the circle) takes a shot (S) and scores a goal.

Figure 5.3 Example of game notation

```
HOW MANY PERIODS?  4

WHICH TEAM HAS FIRST CENTRE PASS A/B  B

ENGLAND (A)  V  SCOTLAND (B)

SCOTLAND TO CENTRE PASS FIRST

     RECORD OF TACTICAL ENTITY
     TEAM POSSESSION B
     SCORE 1  0
     START OF PLAY C
     AREA       8   9   6   3   6   2   3   3
     GOAL AREA                -       0   -   0
     PLAYER     C   GA  WA  GA  WA  GS  WA  GS
     COMMENT                                   S  G

TEAM POSSESSION A
SCORE 0  1
START OF PLAY C
AREA       8   8   5   2       2
GOAL AREA                -       -
PLAYER     C   WA  C   WA      WD
COMMENT                  O     *

TEAM POSSESSION A
SCORE 1  1
START OF PLAY p
AREA       2   3   3
GOAL AREA -    0   I
PLAYER     WA  GA  GS
COMMENT                S  G
```

The score is automatically recorded and the next tactical entity, starts with a centre pass (automatically noted by the computer, since each goal signifies that play must begin with a centre pass). Once again play continues until it reaches the WA

in area 2 - where she is obstructed (0), in the same area by the WD. The '*' notes that play has been interrupted but possession remains with the same team (A). The new tactical entity starts with a 'p' (penalty pass, again this is automatically recorded following an '0' symbol), the pass is taken in area 2 - by the WA who 'feeds' the ball to the GA in area 3 0 who makes a final pass to the GS in area 3 I (inner left region of the circle) where she shoots (S) and scores (G) making the score 1-1.

The software abstracts relevant information from the on-going notation and then manipulates it to produce data for any one of the seven performance areas highlighted by the national coach. (see chapter 2 pages 55-56).

A full match notation consisting of 50-60 pages detailing every tactical entity is generally of little immediate relevance or interest to the coach (see appendix 1).

ANALYSIS

Goals scored

The analysis starts by showing the goals scored for each period of the game and the match score at the end of each period, (see figure 5.4). This identifies the periods of strength/weakness in scoring for both teams throughout the match.

Figure 5.4 shows that England establish a steady scoring rate and manage to maintain that for the first three periods; the last period shows a fall but by this stage they have already established a convincing lead. Scotland by contrast improve through each period, the last being their best as England tail off.

Once equipped with this information a coach is able to look at those periods showing 'peaks' and troughs' in the analysis that follows.

Figure 5.4 Goals Scored

	ENGLAND				SCOTLAND			
PERIOD	1	2	3	4	1	2	3	4
GOALS SCORED EACH PERIOD	17	16	15	10	3	6	7	9
TOTAL GOALS	17	33	48	58	3	9	16	25

Shooting analysis

The shooting analysis contains three separate sources of information relating to the scoring of goals for both teams. The first provides basic technical information for shots attempted and goals scored for each period of the game and for both

Figure 5.5 shooting analysis

SHOOTING ANALYSIS FOR ENGLAND

	GOAL SHOOTER					GOAL ATTACK					TEAM TOTALS				
	1	2	3	4	TOT	1	2	3	4	TOT	1	2	3	4	TOT
SHOTS ATTEMPTED	13	17	11	14	55	6	6	3	5	20	19	23	14	19	75
GOALS SCORED	11	15	7	11	43	3	3	0	2	8	13	18	7	13	51
% SUCCESS	90	92	88	79	78	50	50	0	40	40	68	78	50	68	77
PENALTY SHOTS ATTEMPTED	6	9	4	9	28	2	4	1	2	9	6	11	3	9	29
PENALTY GOALS	5	8	2	7	22	2	2	1	1	6	6	10	2	8	27
% SUCCESS	100	100	66	87	91	100	66	100	50	80	100	90	66	88	89
FREE SHOTS ATTEMPTED	7	8	7	5	27	4	2	2	3	11	11	10	9	8	38
GOALS	5	7	5	4	21	2	1	0	1	4	7	8	5	5	25
% SUCCESS	71	87	71	80	77	0	50	0	33	36	63	80	55	62	65

shooting players (GS & GA). Attempts and goals are then broken down to give details of penalty and non-penalty shots ('free shots'). Rule infringement faults, such as 'footwork' and 'held ball', are recorded if they occur during a shot attempt (see figure 5.5).

The analysis clearly shows that the England GS is the dominant shooter of the two circle players attempting a total of 55 shots as compared to 20 for the GA. Furthermore, the GS has a very high success rate particularly for the first half of the match (92% average). The number of attempts and success rates for Scotland are far below those of England. Their shooters attempt just over half as many as England and the conversion rate for those attempts is 60% as compared to England's 77%. The low number of attempted shots indicates that attacking play is not successful at creating scoring opportunities. Turnover/centre pass analysis will show where and why attacking play was broken down.

The second shooting analysis provides more detailed information regarding the circle position from which attempts and goals are scored. The analysis records shot attempts and goals from the six circle areas; left, centre and right sides and the inner and outer regions of those approach channels (see figure 5.6). From the information shown in the goal area analyses, the England GS shows positional dominance as she is able to attempt the majority of her shots close to the goal post. She is consistent in shooting from the centre inner region which enables an 'easy'

feed from centre court players. The GA by contrast seems to have taken most shot attempts from the outer regions which may account for her low shooting efficiency.

Figure 5.6 Shot analysis by area

GOAL AREA ANALYSIS FOR ENGLAND
****

GOAL SHOOTER

	RI	RO	CI	CO	LI	LO
PERIOD 1						
ATTEMPTS	1	0	15	0	1	0
GOALS	1	0	14	0	1	0
PERIOD 2						
ATTEMPTS	0	0	12	0	0	0
GOALS	0	0	11	0	0	0
PERIOD 3						
ATTEMPTS	1	1	12	0	1	0
GOALS	1	0	10	0	1	0
PERIOD 4						
ATTEMPTS	0	0	10	1	0	0
GOALS	0	0	8	0	0	0

GOAL ATTACK

	RI	RO	CI	CO	LI	LO
PERIOD 1						
ATTEMPTS	0	1	0	0	0	2
GOALS	0	0	0	0	0	1
PERIOD 2						
ATTEMPTS	0	4	1	1	1	1
GOALS	0	0	0	0	0	0
PERIOD 3						
ATTEMPTS	0	0	1	2	0	1
GOALS	0	0	1	2	0	0
PERIOD 4						
ATTEMPTS	0	1	1	1	1	1
GOALS	0	0	1	0	1	0

The final shooting information ignores the inner and outer regions of the circle and gives the statistics for attempts and goals from the left, centre and right sides of the circle (see appendix 2).

Centre pass analysis

The centre pass analysis lists each centre pass, providing information with regard to the player receiving the centre, whether a shot attempt was made before possession was lost and the eventual team to score from each centre (see appendix 3a). The listing enables the identification of patterns or trends that a summary table might not show.

A summary of the listing records the success both teams have in achieving a shooting opportunity from each centre pass with regard to the player receiving the centre (see appendix 3b). Although the player to receive the centre pass may not be responsible for creating/ losing a shooting opportunity, their reception of the first pass may influence the tactical play for the remaining attack. It may also highlight the key player to receive the centre for each team during each period of the game.

Finally all the centre pass information is summarised to show the number of centre passes taken in each period, the number of centres that led to goal opportunities before possession is lost and the number of goals scored from a team's own centre pass.

Figure 5.7 shows England's summarised centre pass information. The number of goals scored from their own centre pass is high (81%). However, their success at creating scoring opportunities directly from centre passes ie.without losing possession is not quite so high. It appears that the team are losing possession before the ball reaches the goal circle from centre plays, although they are able to regain possession and score before the opposition. Reference to loss of possession analysis could inform the coach how the possession was lost at centre pass.

The lack of shooting attempts by Scotland can be partially accounted by their poor success in creating a shooting opportunity from their own centre passes (43%). England's high scoring rate coupled with their success at creating shooting opportunities from their own centre passes, meant that Scotland had little opportunity to regain possession for creating goal attempts. The analysis of lost possession will identify how and where their tactical entities were being broken.

Figure 5.7 Centre pass analysis

TEAM = ENGLAND

Period of play	Number of centre passes	Those leading to shots before a turnover		Number of goals scored from own C.P.	
1	10	8	(80%)	9	(90%)
2	12	9	(75%)	10	(83%)
3	11	8	(72%)	10	(90%)
4	10	3	(30%)	6	(60%)
TOTAL	43	28	(65%)	35	(81%)

TEAM = SCOTLAND

Period of play	Number of centre passes	Those leading to shots before a turnover		Number of goals scored from own C.P.	
1	10	4	(40%)	2	(20%)
2	12	6	(50%)	5	(41%)
3	12	6	(50%)	6	(50%)
4	10	3	(30%)	5	(50%)
TOTAL	44	19	(43%)	18	(40%)

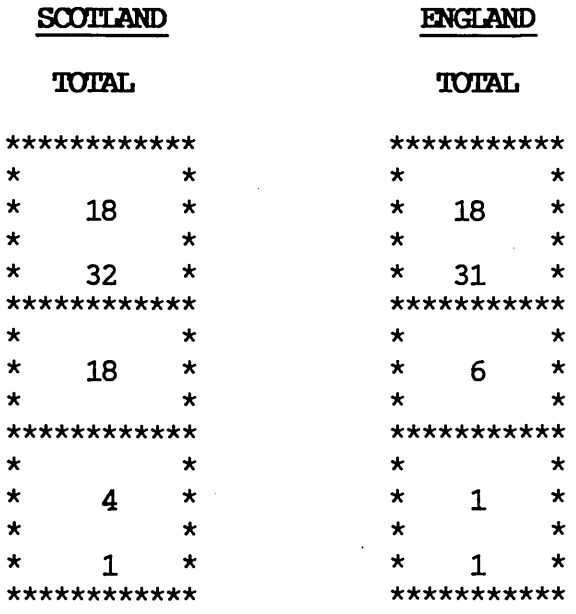
Loss of possession

A chronological list details how, where and who is involved each time possession is lost, how play started at the beginning of each of those tactical entities and whether the opposition score as a result of losing possession (see appendix 4a).

The areas in which turnovers occur are further detailed in diagrammatic form see figure 5.8.

This gives an instant summary of where on court possession is lost, indicating where a team struggled during attacking moves or, where the defence players were particularly strong at regaining possession. Figure 5.8 shows the areas in which possession was lost for both teams over the entire match (see appendix 4b for each period). It is interesting to note that both teams lose equal amounts of possession in the attacking third of

Figure 5.8 Areas of lost possession



the court, but as shown in the earlier analysis England are still creating more shooting attempts. However, it is in the centre third that Scotland differ from England in that they lose almost three times more possession than England.

Player profiles

Player profile analysis supplies positive and negative performance techniques for each player throughout the duration of a match (see figure 5.9).

Figure 5.9 shows that England regained 15 possessions through interceptions (accounting for almost 40% of Scotland's lost possession). As would normally be expected, the three defending players achieve the greatest number of interceptions and tips.

Negative technique analysis consists almost entirely of technical information regarding rule infringements It tables each player's involvement in a loss of possession and totals the team's number of lost possessions under each category. Two further categories have been added to provide information with regard to the number of obstructions and contacts that the circle defence commit during a match. Both of these rule infringements result in the opposition being awarded a penalty shot (which often gives a shooter an opportunity to shoot without being defended). Throughout the entire match England circle defence gave only 15 penalties, although in relation to the number of shot attempts by Scotland this figure shows that in actual fact the defence gave penalties away on 36% of the shots attempted.

Figure 5.9 Player profiles for England

POSITIVE TECHNIQUES

PLAYER PROFILES
Team: ENGLAND

PLAYERS	INTERCEPTIONS	REBOUNDS	TOSS-UP WON	LOOSE BALL RETRIEVAL	TIPS
GS	0	6	0	1	1
GA	0	2	2	2	1
WA	2	0	1	2	1
C	1	0	0	2	1
WD	4	0	1	1	6
GD	3	4	0	1	1
GK	5	4	1	4	8
TOTAL	15	16	5	13	19

NEGATIVE TECHNIQUES

PLAYER PROFILES
Team: ENGLAND

PLAYER	FOOT FLT	RPLY	HLD BALL	OVR 1/3	CNTCT	INAC PASS	DRP PASS	CIRC CNTCT	CIRC OBST
GS	0	0	0	0	1	0	0	1	0
GA	1	0	0	0	1	2	0	0	0
WA	0	0	0	0	0	1	0	0	0
C	0	0	1	0	0	2	0	0	0
WD	0	0	0	0	0	2	0	0	0
GD	0	0	0	0	1	1	0	2	3
GK	0	0	0	0	0	0	0	4	6
TOTAL	1	0	1	0	3	8	0	7	9

Circle feeds

Circle feed analysis provides information regarding the success of passing the ball to a player within the shooting circle from an area outside the circle. The analysis shows the success rates for each player 'feeding' the ball from nine different court areas. Figure 5.10 shows the circle feeds for England who show a marginal preference to feed the ball into the shooting circle from the left hand side of the court (areas 3 and 6). The WA and C are the main feeders of the game, both having very high success rates which may be accounted for by the court area from which the 'feed' was made, the majority coming from the circle edge. This supports coaching theory which suggests the circle edge is tactically a good area from which to make a 'feed' since accuracy is likely to be better if the ball spends less time in the air. The longer the ball is in the air, the more time the defence have to make an interception.

