

**Modelling in Competitive Sports,  
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"The modelling of competitive sport is an informative analytic technique because it directs the attention of the modeller to the critical aspects of data which