Coach acceptability

The system has been tested and developed in conjunction with the national netball squad, tailoring the analysis to the coach's specific needs. National squad training weekends were used to familiarise the head and assistant coach with the information generated by the system and the time taken to produce such information. The squad players were also introduced to the

Figure 5.10 Circle feeds for England

ENGLAND

	AREA										
PLYR	1-	2-	3-	4	5	6	7	8	9	TOTAL	% SUCCESS
GS	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	1/1	100
GA	0/0	0/0	2/2	2/2	1/2	0/0	0/0	0/0	0/0	5/6	83
WA	7/8	10/11	16/16	1/2	2/3	2/2	0/0	0/0	0/0	38/42	90
C	12/12	7/7	5/7	2/2	2/2	2/2	0/0	1/1	0/0	31/33	93
OTHERS	0/0	0/0	0/0	0/0	0/0	0/0	0/1	1/1	0/0	1/2	50
TOTAL	19/20	18/19	23/25	5/6	5/7	4/4	0/1	2/2	0/0	76/84	90

information available from the system in order to monitor personal performance targets. During the 'build-up' period prior to the World Tournament, additions and modifications to the analysis were made so that the system would be of maximum aid to coaching during the tournament fortnight.

The system was used by the England coach throughout the two weeks of the World Tournament. In the tournament situation it was often impossible for the coach to watch opponents performing prior to their meeting England. The system was frequently used to provide performance analysis of opposing teams. This data about opposition performances was highly regarded throughout the period of the tournament. An important aspect of the analysis

was that it often confirmed coaching decisions and subjective views providing supportive backing for judgements.

Limitations

Whenever possession is 'turned-over' the input mechanism provides the facility to add a further comment on the nature of the comment ie. poor technical/ tactical ability or not. However, in some cases it is difficult to make an objective assessment of the game situation and a player may be noted as making a poor decision/ technical move when in fact the turnover was resulted for other reasons.

For example a player may be credited with making an interception when perhaps they received the ball fortuitously, through an ill judged pass of another player. However, when recording such situations a subjective judgement is made which may result in a wrong recording.

Conclusion

Match analysis should provide coaches with a powerful evaluation tool in their task as performance developers. The introduction of a computerised analysis system can further enhance the analytic process since it allows for rapid analysis of a whole range of variables that would otherwise take too long. The major objective of this project is to produce a means through which

coaches can be better informed of a team's performance and which may aid them in coaching, selection and scouting activities. Whilst such a system can never be a replacement for coaching experience and decision-making it could become a useful supplement to their existing expertise.

This system was designed to overcome the problems of objectivity and memory limitations normally encountered by coaches observing netball matches (see chapter 1 pages 18-21). The information generated by the system was used by the head English coach and her assistant throughout the two weeks of the 1987 World netball tournament. Whilst these two coaches undoubtedly had access to more playing information than any other coach at the tournament, they faced difficulties in attempting to interpret the material since they had few bench marks against which to make comparisons. This proved especially difficult in the early stages of the tournament. On reflection, it was also felt that too much information was available after matches. The time span between games was often less than 24 hours hence limiting the amount of information which could be digested by the coaches and the amount which could be included during coaching prior to the next match. Although the coaches had the option of selecting specific analysis ie. centre pass analysis the value of choosing one area over another of the seven available was not known.

Clearly the need to establish 'benchmarks' against which performance data can be compared is important in order that

maximum coaching benefits are gained. When the netball system was used at the World tournament the significance of some match information was not recognised or valued more than perhaps it should have been. These observations simply highlight the necessity of game models that can help to identify those features of play that differentiate winners from losers. The relevance and importance of certain match data will only become clear if a model emerges.

On a more positive note both coaches felt that the information often supported their intuitive thoughts on a particular match and was used to back-up coaching decisions. They felt that having 'hard' evidence of individual player performances made substitutions easier and provided players with personal goal setting throughout the tournament.

The initial aim of this study was to develop a systematic method of recording and analysing match data, this has been achieved with some success. However, it must be noted that the value of this system as a coaching aid is limited until performance 'benchmarks' and more sophisticated models are available to evaluate new match information.

CHAPTER 6

Experiment

Introduction

Chapter 5 demonstrated the value of the computer-based analysis system for generating match information which is not normally available to coaches/ players. The information focused on six areas of performance which the national coach deemed valuable and important to coaching decisions in netball. These six areas were;

i. goal scoring rates across game quarters,
ii. shooting efficiency,
iii. creation of goal opportunities from centre passes,
iv. court areas in which possession is lost,
v. technical profiles for individual players, and
vi the court areas from which the ball is passed into the shooting circle.

The analysis of information generated in these six areas of performance presented volumes of data for potential coaching use. However, the coach faced some problems in attempting to use the data. Firstly, interpretation proved difficult because of the lack of appropriate performance 'benchmarks' against which to assess player/ team results. Secondly, the relative contribution of each performance area to an understanding of

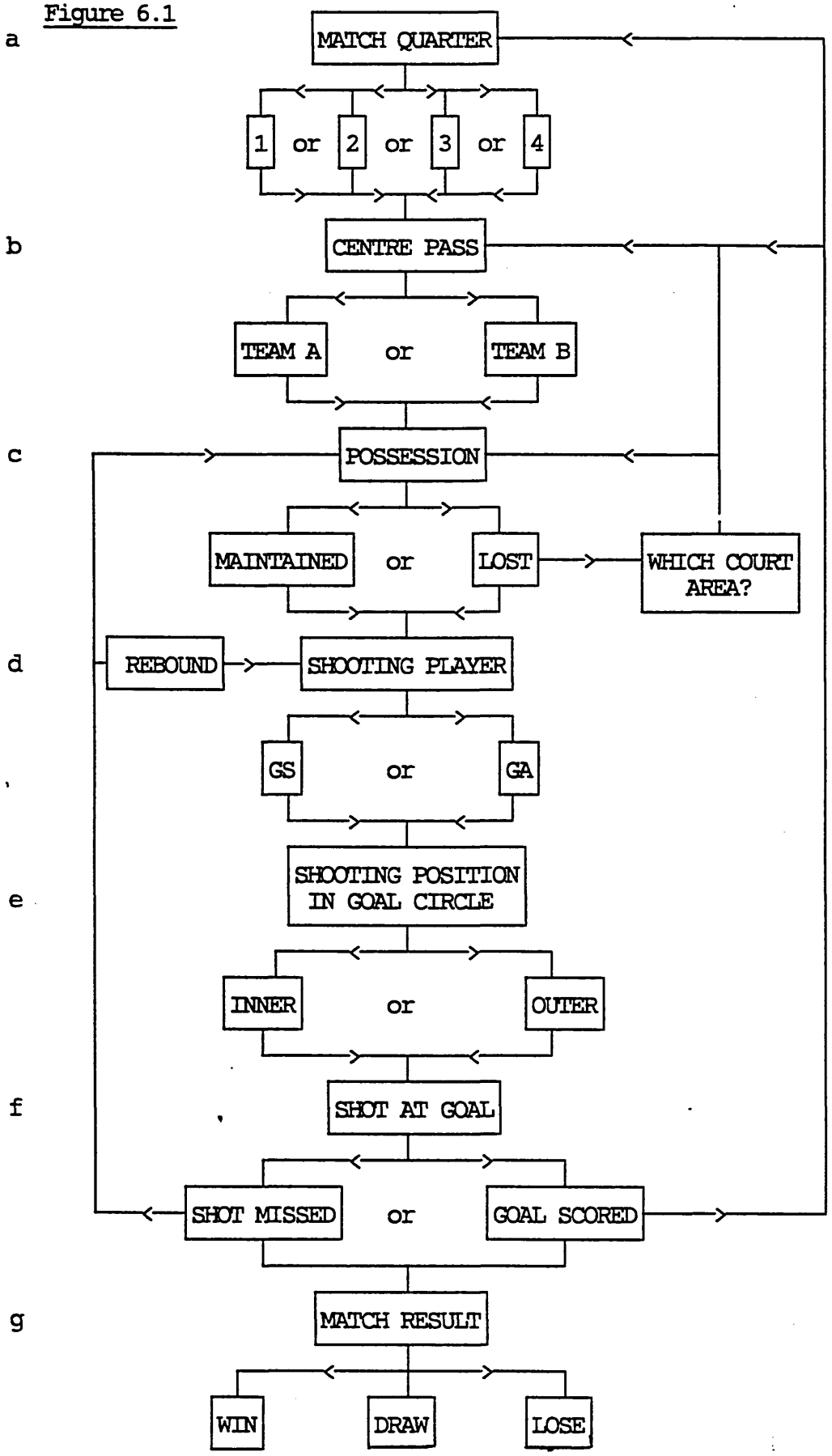
winning and losing was not known. Hence, during the tournament, the coach was not sure which of these aspects of play to analyse, or indeed how to interpret the results once obtained.

The intention of this chapter is therefore to further investigate aspects of netball play in order to try to identify those performance characteristics which differentiate winners from losers (the first four of the six listed above, were selected for this investigation). If such an investigation were to reveal characteristics of performance reliably associated with winning, then these could begin to form a 'model' of play as a basis for coaching and against which a team's performance can be evaluated. The investigation of performance data will aim to establish quantifiable benchmarks for each performance characteristic that will be of value to coaches and players.

Post-tournament discussions with the national coach suggested that a number of the areas of performance analysed at the tournament link together to form a progressive series of events leading towards goal scoring. Figure 6.1 below shows the 'flow' of play, identifying a succession of performance parameters (points a-g), in the approach to goal. The 'values' which each of these performance parameters may take are identified below:

a. In any given match, play takes place in one of four game quarters. Game period; first, second, third or fourth.

Figure 6.1


a
MATCH QUARTER
1
or
2
or
3
or
4
b
CENTRE PASS
TEAM A
or
TEAM B
c
POSSESSION
MAINTAINED
or
LOST
WHICH COURT AREA?
d
REBOUND
SHOOTING PLAYER
GS
or
GA
e
SHOOTING POSITION IN GOAL CIRCLE
INNER
or
OUTER
f
SHOT AT GOAL
SHOT MISSED
or
GOAL SCORED
g
MATCH RESULT
WIN
DRAW
LOSE

b. At the start of each game period and after each goal, play commences with a centre pass taken alternately by one of the two teams. Team; **A** or **B**.

c. The team starting with the centre play will try to maintain possession and progress an attack towards goal, although possession may be lost to the opposition at any given point in the attack. Whilst it is inevitable that possession will be lost on some of these attacks, it is important for coaches to have guidelines on acceptable levels of loss. The goal-orientation of netball play would suggest that more possession will take place in the centre and attacking thirds than the defending third, hence it is important to consider where possession is lost on court rather than blanket figures for all possession lost. Court Area; **shooting circle, attacking third, centre third** and **defending third.**

d. Every attack will progress until it reaches one of two players who are able to shoot at goal and who are in a shooting position within the goal circle. Players; **GS** or **GA.**

e. The area from which shots are attempted may be close to the goal post, an **inner area** of the goal circle, or further from the post in the **outer area** of the goal circle. Shooting Area; **inner** or **outer.**

f. For each shot attempted, one of two outcomes are possible; a **goal is scored** and hence the match score-line alters, or the **shot misses** and one of three outcomes may result; i) one of the shooters may rebound the missed shot and attempt to shoot again, ii) the opposition gain possession, counter attack and score, iii) the opposition will gain possession, counter attack but fail to score because they lose possession, miss a shot or the game quarter ends. These possibilities are implicit in the flow diagram (6.1) from sections f. Shot outcome; **goal** or **miss**.

g. At the end of the fourth quarter the number of goals scored will provide the match result and categorise teams into one of three outcomes; **winner, loser** or **drawer**

Play passes through this performance cycle many times in a match. For every attack that is mounted a particular 'route' will be taken through the attacking process shown in figure 6.1. These 'routes' show variation across match quarters, and, in terms of the 'values' occurring for the performance parameters identified in 6b-6f. The intention of the analyses reported here is to investigate performance parameters 6a-6f with reference to the match outcomes identified at 6g, in order that any picture of play characteristics which differentiate winning from losing performance may emerge.

Data base

The investigation of winning and losing performance characteristics in netball required the establishment of a suitable data base. Matches from the 1987 world netball tournament and the 1987 Milo games were notated to provide a data base of 28 matches, all of which were recorded on video tape and then input to the microcomputer using the purpose-designed keyboard. Each match consisted of four periods of fifteen minutes playing time.

In order to investigate the performance characteristics of 'winning' it was first necessary to divide the data according to match result. According to the rules of play, winners and losers are defined as those teams scoring most and least goals respectively, whereas drawers are those teams ending a match with an equal number of goals. However, in each game quarter, it is possible that one team will have one less opportunity to score from their centre pass because time is called before they are able to work the ball to a suitable shooting position. In theory this could occur to the same team across all four game quarters, hence resulting in a loss of four goal opportunities for one of the teams. In order to reduce the 'clouding' effect that this situation could introduce to the winner and loser categories of data, the 'drawn' category was extended to admit games where the score difference was less than 5 goals. Twenty of the matches in the data base fell into a distinct win/ lose

category; the remaining eight fell into this redefined 'drawn' category.

This categorisation of team data into winning, losing and drawing categories forms the major independent variable for the following investigation of the winning characteristics of top level netball play.

Defining the analyses required

The National Coach's requirements, set against the model of play illustrated in figure 6.1, suggested an investigation of winners', drawers' and losers' data under the three main headings of scoring, centre pass play, and loss of possession.

1. Scoring:

Four types of analysis helped to investigate the parameters of goal scoring.

a) skill and chance in match results;
b) patterns of goals across game quarters;
c) technical shooting efficiency;
d) tactical creation of goal opportunities

a) Skill and chance in match results

In theory, competing netball teams have an equal

opportunity to score because of the alternate centre pass rule. Differences in the numbers of goals actually scored by winners and losers tends to be attributed to relative differences in match performance, and hence to underlying skill. However, in their investigation of association football, Reep and Benjamin (1968) demonstrated that goal scoring, and hence winning and losing, was significantly affected by chance/ luck. Hence it may be a false assumption to pre-suppose that any difference in goal distribution, however small, results from the superior skill of the winning team. Although Reep & Benjamin's research focused on football, the idea may have some relevance to netball. Netball, like football, relies on successful passes between players attempting to work the ball to an attacking position where a shot on goal can be attempted.

b) Patterns of goals across game quarters

Since each netball match is divided in to four periods, a question of interest is the consistency of a winning, drawing or losing 'profile' across all game quarters, and the maintenance of scoring rates from match start to match end.

c) & Technical shooting efficiency, and

d) tactical creation of goal opportunities

Goal scoring is largely associated with two separate

concepts. One involves successfully working the ball to a shooter, within the shooting circle, from a centre play or from a regained possession, and is here referred to as a 'created goal opportunity'. The other involves the technical ability of shooters to score goals once a shooting opportunity has been created, and is here termed 'shooting efficiency'. Once the ball has been 'worked' to a shooter in a potential shooting position, the rule structure prevents direct dispossession or interference by other players; hence shooting is seen as a relatively straightforward technical skill.

Of interest to coaches is whether the difference in the number of goals scored is a result of winning teams' tactical ability in creating more scoring opportunities, or their technical skill in converting scoring opportunities into goals more efficiently, or a combination of both.

2. Centre pass play

All netball matches begin with a centre pass, taken by the centre player, in the centre third. The very first possession is decided by the toss of a coin; thereafter, play restarts with a centre pass following each goal and after each game quarter, possession being awarded alternately. This rule ensures that teams, in theory at

least, have an almost equal opportunity to score. Therefore the ability to create a scoring opportunity from possession at centre play is deemed important for success. Likewise, defending at a centre play in order to stop the opposition from scoring is important to winning. Intercepting and scoring from an opponent's centre play has a double advantage since the team who intercept remain in possession for the next centre play and hence have the opportunity to create a two goal change in the score line.

The centre pass analysis therefore investigated the following areas of performance:

a) Creation of goal scoring opportunities direct from own centre plays,
b) Goals scored from own/ opponent's centre plays.

3. Loss of possession by court area

The court was broken into attacking, centre and defending thirds, with two further divisions in the attacking third; this is in keeping with the court divisions used for recording match information (see figure 4.1 page 127). However, the original division of the defending third has been collapsed due to the small frequencies of possession lost in these areas. The analysis conducted during the world tournament showed different, stable patterns for the

distribution of possession loss throughout the court for winners and losers. Winners were tending to lose less possession in the centre third of the court than losers. Hence, a more detailed analysis of winning and losing profiles was considered necessary. In accordance with the findings of Reep & Benjamin (1968) & Hughes (1984) it was expected that the greater the number of passes within an attack, the greater the chance of a team losing possession. The rules of netball prohibit the use of a long ball from the defending third into the attacking third and prevent the centre pass being received in the attacking third. It is therefore implicit that many possessions reaching the attacking third will involve a relatively high number of passes. Hence it is logical to expect a progressive increase in lost possession towards the attacking third, regardless of match outcome.

Of interest to coaches are the 'acceptable' levels of possession lost in each court area, and the comparative vulnerability of possession in different court areas, so that a judgment can be made regarding their own team's performance.

Analysis

1. Analysis of scoring

a) Skill and chance in match results:

The extent to which chance rather than skill might be

responsible for the observed difference in numbers of goals scored by winning and losing teams was investigated using the chi-square test of association.

Null Hypothesis:	The difference in goals scored between winning and losing teams can be attributed to chance.
Alternative Hypothesis:	The difference in goals scored between winning and losing teams can not be attributed to chance and hence can be attributed to differences in skill.

Results

Table 6.1 shows the number of goals scored by winners and losers across the twenty matches analysed.

Table 6.1 Total number of goals scored

	GOALS
WINNERS (n=20)	1082
LOSERS (n=20)	655
TOTAL	1737

The difference in this table is significant; X^2=104.9 degrees of freedom = 1 $p<0.001$ level

A chi-square test of this data produced a significant result at the $p<0.001$ level, indicating that chance is unlikely to be responsible for the observed difference (see appendix 5). This result suggests that, overall, the winning margin of goals observed can be attributed to 'greater' levels of skill. However, it is interesting to ask at which point the distribution of 1737 total goals scored by the two game outcomes would cease to be

statistically significant. Table 6.2 shows how the 1737 goals would be distributed if each game was won by just 4 goals (ie, the widest margin of goal difference that is classed here as a 'draw'), and how the goals would be distributed in a marginal win (ie, a 5 goal win per match).

Table 6.2 Distribution of the total 1737 goals to show difference between 4 and 5 goal win margins per match.

	4 GOAL DIFFERENCE PER MATCH	5 GOAL DIFFERENCE PER MATCH
WINNERS (n=20)	908.5	918.5
LOSERS (N=20)	828.5	818.5
TOTAL	1737	1737
	Not Significant	The difference in this column is significant; $X^2=5.76$, df=1, $p<0.05$

An analysis of data which was manipulated to produce a 4 goal difference, proves non-significant. Chi-square results of the data re-distributed to show a 5 goal difference is significant at the $p<0.05$ level (see appendix 6).

Discussion

This result lends further support to the argument of categorising matches won/ lost by less than 5 goals into a 'drawn' category of match outcomes to reduce 'clouding' the winning and losing data with chance effects. Furthermore, this result produces a benchmark, in a statistical sense, for a 'true' winning margin; a win of five or more goals

confirms that skill and not luck is largely responsible for the result.

b) Patterns of goals across match quarters:

Table 6.3 shows the frequencies of goals scored by winners, drawers and losers across match quarters. Percentage distributions across match quarters for each group are given in brackets.

Table 6.3 Goal distribution across match quarters

Match outcome	1st quarter	2nd quarter	3rd quarter	4th quarter
Win	266 (25%)	285 (26%)	273 (25%)	258 (24%)
Lose	152 (23%)	189 (29%)	154 (24%)	160 (24%)
Draw	177 (23%)	200 (25%)	183 (24%)	216 (28%)
Totals	595 (24%)	674 (27%)	610 (24%)	634 (25%)

There is no analytic evidence in the literature to suggest that there should be any difference in the relative scoring rates across game quarters. The suggestion that fatigue may cause losers' heads to 'go down' later in a match (Crouch 1984) would suggest a relatively low scoring rate for losers later in matches, although the data in Table 6.3 do not appear to support this notion.

Null Hypothesis: There is no difference in the relative distribution of goals scored

across match quarters between winners, drawers and losers.

Alternative Hypothesis: There is a difference in the relative distribution of goals scored across match quarters between winners, drawers and losers.

Results

Chi-square analysis of the win/lose/draw data in table 6.3 (see appendix 7) proved non-significant (X^2=5.90 df=6); ie, there is no difference in the distribution of goals across match quarters for winners, losers and drawers. This result suggests that all three match outcomes have a similar pattern of goal scoring across the four match periods, though the rate of goal scoring across match quarters may not be consistent. This probability was investigated through a chi square analysis on the total number of goals scored in each quarter (bottom row of data in Table 6.3). The result proved to be non-significant, suggesting that teams maintain an even goal-scoring profile across all four game quarters.

Discussion

From the results of the chi-square analysis it seems quite clear that the pattern of distribution for goal scoring remains stable for all match outcomes across the data-base as a whole. Hence the null hypothesis is accepted. However, the trend that has emerged from the cumulative data for

winners and losers, does not necessarily hold 'true' for a given match.

Figure 5.4

	ENGLAND				SCOTLAND			
PERIOD	1	2	3	4	1	2	3	4
GOALS SCORED EACH PERIOD	17	16	15	10	3	6	7	9
TOTAL GOALS	17	33	48	58	3	9	16	25

Figure 5.4 (repeated from page 139) shows the goals scored across game quarters in a match played between England and Scotland. Although England were convincing winners, the pattern of goal scoring differs for the two teams. England's scoring rate steadily decreases, whilst Scotland's increases; in fact, there is only one goal difference in the score of the fourth quarter. By half time, the England team had created a large enough goal difference to maintain their lead with a lower rate of goal scoring and perhaps a less vigorously enforced defence. This result may be more common in games where teams are not closely matched for skill.

c) Technical shooting efficiency

Technical shooting efficiency is here defined as the ratio of goals scored to the number of shots attempted, and is expressed as a percentage. Efficiency data is therefore independent of the number of opportunities a shooter has. Once the ball has been 'worked' to a shooter she can not be directly dispossessed or interfered with: hence, shooting is a relatively straightforward technical skill. Clearly, more skilful (efficient) shooters will contribute to the conversion of shooting opportunities into goals. However, there is no reason to suggest that there should be a difference in shooting efficiency between shooters of winning, drawing and losing teams in this study, since a very high level of skill is expected of all shooters at international level play.

In addition to match outcome, two further independent variables are taken into consideration during the analysis of technical shooting skill. These are:

i. Playing position of shooters. The demands of the two shooting positions (goal shooter and goal attack) differ with respect to their involvement in court play. A goal shooter (GS) is restricted to play in the attacking third of the court while the goal attack (GA) can be involved in the attacking and centre

thirds of the court. The coaching literature suggests that the shooting role of the GA is secondary to that of GS since the former has increased playing demands that involve her in approach play (Crouch 1984). In practice the GS is able to position herself more favourably in the shooting circle, (ie, closer to the post) since she spends more time in the circle and is less involved in the build-up of the attack to the circle.

ii. Distance of player from the shooting ring. Each shot must be attempted from within the shooting circle (which has a radius of 4.9 metres). Shooting from the outer regions of the circle is likely to result in lower efficiency than shooting from the inner regions since any error on release of the ball will be magnified over a longer trajectory. It is therefore reasonable to assume that the position from which a shot is attempted will influence the level of shooting success.

Consideration of these variables leads to the following three sets of hypotheses:

1	Null Hypothesis:	There is no difference in shooting efficiency between winning, losing and drawing teams.
	Alternative Hypothesis:	There is a difference in shooting efficiency between winning, drawing and losing teams.

2	Null Hypothesis:	There is no difference between the two shooting positions in shooting efficiency.
	Alternative Hypothesis:	The GS shows a better rate of shooting efficiency than the GA.
3	Null Hypothesis:	There is no difference in shooting efficiency from the inner and outer areas of the circle.
	Alternative Hypothesis:	Shooting efficiency from the outer circle areas is lower than that of the inner circle areas.

Results

Playing position and shooting efficiency - Columns 1 to 3 of Table 6.4 illustrate the number of goals scored, the number of shots attempted and the percentage shooting efficiency, for GSs and GAs from winning, losing and drawn match outcomes. From an observation of the percentage efficiency rates for GS and GA (column 3, Table 6.4) it is clear that GSs have a better efficiency rate than GAs and that this difference is common to all game outcomes. A chi-square analysis performed on the data in Table 6.4 columns 1 and 2, for all GSs and all GAs confirms that this observation is statistically significant (X^2=12.79 df=1 $p<0.01$), suggesting that, in general, goal shooters are technically more efficient than goal attacks. Three further chi-square tests were used on the data for each of the match outcomes and confirmed that this trend of efficiency is common to all match outcomes ($p<0.01$, see appendix 8).

Furthermore, observation of the gross number of shots attempted by GS and GA suggest that GS is the more dominant shooter of the two players. A chi-square analysis performed on this data confirms that the difference is statistically significantly ($p<0.01$ see appendix 9), this trend is again significant across all game outcomes.

Table 6.4 Shooting efficiency for GS and GA

		GOALS	ATTEMPTS	% EFFICIENCY
ALL	GS	1679	2260	71%
ALL	GA	834	1364	62%
WINNERS	GS	659	881	73%
	GA	423	631	65%
LOSERS	GS	430	636	68%
	GA	225	401	56%
DRAWERS	GS	590	744	79%
	GA	186	333	56%

Circle shooting area and match outcome - The data in Table 6.5 shows the number of goals scored from the inner (I) and outer (O) regions of the goal circle (columns 1 and 2), the number of shots attempted from inner and outer circle areas (columns 3 and 4) and the shooting efficiency rate for inner and outer goal areas (columns 5 and 6).

Analysis of inner and outer shooting areas (table 6.5) show that;

i. As hypothesised, inner areas of the shooting circle are associated with a better shooting efficiency rate

(percentage), for all outcomes. Chi-square analysis confirms a higher number of goals are scored from the inner circle areas for all match outcomes (X^2=159.45 df= 1 p<0.01 see appendix 10).

Table 6.5 Inner and outer circle areas and shooting efficiency by winners, losers and drawers.

	GOALS		ATTEMPTS		% EFFICIENCY	
	I	O	I	O	I	O
ALL	1573	940	1900	1724	83	55
WINNERS	686	396	815	695	84	57
LOSERS	367	288	457	580	80	50
DRAWERS	520	256	628	449	82	57

ii. Observation of the number of shot attempts shows that winners and drawing teams both attempt more shots from the inner regions than from the outer regions. However, the results of chi-square analysis on this data suggests that there is a statistical difference in the distribution of shot attempts across inner and outer circle areas (X^2=4.79 df=1 p<0.05). The data for losers is in contrast to the trend shown by winning and drawing teams, losers attempt more of their shots from the outer regions of the circle rather than the inner regions. This difference in profile is statistically significant when tested against winners and drawers (winners X^2=24.12 df=1 p<0.01, drawers X^2=42.89 df=1 p<0.01). These results merely confirm the obvious, however, what they do provide is some

quantifiable data which will lend itself to the establishment of bench marks for this area of performance.

iii. The data found in table 6.6 show the frequency with which teams displayed shooting efficiency rates; less than 49% (column 1), between 50 and 69% (column 2) and greater than 69% (column 3), from inner and outer regions of the goal circle. The data shown in rows 1-6 are for GS and data in rows 7-12 for GA of winning, losing and drawing match outcomes. Efficiency rates are per game quarter in order to produce a sufficiently large data set for a frequency table. The three rates of efficiency used are <49%, 50 - 69% and >70. These three bands of efficiency result from collapsing an original efficiency table which contained five bands (<40%, 41-50%, 51-60%, 61-70% & >70%). The original frequency table contained several empty cells, hence the matrix was collapsed in order to fill empty cells and enable the use of chi-square computations. Observation of the percentage shooting efficiency for both winning GS and GA show a better technical profile than losers, from both inner and outer regions of the goal circle. In order to conduct a Chi-square analysis of percentage efficiency the data is expressed in a frequency table (see table 6.6). Chi-square analysis of all data in table 6.6

indicates that the differences in rates of efficiency are significant (X^2=251.68, df=22 p<0.01).

Further investigation of the relative strengths of the independent variables causing the difference in Table 6.6 is, unfortunately, statistically impossible. However, during analysis procedures, chi-square figures generated per cell in table 6.6 show those variables that contribute the highest figures to the chi-square total.

Table 6.6 Frequency of shooting efficiency rates for GS and GA in inner and outer circle areas by winners, drawers and losers.

			<49%	50-69%	>69%
GS	WIN	I	2	12	66
		O	30	16	24
	DRAW	I	1	5	59
		O	16	16	66
	LOSE	I	8	16	53
		O	35	21	17
GA	WIN	I	4	20	53
		O	23	36	18
	DRAW	I	10	12	31
		O	30	21	9
	LOSE	I	11	16	30
		O	31	18	12

Although, statistically, this is not a conventional method of investigation, it can give some help in identifying the those variables that differentiate winners from losers most strongly.

The chi-square analysis in appendix 11 shows those cells that generate the highest figures. The variables concerned are discussed below:

Winning goal shooters have a lower than expected frequency for shooting at an efficiency rate of 40% and below in the **inner circle area** and they have a higher than expected frequency of efficiency in the inner circle area for rates of 70% and above.

Drawing goal shooters have a higher than expected frequency of shooting at an efficiency rate of 70% and above in the **inner circle area.**

Losing goal shooters have a higher than expected frequency of shooting at an efficiency rate of 40% and below.

Losing goal attacks have a higher than expected frequency of shooting at an efficiency rate of 40% and below.

Discussion

The results of these analyses confirm that playing position is associated with variation in shooting efficiency; namely, goal shooters are more efficient than goal attacks. However, this result does not appear to be a consequence of technical skill per se, but is related to the circle area from which goals are attempted. The result that shooting efficiency is significantly better when shots are attempted closer to the post (inner regions of the circle) than when taken further away (outer regions of the circle), supports the point made earlier that errors on shot release are magnified over longer trajectories. Herein lies an explanation for the difference in shooting efficiency between goal shooter and goal attack. The

goal shooter is able to position herself so that she attempts more shots from the inner regions of the circle as compared to the goal attack, whose game role tends to force more attempts from the outer circle regions. As suggested earlier, the goal shooter is rarely involved in court play and thus has time to position herself. In addition, it is common for the GS to have the freedom of the circle area to position herself favourably whilst the GA is engaged elsewhere in the centre and goal thirds taking centre passes and being involved in the build up of attacks in the centre and goal thirds. Hence, on entering the circle, she will most likely have to play 'around' the space held by the GS.

Differences in the number of shots attempted by GS and GA might also be expected when the additional court coverage by GA is taken into account. However, better positioning in the circle by GS may also effect the number of shots attempted, since players passing the ball into the circle are likely to pass to the player most favourably positioned in relation to the goal post.

After England's 1991 World Championship result of fourth place, Galsworthy (1991) commented on the different performance roles commonly displayed by English GSs and GAs;

> "GAs follow the pattern of being play makers, feeders and occasional scorers of goals. Our GSs stay in the circle, make occasional excursions outside the circle, but basically score goals."

Galsworthy suggests that this pattern of performance partially accounts for England's fourth place result and is a factor that differentiates England from the top three teams. She implies that the GA for the top three teams is more than an occasional shooter, rather she is as able as the GS to score. The difference in shooting efficiency between winning and losing GSs and GAs observed in this study, lends support to Galsworthy's suggestion. At a descriptive level, the efficiency gap between GS and GA is greater for losers than for winners, however the greatest difference in efficiency appears for 'drawn' matches. Galsworthy goes on to say that the pattern displayed by the English does not present a problem <u>until</u> the GS meets a top class defender, when the GA is suddenly expected to become 'the' goal scorer and an 'accurate' shooter. In other words, it is not until a GS faces difficulties in receiving a pass, in the goal circle, that the spotlight is switched to the GA for accurate shooting efficiency. This suggests that English netball coaching does not take account of this factor and maintains a bias towards GSs as the main goal scorer.

The circle area from which shots are attempted highlight the winner-loser difference in shooting efficiency most profoundly. In terms of goal scoring, the difference between winning and losing seems to lie in a combination of both shooting efficiency and the ability to create goal opportunities. Losers are unable to compensate for fewer goal opportunities with a better shooting efficiency, although they appear nearer to matching

winners in technical skills than in creating goal opportunities. This point alone seems to suggest that, at elite levels of performance, approach play is a more influential factor in deciding game outcomes than is shooting skill per se. Furthermore, in creating shooting opportunities, losers are less able to gain advantageous shooting positions close to the post. Not only were losers worse at creating shooting opportunities, but those that they did create placed their GS and GA in relatively unfavourable shooting positions.

2 Centre plays

After every goal scored and after each game interval, play restarts with a centre pass taken alternately by the two centres throughout a game. Alternately awarded possession at centre passes ensures that, in theory, teams have an equal opportunity to create a scoring opportunity. From the preceding shooting analysis it is clear that winners are better technical shooters and are able to create more shooting opportunities overall than losers. Of interest to coaches is the level of success with which teams are able to 'work' the ball to a shooting position, specifically from their own centre plays.

a) Creation of goal scoring opportunities direct from own centre plays.

In theory, winners and losers could be equally efficient at creating shooting opportunities direct from their own

centre plays; ie, before a turnover of possession. From the preceding shooting analysis we know that winners create more scoring opportunities. Therefore, the success with which losing teams are able to create shooting opportunities direct from their own centre plays is an area worthy of investigation. It may be that the ability to create more goal opportunities per se is a result of poor shooting by losers, which offers winners a chance to take possession, rather than losers' ability to work the ball from their centre play chances.

Null Hypothesis:	There is no difference in the number of goal opportunities created directly from centre plays between winning, losing and drawing teams.
Alternative Hypothesis:	There is a difference in the number of goal opportunities created directly from centre plays between winning, losing drawing teams.

Results:

Table 6.7 Goal opportunities created directly from own centre pass.

	NUMBER OF CENTRE PLAYS TAKEN	NUMBER OF GOAL OPPORTUNITIES ACHIEVED DIRECT FROM CENTRE PLAYS	GOAL OPPS AS A % OF CENTRE P
WINNERS (n=20)	944	545	(58%)
LOSERS (n=20)	946	423	(45%)
DRAWERS (n=16)	826	471	(57%)

Table 6.7 contains data showing the total number of centre passes taken (column 1) and the number of occasions goal opportunities were created directly from these centre plays (column 2). Column 3 gives the percentage of goal opportunities in relation to the number of centre plays taken. The number of centre plays and therefore goal opportunities from centre plays are lower for drawing teams due to the lower number of matches played.

The data in Table 6.7, column 2, show that winners are more able to 'work' the ball to a shooting position directly from their own centre plays than are losers. A chi-square analysis of the data for winners and losers confirms the difference as statistically significant (X^2=10.36, df=1 $p<0.01$, see appendix 12). As a percentage of the number of centre plays taken, drawers show a similar profile to winners, working 57% of their centre plays to a shooting position before possession is lost. There is no statistical significance shown between the profile of winners and drawers (X^2=0.02 NS).

The significant difference between winners and losers, in success rates at creating shooting opportunities from opponents' centre plays suggests that skill rather than chance/luck accounts for success when 'working' the ball to a shooting position. It also suggests that shooting efficiency <u>alone</u> does not account for the winner/ loser

difference: the efficiency to 'work' the ball to a shooting opportunity direct from a centre play situation also influences match outcome.

Although winners and losers can be differentiated by reference to their relative ability to work the ball to a "shooter" directly from centre play, high success rates in this aspect of play may not always lead to a win. This performance characteristic, coupled with high shooting efficiency rates, can be displayed by both teams and result in +/- four goal draw. The data in Table 6.7 demonstrate that in these respects "drawing" teams all display "winning" characteristics.

Discussion

Winning teams are able to 'work' the ball safely to a shooting opportunity from their own centre plays more efficiently than their opponents. When this capacity is combined with a higher rate of shooting efficiency, opposing teams have less opportunity to gain possession, and therefore score, when it is not their own centre play. The lower ability of losers to create shooting opportunities from their own centre plays, combined with a poorer shooting efficiency than winners, greatly reduces their capacity to score. Moreover, for each losers' centre play that does not reach a shooter, winners are likely to capitalise on the opportunity.

b) Goals scored from own/ opponents' centre plays.

It is clear from the previous analysis that winners are more successful at creating shooting opportunities direct from their own centre plays and are more efficient shooters than losers. It appears that winners are able to score more goals from their own centre plays than are losers. It would therefore seem logical to assume that winners are also successful in working the ball to a shooting position from losers' centre plays that do not result in a goal. Therefore, winners are likely to score more goals from losers' centre plays than are losers from winners' centre plays, since losers score goals on less of their centre plays than do winners.

Null Hypothesis:	There will be no difference in the number of goals scored from own and opponents' centre plays between winning, losing and drawing teams.
Alternative Hypothesis:	There will be a difference in the number of goals scored from own and opponents' centre plays between winning, losing and drawing teams.

Results

Table 6.8 contains data showing the number of goals scored from own and opponents' centre plays (column 1 and 3 respectively). The percentage efficiency rate that teams score from their own and opponents' centre plays are shown in columns 2 and 4 respectively. Table 6.8 (columns 1 and 2) shows that winners are more successful goal scorers from

their own centre plays than are losers off their centre plays (70% successful scoring rate for winners as compared to 50% for losers). By implication, winners must therefore score more goals from losing teams' centre plays than losing teams do from winners' centre plays. The descriptive data confirms this, showing that winners score from 45% of losers' centre plays whereas losers are only able to score from 20% of winners' centre plays. A chi-square analysis of the data confirms the hypothesis that the number of goals scored from own and opponents' centre plays is significantly different for winners and losers (data from columns 1 & 3 table 6.8. $X^2=21.38$, df=1 $P<0.01$). Drawing teams show percentage efficiency rates that appear to fall 'between' winners and losers. However, in statistical terms, drawers' data is significantly different from that of losers ($X^2=7.37$, df=1 $P<0.05$) whilst no statistical difference is found between winners and drawers.

Table 6.8 Goals scored and percentage efficiency rate of goals scored from own centre play and from opponents' centre play.

	GOALS FROM OWN CENTRE PLAY	% EFFICIENCY OF GOALS FROM OWN CENTRE PLAYS	GOALS FROM OPPONENT'S CENTRE PLAYS	% EFFICIENCY OF GOALS FROM OPPONENT'S CENTRE PLAYS	NUMBER OF CENTRE PLAYS
WINNERS	660	70%	422	45%	944
LOSERS	471	50%	184	20%	946
DRAWERS	506	61%	270	33%	826

Discussion

A comparison of columns 2 & 4 in Table 6.8 show that winners are more skilful at scoring goals from their own centre plays (70% efficient) than losers are from theirs (50% efficient). In addition winners also show a better rate of scoring from losers' centre plays (45%) than losers do from winners' centre plays (20%). Several explanations could account for winners' more skilful profile: i) Winners are skilful at scoring from their own centre plays and hence there are few opportunities for losers to score from these situations. ii) Winners are better at capitalising on errors made by losers when 'working' the ball to a shooting opportunity from centre plays.

Although no statistical difference is found between winners and drawers regarding the number of goals scored from own and opponents' centre plays, they appear to have closer efficiency profiles for goals scored from own centre plays (70% and 61% respectively), than they have for goals scored from opponents' centre plays (45% and 33% respectively). The greatest difference between winners and drawers and winners and losers appears to lie in the ability to score from opponents' centre plays. By maintaining high scoring rates from own centre plays, teams deny their opponents the opportunity to gain a scoring advantage and therefore reduce the chances of being beaten. However, in order to win, teams must not only score from their own centre plays

but also gain possession and score from their opponents' centre plays. By preventing opponents scoring from their own centre play, for example through an interception or forced error, teams are able to take possession and gain a scoring opportunity. If this opportunity is successfully converted to a goal the same team maintain possession at the next centre, due to the alternate award of centre plays and hence gain a further opportunity to score.

These results highlight the importance of;

a) maintaining possession from own centre play: ie, playing 'safe' possession, rather than building exciting, but risky attacks. Galsworthy (1991) comments on England's attacking play at the 1991 World netball tournament. Their attacking skills, she claims were, "exciting and visual", but were noted to break down under pressure. The passing was of an aerial nature and required great accuracy for success. As a result, the higher ball offered too many interception opportunities and the passing accuracy deteriorated during the demands of an hour's match. Hence, England produced entertaining performances but not necessarily winning performances.

b) Developing an effective strategy to break down the play from an opponents' centre start also appears to

be an important contributor to winning netball performances. Since the centre pass is a set play situation, it offers defences the time to apply pre-prepared, well-rehearsed, defending tactics.

3. Area of lost possession

It is clear from the analysis in the previous section that losing teams are less skilful than winners at 'working' the ball to a shooting opportunity; by implication, their lack of skill causes them to lose possession to winning teams, who capitalise on such opportunities by scoring. The following investigation was designed to analyse where on court possession was lost by winning, losing and drawing teams. This included possession lost from all attacking play, not just play from centre passes.

Reep & Benjamin's (1968) results on football possession, showed that as an attack proceeds the chances of losing possession will increase. The researchers suggested that the longer a possession continues the better the defending opponents are able to progressively dispose themselves into a defensive organisation that will improve the chance of an interception or forced error. There is no reason to assume that the same principle should not apply to netball; ie, the probability of possession being lost will increase with the number of passes made. Presumably, teams that are less

skilful are likely to lose possession relatively early in the progress of an attack, whereas more skilful teams are likely to progress possession further. Since the aim of attacking is to move the ball to a shooting position (in the goal circle), it is assumed that as an attack develops it will move toward the attacking goal circle.

It was therefore of interest to investigate whether winning teams penetrate further toward their goal area than losing and drawing teams. The court position where possession was lost was used to identify the progress made by an attack.

Null Hypothesis: There is no difference in the pattern of lost possession across court areas for winning losing and drawing teams.

Alternate Hypothesis: There is a difference in the pattern of lost possession across court areas for winning, losing and drawing teams.

Results

Table 6.9 shows the figures for possession lost in each third of the court, (including possession lost via missed shot attempts), by match outcome.

Goal end of attacking third	Rear half of attacking third	Centre third	Defending third

Table 6.9 Breakdown of possession by court area for winning, losing and drawing teams.

AREA	WINNERS (n=20)		LOSERS (n=20)		DRAWERS (n=16)		TOTALS	
GOAL END OF ATTACKING THIRD	482	(34%)	455	(27%)	265	(31%)	1201	(31%)
		80%		70%		75%		75%
REAR HALF ATTACKING THIRD	664	(46%)	701	(43%)	373	(44%)	1738	(44%)
CENTRE THIRD	206	(14%)	330	(21%)	155	(18%)	691	(18%)
		20%		30%		25%		25%
DEFENDING THIRD	85	(6%)	144	(9%)	53	(7%)	282	(7%)
TOTALS	1437	(100%)	1630	(100%)	846	(100%)	3912	
NUMBER OF POSSESSIONS LOST PER MATCH	72		81.5		53			

Since the three outcomes have a different number of matches the percentage of possession lost in each area is also given. The defending third shows the least amount of possession lost for all match outcomes. An increase in the loss of possession continues through to the attacking third, which shows the highest losses for all three outcomes. However, the goal end of this third shows slightly lower figures than the rear half (although the difference is not statistically significant.

Despite the similar pattern of lost possession across all 3 match outcomes, chi-square analysis of the data in figure 6.9 suggests that there are significant differences in this distribution pattern ($p>0.01$ $X^2=35.52$ $df=6$, see

appendix 13). To investigate the source of this difference a chi-square analysis of winning and drawing data suggest no significant difference; ie, they appear to lose possession in similar ratios throughout the court (see appendix 14). Significant differences are found between winners and losers ($p>0.01$ $X^2=33.66$ $df=3$), and drawers and losers ($p>0.05$ $X^2=8.05$ $df=3$ see appendix 15). The pattern that emerges shows winners and drawers lose less possession in the defending and centre thirds of the court but more possession than losers in the attacking third (particularly the rear half of the attacking third). Of the possession lost, winners are losing 80% in the attacking third and 20% in the rest of the court (centre and defending thirds), whereas losing teams lose 30% in the centre and defending thirds and 70% in the attacking third.

The percentage of possession lost for drawing teams (Column 6) is between that of winners and losers. The final row of data in Table 6.9 shows the mean number of possessions lost per match. Drawing teams lose less possession per hour's match than winners or losers (53 per match as compared to 72 per match for winners and 81.5 per match for losers).

Discussion

It was expected that more possession would be lost as

attacks progressed toward the goal area, however the results seem to suggest that most possession is lost in the first part of the attacking third and not the goal end. This may be for several reasons;

i. less possession will actually reach this third, since a high percentage is lost before it gets there, (ie, there appears to be a law of diminishing returns in operation);

ii. fewer passes will take place in the goal end third because it is largely made up of circle area in which more shots as opposed to passes are likely to be taken.

There appears to be a straight trend in the percentage of possession lost by winners, losers and drawers. For the attacking areas (defined as a combination of goal end and rear end of this third), winners lose the greatest percentage of possession in this area (80%) followed by drawers (75%) and then losers (70%). This trend is reversed in the defending third; ie, winners lose less of their possession in the defending and centre third (20%), followed by drawers (25%) and losers (30%). This pattern may be a result of skill in attacking play; ie, winners progress more of their possession to the attacking third of the court and therefore have a greater amount of possession to lose in that area compared to losing teams.

The first half of the attacking third appears to be the most vulnerable court area for losing possession and not the goal end as previously thought. Hence, it may be valuable for coaches to alert their players to the importance of 'safe' attacking play when entering the attacking third in order to increase the chances of keeping possession and getting the ball to a shooting player.

Summary

In terms of goal scoring, the difference between winning and losing seems to lie in a combination of both shooting efficiency and the ability to create goal opportunities. Losers are unable to compensate for fewer goal opportunities with a better shooting efficiency, although at this level of play, they appear nearer to matching winners in technical shooting skills than in creating goal opportunities. This point alone seems to suggest that, at elite levels of performance, approach play is a more influential factor in deciding winners than is shooting skill per se. Furthermore, in creating shooting opportunities, losers are less able to gain advantageous shooting positions close to the post. Not only were losers comparatively poor at creating shooting opportunities, a greater proportion of those that they did create placed their GS and GA in unfavourable shooting positions ie, outer regions of the circle.

With regard to the the start of play following each goal, the data suggested that teams which maintain a high scoring rate

from own centre plays prevent opponents from gaining a scoring advantage and therefore reduce the chances of being beaten. However, in order to win, teams must not only score from their own centre plays but gain possession from their opponents' centre plays. By stopping opponents from scoring off their centre plays, teams have the potential to gain a two goal difference in score due to the alternate award of centre plays.

From the seven performance criteria analysed and reported above, it is possible to summarise the main characteristics associated with international netball performances as follows:

i. The differences in goal distribution between winners and losers is so highly significant as to be associated with skill not chance.

ii. The point at which the goal difference between winning and losing is no longer significant is 4 goals. Hence a 'true' win is one of 5 goals or more.

iii. Goal scoring across match quarters is consistent for all match outcomes, although differences may be observed at individual game level.

iv. Although shooting is a relatively straightforward, 'closed' technique, significant differences are observed in the

levels of success across match outcomes and playing position:

	GS	GA	Percentage success
WIN	73%	65%	rate of shooters.
LOSE	68%	56%	
DRAW	79%	56%	

v. A greater number of goals are scored from the inner circle areas for all match outcomes:

WIN 63% OF ALL GOALS ARE SCORED FROM INNER AREA

LOSE 56% OF ALL GOALS ARE SCORED FROM INNER AREA

DRAW 67% OF ALL GOALS ARE SCORED FROM INNER AREA

However, only winners and drawers attempt more than 50% of their shots from the inner circle area:

WIN 54% OF ALL SHOTS ATTEMPTED FROM INNER AREA

LOSE 44% OF ALL SHOTS ATTEMPTED FROM INNER AREA

DRAW 58% OF ALL SHOTS ATTEMPTED FROM INNER AREA

vi. Creating goal opportunities and scoring from own centre plays can, theoretically, prevent a team from losing in netball. There are some observable difference in the success rates of these performance criteria:

WINNERS CREATE GOAL OPPORTUNITIES DIRECT FROM 58% OF THEIR OWN CENTRE PLAYS

LOSERS CREATE GOAL OPPORTUNITIES DIRECT FROM 45% OF THEIR OWN CENTRE PLAYS

DRAWERS CREATE GOAL OPPORTUNITIES DIRECT FROM 57% OF THEIR OWN CENTRE PLAYS

WINNERS SCORE 70% OF GOALS FROM THEIR OWN CENTRE PLAYS

LOSERS SCORE 50% OF GOALS FROM THEIR OWN CENTRE PLAYS

DRAWERS SCORE 61% OF GOALS FROM THEIR OWN CENTRE PLAYS

vii. Losers lose more possession per match than do winners:

AVERAGE NUMBER OF POSSESSIONS LOST OVER A 1 HOUR MATCH:

WIN	72
LOSE	82
DRAW	53

It appears that possession is lost in different proportions across the court for the three match outcomes:

	ATTACKING THIRD	CENTRE & DEFENDING THIRDS
WIN	80%	20%
LOSE	70%	30%
DRAW	75%	25%

From these results it has been possible to detect patterns of netball performance that are statistically significant in differentiating winning from losing netball performances. The differences observed cover both technical and tactical aspects of performance and should help to establish a model which can be used by coaches to monitor and regulate their teams' performances at international level play.

Research Critique

1. Data Collection Hardware

The BBC microcomputer coupled to the purpose-built keyboard proved to be a satisfactory device for the collection of data for the original purposes of supplying coaches with match analysis data during a tournament and for establishing a database for further academic analysis. However, the small memory of that machine meant that the scale of work attempted here was at the limit of the system's capability.

In the intervening period, microcomputers have increased greatly in both memory and processing capacity, and would hence be more suitable for further research of this type.

2. Statistical Analysis

The majority of the statistical analyses reported in this thesis used the Chi Square statistic of association. The data was appropriate for Chi Square in that it consisted of simple frequency counts of nominal level data. However, the Chi Square test does require independence in the derivation of data and that condition was not met since the separate sub-sets of winners' and losers' data were derived from the same set of matches and the drawers sub-set was composed of mutual opponents. What is more, the whole data set was sub-divided repeatedly in order to isolate specific variables, whereas, in strict statistical terms, the matrix should have been analysed as a single, complex entity.

An attempt was made to circumvent these problems by re-casting the data as a multi-dimensional matrix for analysis by a complex ANOVA technique. The subsequent analysis proved to be of no use, since variables interacted to such an extent that the statistician guiding the exercise commented that the ANOVA lent no more clarity to the analysis than did the original Chi Square results. It is clear that the inferential techniques currently available were not developed to deal with situations like interactive sport performance, and that currently, there is no adequate statistical technique for analysing nominal

level match derived data within the rules of the 'inferential statistical' game!

It is perhaps worth noting that by far the majority of the Chi Square results in the analysis sections were significant at the 0.01 level or better, suggesting that the differences observed may well have been reliable, despite the short-comings of the data.

3. Future Developments.

Given the problems about independence of data, it would be appropriate for an investigation to be conducted which produced a very large data set, thus enabling sufficiently large subsets of mutually exclusive winners', losers' and drawers' data to be extracted for analysis by the available nominal level techniques. The recent developments in microcomputer sophistication would allow the preliminary organisation, if not the whole analysis, to be performed directly as an outcome of the original match notation and analysis process.

The results of this study have concentrated on 'modelling' netball performances in four areas namely;

i. goal scoring
ii. shooting efficiency
iii. creation of goal opportunities from centre plays
iv. court areas in which possession is lost.

Further research that involves the development of benchmarks for;

i. technical player profiles and

ii. circle feeding areas

may be useful additions to the model developed here. These two areas of performance were deemed as important for coaching decisions by the national coach, although due to the sophisticated level of computer programming they were not analysed for benchmarking purposes here.

During the analysis of centre pass play and loss of possession it became apparent that further information relating to the termination of possession would have been useful. Hence an analysis of reasons for possession breakdown and an investigation of the number of passes preceding loss of possession may help to enhance the understanding of this aspect of netball.

The model developed here refers solely to play at international standard. Further research of a similar nature to this study, may be useful to investigate the existence of benchmarks at lower levels of netball performance.

CHAPTER 7

The model of winning netball performances at International level.

Introduction

The analysis reported in Chapter 6 produced a statistical benchmark for a 'true' winning margin for a 60 minute international netball match. A win of four goals or less was statistically non-significant, suggesting such results may be largely affected by chance. Conversely, a win of five goals or more appeared progressively to confirm that differences in the skill levels of the two teams and not luck was largely responsible for the result. Hence, the characteristics of winning netball described here refer to matches won by more than four goals. The performance of winning teams is closely associated with the actions of opposing losing teams and likewise losers lose, at least in part, because they are playing 'winning' teams. 'Drawing' teams appear to show characteristics closer to winners than to losers on most of the performance characteristics measured here. This effect may occur because two teams of a similar standard both perform essentially with 'winning' characteristics.

A common sense approach has been taken to provide the following set of performance indicators that together describe winning performances. Each of the benchmarks represent a target for

which teams/ coaches can aim and against which performances may be monitored. However, it should be noted that each benchmark has been generated by analysing winning performances over a series of matches, and as such, is subject to variability from match to match. Hence achievement of any given benchmark in any one match does not necessarily guarantee a winning result. In part, this reflects the not insignificant role that chance plays in determining game outcomes and highlights the importance of assessing a team's performance over a series of matches. The view of coaching as an ongoing cyclic process (see chapter 1 page 7), is reinforced by this suggestion, as is the need for managing performance information through the use of match analysis to accumulate data over a number of matches.

The characteristics of winning

In the process of attempting to develop a netball model, selected characteristics of winning and losing have been identified as a start point:

Technical skills

* Winning GSs are more efficient shooters than losing GSs.

* Winning GAs are more efficient shooters than losing GAs.

* There is less difference in efficiency between winning GSs and GAs than between losing GSs and GAs.

* Winning shooters (GS and GA) have more shot attempts on goal than losing shooters.

* Winning GSs attempt more shots from the inner area of the goal circle than do losing GSs.

* Winning GSs attempt a lower proportion of their shots from the outer area of the goal circle than do losing GSs.

* Winning teams have a higher success rate in 'working' the ball to a shooter from their own centre plays than do losing teams.

* Winning teams score from a higher percentage of losers centre plays than do losers from winners' centre plays.

* winning teams lose less of their possession in the centre and defending thirds of the court than do losing teams. Hence, winning teams progress more of their possession to the attacking third of the court than do losers.

In order to be of value to coaches and players it is necessary to quantify the differences between winning, drawing and losing so that performance targets can be identified. The benchmark figures are mean results taken from the data base of winning

performances. These figures represent the central tendency of the distributions of characteristics of winning performances. These are offered as suggested targets which teams should aim to achieve or better, since they represent 'average' winning performances. In addition, the model includes the mean result of each performance characteristic from the data base of losing performances. The 'average' figures for losers represent a base line or performance threshold which teams should aim to better.

The benchmarks:

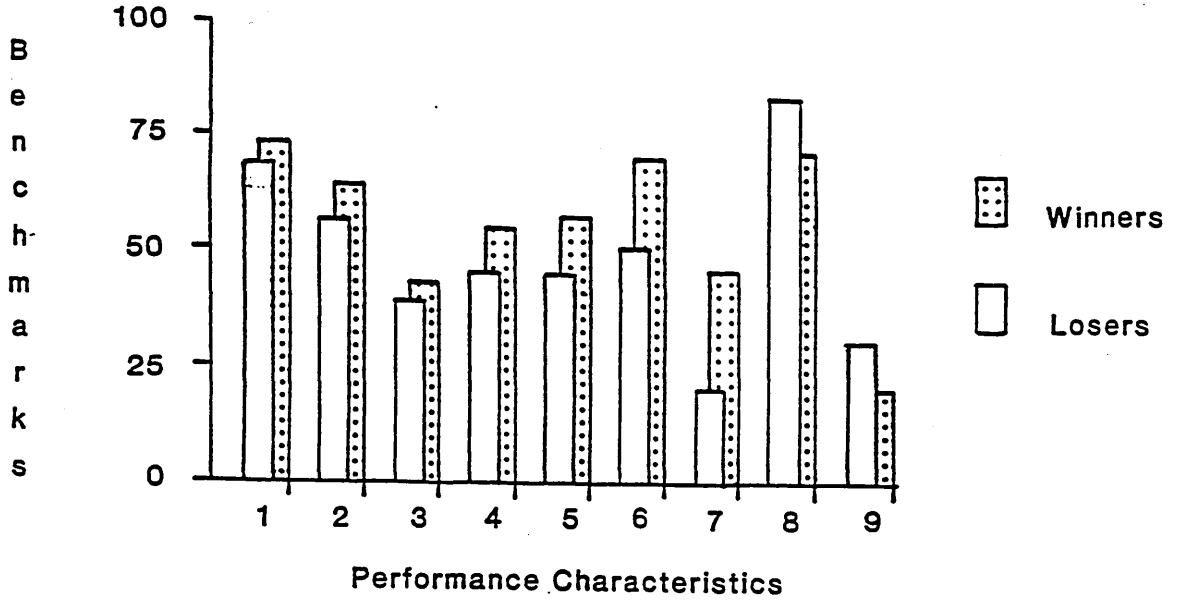
In the following definition of target winning benchmarks as compared with losing team profiles figure 7.1 refers.

i The average shooting efficiency rate for losing Goal Shooters was 68%, whereas that for drawers and winners bettered 73%. It would therefore appear that an average shooting efficiency of no less than 73% should be regarded as the target benchmark for this aspect of performance.

ii The average shooting efficiency rate for losing and drawing Goal Attacks was 56%, whereas that for winners was 65%. It would therefore appear that an average shooting efficiency of no less than 65% should be regarded as the target benchmark for this aspect of performance.

iii Losing and drawing Goal Attacks attempted 39% and 31% respectively, of all shots, whereas winning Goal Attacks

Figure 7.1 Model of international netball performances.



Performance characteristics code:

1. Shooting efficiency rate GS
2. Shooting efficiency rate GA
3. Percentage of shot attempts by GA
4. Shot attempts from inner region of goal circle
5. Shooting opportunities direct from centre plays
6. Scoring rate from own centre plays
7. Scoring rate from opponents' centre plays
8. Number of lost possessions per 1 hour match
9. Percentage of possessions lost in the defending and centre thirds

attempted 42% of all shots. Hence, Goal Attacks should aim to take 42% of all shots attempted as the target benchmark for this aspect of performance.

iv Losing teams attempted an average of 44% shot attempts from the inner region of the goal circle, whereas winning and drawing teams bettered 54%. An average of 54% or more of shots from the inner region of the goal circle should be regarded as the target benchmark for this aspect of performance.

v Losing teams create a shooting opportunity directly from an average of 45% of their own centre plays whereas winning and drawing teams better 57%. It would therefore seem appropriate that a target benchmark be set of no less than 57% of centre plays to reach a shooting opportunity direct, for this aspect of performance.

vi Losing teams score on average from 50% of their own centre plays, whereas winning and drawing teams score 70% and 61% respectively. It would therefore seem appropriate that a target benchmark be set of no less than 70% of goals scored from own centre plays for this aspect of performance.

vii On average 20% of losing teams' goals come from opponents' centre plays, whereas winners and drawers score 45% and 33% respectively. It would therefore seem appropriate that a

target benchmark of no less than 45% of goals be scored from opponents' centre plays be set as a target benchmark for this aspect of performance.

viii Losing teams lose, on average, 82 possessions per one hour match whereas winners and drawers lose 72 and 53 possessions respectively. It would therefore seem appropriate that a target benchmark of no more than 72 possessions be lost per one hour match for this aspect of performance.

ix On average, 30% of losing teams' possessions are lost in the defending and centre thirds, whereas winners and drawers lose on average 20% and 25% respectively in these areas. Hence it would appear that a target benchmark of no more than 20% of total lost possessions be lost in the defending and centre thirds of court, for this aspect of performances

The area between the performance threshold (losers) and the performance benchmark (winners) should be viewed as an 'improvement zone', and an area through which teams should strive to move.

Conclusions

The initial aim of this study was to develop an appropriate means of collecting and analysing match data which in turn could

aid the coach in evaluating and enhancing netball performance. It is the author's view that this initial aim has quite clearly been achieved and was reported in Chapter 4.

The second aim of the study was to develop a model against which coaches and players could evaluate a team's performance over a given set of matches. The above model reflects the extent to which this aim has been achieved in respect of the characteristics of performance identified here. However, the research limitations discussed in chapter 6 should be considered when evaluating the success of this aspect of the project.

Finally, there may be many more features of play that are important in determining match results. To explain how, for example, winners achieve more success in regaining possession from opponents' centre plays, and how they create more shooting opportunities close to the goal post, requires further, deeper evaluation, for which match analysis may or may not be an appropriate 'measuring tool'.

The kind of modelling work attempted in this study is, according to Alderson (1990), in its infancy, but in theory at least, it should provide coaches with benchmarks against which some assessment of their own players' performances can be made.

It is of crucial importance that the reporting of these features and models of play are treated with caution. Indeed it is

important that these efforts are 'refereed' and tested by the coaching community. As Reep & Benjamin (1968) demonstrated in their classic football study, during any given game the run of play is open to so many variables that the role of 'chance' can be central in determining match outcomes. There is no reason to suppose that netball is significantly different from soccer in this respect. Achievement of the performance benchmarks highlighted here does not necessarily imply a certainty in match outcome. It does not mean that all winning goal shooters will have an efficiency rate of 73% or better, nor does it mean that if a team achieves all the benchmarks suggested that they will necessarily win.

The type of inferential statistic used in attempting to quantify features of netball performance in this study, is a 'tool' that was originally developed for use in the physical sciences. As such the statistical tests was developed to measure and quantify phenomena in order to form and test scientific laws. The subsequent knowledge gained from orthodox scientific research provides a basis upon which predictions and future developments can be made according to the describe, explain, predict, control model.

However, human behaviour, including sporting encounters, is not as predictable an entity as is the physical world. According to Martens (1987)

> "... the study of human behaviour cannot be an exact science; at best we will be able only to understand and predict behaviour imperfectly."

Martens continues by suggesting that orthodox physical science can not accurately measure and predict human behaviour in the same way that it can with physical phenomena. Rather he suggests a tacit approach in developing knowledge. This embodies information, (defined as organised data), internalised and integrated with everything else that might be of relevance gained from experience, intuition or study.

By taking the approach suggested by Martens, match analysis and resulting models may be used as a tool, in conjunction with coaching experience, to develop knowledge of sport performance and a sound foundation for future coaching development. In the same way that research in the physical sciences enables prediction and progression of scientific knowledge, match analysis can make a significant contribution to the knowledge on which, predictions of future netball performance may be made.

However useful match analysis might be, it must always serve as an aid to the coach's skilled judgements. As far as coaching is concerned, match analysis should never be seen as an end in itself: there is no simple formula for success. Success is dependant on commitment from coach and players to work together to improve performance over extended periods such as a season or the run-up to a tournament. Match analysis and the model offered

here is seen only as another 'weapon' in the armoury used to pursue success in elite netball performance.

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APPENDICES

Appendix 1

```
AT ARE THE TEAM NAMES ?

AM A: ENGLAND

AM B: NEW ZEALAND

 YOU WISH TO ENTER THE TEAM MEMBERS NAMES (Y/N)

W MANY PERIODS OF PLAY ARE THERE ?   4

ICH TEAM HAS FIRST CENTRE PASS. A/B  B

ELAND(A) V. NEW ZEALAND(B)

W ZEALAND TO CENTRE PASS FIRST.

        RECORD OF TACTICAL ENTITY

        TEAM POSSESSION B
        SCORE          0   0
         START OF
           PLAY        C
        AREA            B   7    1    2    3    1    1         2
        GOAL AREA                -    -    -    -    D.        I
        PLAYER          C   WA   GS   GA   C   WA   GS       GD
        COMMENT                                          O    *

        RECORD OF TACTICAL ENTITY

        TEAM POSSESSION B
        SCORE          1   0
         START OF
           PLAY        P
        AREA            2
        GOAL AREA       I
        PLAYER         GA
        COMMENT             S   G

ORD OF TACTICAL ENTITY

M POSSESSION A
RE          0   1
ART OF
PLAY      C
9          8
L AREA
YER        C
MENT           H
```

Appendix 1

```
TEAM POSSESSION B
SCORE          1    1
 START OF
   PLAY       F
AREA          15        15
GOAL AREA      -         -
PLAYER        GK        GS
COMMENT              O    *
```

```
RECORD OF TACTICAL ENTITY

TEAM POSSESSION B
SCORE          1    1
 START OF
   PLAY       P
AREA          15   12    8    8    9
GOAL AREA      -
PLAYER        GK   WD    C   WD   WA
COMMENT                                 Q    X
```

```
RD OF TACTICAL ENTITY

 POSSESSION A
T             1    1
NT OF
LAY       T
          13   10   12    9    9    9    7
 AREA      -
ER        GK   WD    C   GD   GA   WD    C
ENT                                      I    X
```

```
RECORD OF TACTICAL ENTITY

TEAM POSSESSION B
SCORE          1    1
 START OF
   PLAY       I
AREA          15   12    9    8    2         1
GOAL AREA      -                   -         D
PLAYER        GK    C   WD   WA   GS        GK
COMMENT                                 A    M
```

Appendix 1

```
ORD OF TACTICAL ENTITY

M POSSESSION A
RE          1   2
ART OF
PLAY     C
A         8   7   3   3       3
L AREA            -   I       I
YER       C  WA   C  GS      GK
MENT                     K   *


ORD OF TACTICAL ENTITY

I POSSESSION A
E           2   2
ART OF
LAY      P
^         3
 AREA     I
ER       GS
ENT           S   G
```

```
RECORD OF TACTICAL ENTITY

TEAM POSSESSION B
SCORE         2   2
 START OF
   PLAY      C
AREA          9   9   5   5   5       5
GOAL AREA
PLAYER        C  WA   C  WD  WA      WD
COMMENT                           K   *


RECORD OF TACTICAL ENTITY

TEAM POSSESSION B
SCORE         2   2
 START OF
   PLAY      P
AREA          5   6   2   2       1
GOAL AREA             -   0       -
PLAYER       WA   C  GA  GS      WD
COMMENT                       A   M
```

Appendix 1

```
TEAM POSSESSION B
SCORE        2   2
 START OF
   PLAY      F
AREA          3        3
GOAL AREA     0        -
PLAYER       GA        C
COMMENT           A    M


RECORD OF TACTICAL ENTITY

TEAM POSSESSION B
SCORE         2   2
 START OF
   PLAY      T
AREA          3        1
GOAL AREA     -        0
PLAYER        C        C
COMMENT           E    *


RECORD OF TACTICAL ENTITY

TEAM POSSESSION B
SCORE         2   2
 START OF
   PLAY      F
AREA          1   2
GOAL AREA     0   -
PLAYER       GA   C
COMMENT               0


RD OF TACTICAL ENTITY

 POSSESSION A
E          2   2
RT OF
LAY      T
         14  10   9   9        9
 AREA     I
ER       GK  WD  GD  WA       WD
ENT                      0    *
```

Appendix 1

```
RECORD OF TACTICAL ENTITY

TEAM POSSESSION B
SCORE          2    2
 START OF
   PLAY        P
AREA            2          2
GOAL AREA       0          0
PLAYER         GS         GS
COMMENT                 0    *


RECORD OF TACTICAL ENTITY

TEAM POSSESSION B
SCORE          2    2
 START OF
   PLAY        P
AREA            2
GOAL AREA       0
PLAYER         GS
COMMENT                 E    *


RECORD OF TACTICAL ENTITY

TEAM POSSESSION B
SCORE          2    2
 START OF
   PLAY        R
AREA            2          2
GOAL AREA       I          I
PLAYER         GS
COMMENT                 U    *


RECORD OF TACTICAL ENTITY

TEAM POSSESSION B
SCORE          3    2
 START OF
   PLAY        W
AREA            2
GOAL AREA       I
PLAYER         GS
COMMENT                 S    G
```

Appendix 1

```
TEAM POSSESSION B
SCORE          3   3
 START OF
   PLAY      C
AREA           8   8   8   7   5
GOAL AREA
PLAYER         C  WD  WA  WD  GA
COMMENT                        O   X
```

```
RD OF TACTICAL ENTITY

 POSSESSION A
E           3   3
RT OF
LAY      T
         13  10   7  11   8   8       8
 AREA     O
ER       GK  WD   C  GK   C  WD      WA
ENT                                K   *
```

```
D OF TACTICAL ENTITY

 POSSESSION A
          3   3
T OF
AY       P
          8   7   8   2       2
 AREA                 -       I
R        WD  WA  WD  WA      GK
NT                       A   M
```

```
D OF TACTICAL ENTITY

 POSSESSION A
          3   3
T OF
AY       T
          1   3       2   3       2
 AREA     I   I       1   -       I
R        GA  GB      GD  WA      GK
NT               A   Z       A   -
```

OAL AREA ANALYSIS FOR AUSTRALIA

****

GOAL SHOOTER

RIOD 1

	RI	RO	CI	CO	LI	LO	
TEMPTS	0	0	0	3	0	0	1
OALS	0	0	3	0	0	0	

RIOD 2

TEMPTS	0	0	3	6	2	0	0
OALS	0	2	6	0	0	0	

RIOD 3

TEMPTS	1	1	1	1	2	0	0
OALS	1	0	1	1	0	0	

RIOD 4

TEMPTS	1	1	2	5	2	1	0
OALS	0	0	4	0	1	0	

GOAL ATTACK

RIOD 1

	RI	RO	CI	CO	LI	LO	
TEMPTS	1	1	1	2	1	0	0
OALS	1	0	2	1	0	0	

RIOD 2

TEMPTS	0	0	1	6	4	1	1
OALS	0	1	6	3	1	1	

RIOD 3

TEMPTS	0	0	1	1	2	0	2
OALS	0	0	1	1	0	1	

RIOD 4

TEMPTS	0	0	1	6	1	0	1
OALS	0	0	5	0	0	1	

****

Appendix 3a

TEAM : ENGLAND

PLAYER RECEIVING CENTRE	SHOOTING OPPORTUNITY BEFORE LOSS OF POSSESSION	TEAM TO SCORE
WD	NO	AUSTRALIA
WA	NO	ENGLAND
WA	NO	AUSTRALIA
TIP	NO	ENGLAND
WD	YES	ENGLAND
GD	NO	AUSTRALIA
OFF SIDE	NO	AUSTRALIA
PERIOD 2		
WA	NO	AUSTRALIA
WA	YES	ENGLAND
GD	NO	AUSTRALIA
WA	YES	ENGLAND
WD	NO	AUSTRALIA
WD	YES	ENGLAND
WA	YES	ENGLAND
WD	YES	ENGLAND
WA	YES	ENGLAND
CONTACT	YES	ENGLAND
GD	NO	AUSTRALIA
WA	YES	ENGLAND
WA	YES	ENGLAND
WD	YES	ENGLAND
GD	YES	ENGLAND
WA	NO	AUSTRALIA
WD	NO	AUSTRALIA
PERIOD 3		
WA	NO	ENGLAND
TIP	YES	ENGLAND
OUT OF COURT	NO	ENGLAND
WA	NO	AUSTRALIA
WA	YES	ENGLAND
WA	YES	ENGLAND
WA	NO	AUSTRALIA
WA	YES	END
PERIOD 4		
WA	YES	ENGLAND

TEAM : ENGLAND

PERIOD OF PLAY	NUMBER OF CENTRE PASSES	THOSE LEADING TO SHOTS BEFORE A TURNOVER		NUMBER OF GOALS SCORED FROM OWN C.P.	
1	7	1	(14%)	3	(42%)
2	17	11	(64%)	11	(64%)
3	8	4	(50%)	5	(62%)
4	10	3	(30%)	4	(40%)
TOTAL	42	19	(45%)	23	(54%)

TEAM : ENGLAND

HOW		WHERE	WHO	START COMMENT	DO OPP. SCORE
TERCEPTION		OUTSIDE OF CIRCLE	C	CENTRE PASS	NO
LDBALL		OUTER CIRCLE	GS	FREE PASS	YES
TERCEPTION	X	CENTRE THIRD	GD	PENALTY PASS	NO
SSED SHOT		OUTER CIRCLE	GS	PENALTY PASS	NO
SS UP		OUTER CIRCLE		PENALTY PASS	NO
SS TOO CLOSE		OUTER CIRCLE	GS	PENALTY PASS	NO
T OF COURT	X	CENTRE THIRD	C	INTERCEPTION	NO
NTACT		CENTRE THIRD	WA	TOSS UP	NO
SS UP		OUTER CIRCLE		CENTRE PASS	NO
SSED SHOT		OUTER CIRCLE	GS	PENALTY PASS	YES
T OF COURT	X			PENALTY PASS	NO
TERCEPTION	X	ATTACKING THIRD	C	INTERCEPTION	YES
NTACT		CENTRE THIRD	WA	CENTRE PASS	NO
SSED SHOT		OUTER CIRCLE	GA	PENALTY PASS	NO
NTACT		OUTER CIRCLE	GA	THROW IN	NO
SSED SHOT		OUTER CIRCLE	GA	FREE PASS	YES
F SIDE		OUTER CIRCLE	WA	PENALTY PASS/SHOT	YES
RIOD 2					
OT FAULT		OUTSIDE OF CIRCLE	GA	CENTRE PASS	YES
TERCEPTION	X	OUTER CIRCLE	GA	CENTRE PASS	YES
>		ATTACKING THIRD	GS	PENALTY PASS	YES
T OF COURT	X	CENTRE THIRD	GD	CENTRE PASS	YES
>		ATTACKING THIRD	WA	LOOSE BALL PICKUP	YES
SSED SHOT		OUTER CIRCLE	GS	PENALTY PASS	YES
RIOD 3					
>		CENTRE THIRD	WA	CENTRE PASS	NO
SSED SHOT		OUTER CIRCLE	GA	REBOUND	NO
T OF COURT		CENTRE THIRD	C	CENTRE PASS	NO
SSED SHOT		INNER CIRCLE	GS	PENALTY PASS	YES
SS UP		OUTER CIRCLE		CENTRE PASS	NO
>		OUTSIDE OF CIRCLE	C	PENALTY PASS	YES
SSED SHOT		INNER CIRCLE	GS	CENTRE PASS	NO
>		ATTACKING THIRD	WA	LOOSE BALL PICKUP	NO
OPPED PASS		INNER CIRCLE	GS	PENALTY PASS	NO
T OF COURT	X	CENTRE THIRD	WD	PENALTY PASS	YES
SSED SHOT		INNER CIRCLE	GS	PENALTY PASS	NO
TERCEPTION	X	OUTSIDE OF CIRCLE	WA	INTERCEPTION	NO
TERCEPTION	X	DEFENDING CIRCLE	GK	FREE PASS	NO
LDBALL		OUTER CIRCLE	GS	THROW IN	NO
SSED SHOT		OUTER CIRCLE	GS	INTERCEPTION	NO

Appendix 4a

RIOD 4

TERCEPTION	X	ATTACKING THIRD	GA	CENTRE PASS	NO
IP		OUTER CIRCLE	GA	REBOUND	YES
ISSED SHOT		INNER CIRCLE	GS	REBOUND	YES
P		CENTRE THIRD	WA	CENTRE PASS	YES
F SIDE		OUTER CIRCLE	WA	INTERCEPTION	NO
SSED SHOT		OUTER CIRCLE	GA	PENALTY PASS	YES
SSED SHOT		INNER CIRCLE	GA	REBOUND	NO
P		OUTSIDE OF CIRCLE	WA	CENTRE PASS	YES
TERCEPTION	X	CENTRE THIRD	C	THROW IN	YES
NTACT		CENTRE THIRD	WA	CENTRE PASS	YES
SS UP		INNER CIRCLE		INTERCEPTION	NO
OT FAULT		CENTRE THIRD	WD	CENTRE PASS	NO
NTACT		INNER CIRCLE	GA	PENALTY PASS	NO
SSED SHOT		OUTER CIRCLE	GA	FREE PASS	NO
TERCEPTION	X	OUTSIDE OF CIRCLE	C	CENTRE PASS	NO

TEAM : ENGLAND

Appendix 4b

1

10
13
4
0
0

2

3
6
1
0
0

3

10
12
3
0
1

4

9
12
4
0
0

TOTAL

32
43
12
0
1

Appendix 5

****
CHI SQUARE ANALYSIS
****

Legend: TOTAL NUMBER OF GOALS SCORED

Contingency Table:

1082 655 1737

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
1082.00	868.50	52.48
655.00	868.50	52.48

Result of the Chi Square Analysis

Chi Square = 104.97

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square = 3.78

Reject the Null Hypothesis

****
CHI SQUARE ANALYSIS
****

Legend: 5 GOAL DIFFERENCE PER MATCH

Contingency Table:

918.5818.5 1737

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
918.50	868.50	2.88
818.50	868.50	2.88

Result of the Chi Square Analysis

Chi Square = 5.76

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square = 3.78

Reject the Null Hypothesis

Appendix 6

****
CHI SQUARE ANALYSIS
****

Legend: 4 GOAL MATCH DIFFERENCE

Contingency Table:

908.5828.5 1737

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
908.50	868.50	1.84
828.50	868.50	1.84

Result of the Chi Square Analysis

Chi Square = 3.68

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square = 3.78

Accept the Null Hypothesis

Appendix 7

****
CHI SQUARE ANALYSIS
****

egend: GOAL DISTRIBUTION ACROSS MATCH 1/4's

ontingency Table:

:ow 1	266	285	273	258	1082
:ow 2	152	189	154	160	655
:ow 3	177	200	183	216	776
	595	674	610	634	2513

able of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
266.00	256.18	0.38
152.00	155.08	0.06
177.00	183.73	0.25
285.00	290.20	0.09
189.00	175.67	1.01
200.00	208.13	0.32
273.00	262.64	0.41
154.00	158.99	0.16
183.00	188.36	0.15
258.00	272.98	0.82
160.00	165.25	0.17
216.00	195.78	2.09

esult of the Chi Square Analysis

ni Square = 5.90

ssume level of confidence is 5% (0.05).
egrees of freedom = 6

-itical value of Chi Square with 6 degrees of freedom = 12.30886028

ni Square observed does not achieve significance; p>0.05. Accept the null
/pothesis.

Appendix 8

****
CHI SQUARE ANALYSIS
****

Legend: GOAL DISTRIBUTION WINNERS

Contingency Table:

266 285 273 258 1082

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
266.00	270.50	0.07
285.00	270.50	0.78
273.00	270.50	0.02
258.00	270.50	0.58

Result of the Chi Square Analysis

Chi Square = 1.45

Assume level of confidence is 5% (0.05).
Degrees of freedom = 3

Critical value of Chi Square = 7.82

Accept the Null Hypothesis

****
CHI SQUARE ANALYSIS
****

egend: SHOOTING EFFICIENCY FOR GS & GA

ontingency Table:

ow 1	1679	2260	3939
ow 2	834	1364	2198
	2513	3624	6137

able of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
1679.00	1612.96	2.70
834.00	900.04	4.85
2260.00	2326.04	1.88
1364.00	1297.96	3.36

esult of the Chi Square Analysis

hi Square = 12.79

ssume level of confidence is 5% (0.05).
egrees of freedom = 1

ritical value of Chi Square with 1 degrees of freedom = 3.498012501

hi Square Observed is significant; p<0.05. Reject the null hypothesis.

rogram finished. JA Feb 84

****
CHI SQUARE ANALYSIS
****

Legend: SHOOTING EFFICIENCY GS/GA WINNERS

ontingency Table:

ow 1	659	881	1540
ow 2	423	631	1054
	1082	1512	2594

able of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
659.00	642.36	0.43
423.00	439.64	0.63
881.00	897.64	0.31
631.00	614.36	0.45

esult of the Chi Square Analysis

hi Square = 1.82

ssume level of confidence is 5% (0.05).
egrees of freedom = 1

ritical value of Chi Square with 1 degrees of freedom = 3.498012501

hi Square observed does not achieve significance; p>0.05. Accept the null
ypothesis.

rogram finished. JA Feb 84

****
CHI SQUARE ANALYSIS
****

Legend: SHOOTING EFFICIENCY GS/GA LOSERS

Contingency Table:

Row 1	430	636	1066
Row 2	225	401	626
	655	1037	1692

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
430.00	412.67	0.73
225.00	242.33	1.24
636.00	653.33	0.46
401.00	383.67	0.78

Result of the Chi Square Analysis

Chi Square = 3.21

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square with 1 degrees of freedom = 3.498012501

Chi Square observed does not achieve significance; p>0.05. Accept the null hypothesis.

Program finished. JA Feb 84

Appendix 9

****
CHI SQUARE ANALYSIS
****

Legend: SHOOTING EFFICIENCY GS/GA DRAWERS

Contingency Table:

Row 1	590	744	1334
Row 2	186	333	519
	776	1077	1853

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
590.00	558.65	1.76
186.00	217.35	4.52
744.00	775.35	1.27
333.00	301.65	3.26

Result of the Chi Square Analysis

Chi Square = 10.80

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square with 1 degrees of freedom = 3.498012501

Chi Square Observed is significant; $p<0.05$. Reject the null hypothesis.

Program finished. JA Feb 84

****
CHI SQUARE ANALYSIS
****

Legend: GOAL ATTEMPTS BY GS & GA DRAWERS

Contingency Table:

744 333 1077

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
744.00	538.50	78.42
333.00	538.50	78.42

Result of the Chi Square Analysis

Chi Square = 156.84

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square = 3.78

Reject the Null Hypothesis

Program finished. JA Feb 88

****
CHI SQUARE ANALYSIS
****

Legend: GOAL ATTEMPTS BY GS & GA

Contingency Table:

2260 1364 3624

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
2260.00	1812.00	110.76
1364.00	1812.00	110.76

Result of the Chi Square Analysis

Chi Square = 221.53

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square = 3.78

Reject the Null Hypothesis

Program finished. JA Feb 88

****
CHI SQUARE ANALYSIS
****

Legend: GOAL ATTEMPTS BY GS & GA WINNERS

Contingency Table:

881 631 1512

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
881.00	756.00	20.67
631.00	756.00	20.67

Result of the Chi Square Analysis

Chi Square = 41.34

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square = 3.78

Reject the Null Hypothesis

Program finished. JA Feb 88

****
CHI SQUARE ANALYSIS
****

Legend: GOAL ATTEMPTS BY GS & GA LOSERS

Contingency Table:

636 401 1037

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
636.00	518.50	26.63
401.00	518.50	26.63

Result of the Chi Square Analysis

Chi Square = 53.25

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square = 3.78

Reject the Null Hypothesis

Program finished. JA Feb 88

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**************************
 CHI    SQUARE    ANALYSIS
**************************
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Legend: GOALS SCORED FROM INNER & OUTER

Contingency Table:

1573	940	2513

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
1573.00	1256.50	79.72
940.00	1256.50	79.72

Result of the Chi Square Analysis

Chi Square = 159.45

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square = 3.78

Reject the Null Hypothesis

Program finished. JA Feb 88

****
CHI SQUARE ANALYSIS
****

Legend: ATTEMPTS IN/OUT BY WIN/DRAW

Contingency Table:

Row 1	815	695	1510
Row 2	628	449	1077
	1443	1144	2587

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
815.00	842.26	0.88
628.00	600.74	1.24
695.00	667.74	1.11
449.00	476.26	1.56

Result of the Chi Square Analysis

Chi Square = 4.79

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square with 1 degrees of freedom = 3.498012501

Chi Square Observed is significant; $p<0.05$. Reject the null hypothesis.

Program finished. JA Feb 84

****
CHI SQUARE ANALYSIS
****

Legend: ATTEMPTS IN/OUT BY LOSERS/WINNERS

Contingency Table:

Row 1	815	695	1510
Row 2	457	580	1037
	1272	1275	2547

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
815.00	754.11	4.92
457.00	517.89	7.16
695.00	755.89	4.90
580.00	519.11	7.14

Result of the Chi Square Analysis

Chi Square = 24.12

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square with 1 degrees of freedom = 3.498012501

Chi Square Observed is significant; $p<0.05$. Reject the null hypothesis.

Program finished. JA Feb 84

Appendix 11

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**************************
 CHI    SQUARE    ANALYSIS
**************************
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Legend: ATTEMPTS IN/OUT BY LOSER/DRAWER

Contingency Table:

Row 1	628	449	1077
Row 2	457	580	1037
	1085	1029	2114

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
628.00	552.76	10.24
457.00	532.24	10.63
449.00	524.24	10.80
580.00	504.76	11.21

Result of the Chi Square Analysis

Chi Square = 42.89

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square with 1 degrees of freedom = 3.498012501

Chi Square Observed is significant; $p<0.05$. Reject the null hypothesis.

Program finished. JA Feb 84

Appendix 12

Legend: EFFICIENCY FREQ FOR W/L/D/ IN/OUT

Contingency Table:

Row 1	2	12	66	80
Row 2	30	16	24	70
Row 3	1	5	59	65
Row 4	16	16	66	98
Row 5	8	16	53	77
Row 6	35	21	17	73
Row 7	4	20	53	77
Row 8	23	36	18	77
Row 9	10	12	31	53
Row 10	30	21	9	60
Row 11	11	16	30	57
Row 12	31	18	12	61
	201	209	438	848

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
2.00	18.96	15.17
30.00	16.59	10.84
1.00	15.41	13.47
16.00	23.23	2.25
8.00	18.25	5.76
35.00	17.30	18.10
4.00	18.25	11.13
23.00	18.25	1.24
10.00	12.56	0.52
30.00	14.22	17.51
11.00	13.51	0.47
31.00	14.46	18.92
12.00	19.72	3.02
16.00	17.25	0.09
5.00	16.02	7.58
16.00	24.15	2.75
16.00	18.98	0.47
21.00	17.99	0.50
20.00	18.98	0.06
36.00	18.98	15.27
12.00	13.06	0.09
21.00	14.79	2.61
16.00	14.05	0.27
18.00	15.03	0.59

66.00	41.32	14.74
24.00	36.16	4.09
59.00	33.57	19.26
66.00	50.62	4.67
53.00	39.77	4.40
17.00	37.71	11.37
53.00	39.77	4.40
18.00	39.77	11.92
31.00	27.37	0.48
9.00	30.99	15.60
30.00	29.44	0.01
12.00	31.51	12.08

Result of the Chi Square Analysis

Chi Square = 251.68

Assume level of confidence is 5% (0.05).
Degrees of freedom = 22

Critical value of Chi Square with 22 degrees of freedom = 33.63999888

Chi Square Observed is significant; $p<0.05$. Reject the null hypothesis.

Appendix 13

****
CHI SQUARE ANALYSIS
****

Legend: CP's AND GOAL OPPS FROM CP W/L

Contingency Table:

Row 1	944	545	1489
Row 2	946	423	1369
	1890	968	2858

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
944.00	984.68	1.68
946.00	905.32	1.83
545.00	504.32	3.28
423.00	463.68	3.57

Result of the Chi Square Analysis

Chi Square = 10.36

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square with 1 degrees of freedom = 3.498012501

Chi Square Observed is significant; $p<0.05$. Reject the null hypothesis.

Appendix 13

****
CHI SQUARE ANALYSIS
****

Legend: CP'S AND GOAL OPPS FROM CP BY W/D

Contingency Table:

Row 1	944	545	1489
Row 2	826	471	1297
	1770	1016	2786

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
944.00	945.99	0.00
826.00	824.01	0.00
545.00	543.01	0.01
471.00	472.99	0.01

Result of the Chi Square Analysis

Chi Square = 0.02

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square with 1 degrees of freedom = 3.498012501

Chi Square observed does not achieve significance; p>0.05. Accept the null hypothesis.

****
CHI SQUARE ANALYSIS
****

Legend: GOAL OWN & OPP'S CP WIN/DRAW

Contingency Table:

Row 1	660	422	1082
Row 2	506	270	776
	1166	692	1858

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
660.00	679.02	0.53
506.00	486.98	0.74
422.00	402.98	0.90
270.00	289.02	1.25

Result of the Chi Square Analysis

Chi Square = 3.42

Assume level of confidence is 5% (0.05).
Degrees of freedom = 1

Critical value of Chi Square with 1 degrees of freedom = 3.498012501

Chi Square observed does not achieve significance; p>0.05. Accept the null hypothesis.

****
CHI SQUARE ANALYSIS
****

Legend: GOALS OWN & OPP'S CF W/L/D

Contingency Table:

Row 1	660	422	1082
Row 2	471	184	655
Row 3	506	270	776
	1637	876	2513

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
660.00	704.83	2.85
471.00	426.68	4.60
506.00	505.50	0.00
422.00	377.17	5.33
184.00	228.32	8.60
270.00	270.50	0.00

Result of the Chi Square Analysis

Chi Square = 21.39

Assume level of confidence is 5% (0.05).
Degrees of freedom = 2

Critical value of Chi Square with 2 degrees of freedom = 5.702236079

Chi Square Observed is significant: p<0.05. Reject the null hypothesis.

****
CHI SQUARE ANALYSIS
****

Legend: LOSS OF POSSESSION BY COURT AREA W/L/D

Contingency Table:

Row 1	482	455	265	1202
Row 2	664	701	373	1738
Row 3	206	330	155	691
Row 4	85	144	53	282
	1437	1630	846	3913

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
482.00	441.42	3.73
664.00	638.26	1.04
206.00	253.76	8.99
85.00	103.56	3.33
455.00	500.71	4.17
701.00	723.98	0.73
330.00	287.84	6.17
144.00	117.47	5.99
265.00	259.88	0.10
373.00	375.76	0.02
155.00	149.40	0.21
53.00	60.97	1.04

Result of the Chi Square Analysis

Chi Square = 35.53

Assume level of confidence is 5% (0.05).
Degrees of freedom = 6

Critical value of Chi Square with 6 degrees of freedom = 12.30886028

Chi Square Observed is significant; $p<0.05$. Reject the null hypothesis.

****
CHI SQUARE ANALYSIS
****

egend: LOSS OF POSSESSION BY COURT AREA W/L

ontingency Table:

ow 1	482	664	206	85	1437
ow 2	455	701	330	144	1630
	937	1365	536	229	3067

able of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
482.00	439.02	4.21
455.00	497.98	3.71
664.00	639.55	0.93
701.00	725.45	0.82
206.00	251.14	8.11
330.00	284.86	7.15
85.00	107.29	4.63
144.00	121.71	4.08

esult of the Chi Square Analysis

hi Square = 33.66

ssume level of confidence is 5% (0.05).
egrees of freedom = 3

ritical value of Chi Square with 3 degrees of freedom = 7.531344322

hi Square Observed is significant; p<0.05. Reject the null hypothesis.

****
CHI SQUARE ANALYSIS
****

Legend: LOSS OF POSSESSION BY COURT AREA W/D

Contingency Table:

Row 1	482	664	206	85	1437
Row 2	265	373	155	53	846
	747	1037	361	138	2283

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
482.00	470.19	0.30
265.00	276.81	0.50
664.00	652.72	0.19
373.00	384.28	0.33
206.00	227.23	1.98
155.00	133.77	3.37
85.00	86.86	0.04
53.00	51.14	0.07

Result of the Chi Square Analysis

Chi Square = 6.78

Assume level of confidence is 5% (0.05).
Degrees of freedom = 3

Critical value of Chi Square with 3 degrees of freedom = 7.531344322

Chi Square observed does not achieve significance; p>0.05. Accept the null hypothesis.

****
CHI SQUARE ANALYSIS
****

Legend: LOSS OF POSSESSION BY COURT AREA L/D

Contingency Table:

Row 1	455	701	330	144	1630
Row 2	265	373	155	53	846
	720	1074	485	197	2476

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
455.00	473.99	0.76
265.00	246.01	1.47
701.00	707.04	0.05
373.00	366.96	0.10
330.00	319.29	0.36
155.00	165.71	0.69
144.00	129.69	1.58
53.00	67.31	3.04

Result of the Chi Square Analysis

Chi Square = 8.05

Assume level of confidence is 5% (0.05).
Degrees of freedom = 3

Critical value of Chi Square with 3 degrees of freedom = 7.531344322

Chi Square Observed is significant; $p<0.05$. Reject the null hypothesis.

****
CHI SQUARE ANALYSIS
****

Legend: LOS OF POSS: DEF/CEN & ATT 1/3 W/L/D

Contingency Table:

Row 1	1146	291	1437
Row 2	1156	474	1630
Row 3	638	208	846
	2940	973	3913

Table of Expected Frequencies and Chi Square values

Frequency Observed	Frequency Expected	Chi Square
1146.00	1079.68	4.07
1156.00	1224.69	3.85
638.00	635.64	0.01
291.00	357.32	12.31
474.00	405.31	11.64
208.00	210.36	0.03

Result of the Chi Square Analysis

Chi Square = 31.91

Assume level of confidence is 5% (0.05).
Degrees of freedom = 2

Critical value of Chi Square with 2 degrees of freedom = 5.702236079

Chi Square Observed is significant; $p<0.05$. Reject the null hypothesis.

Program finished. JA Feb 84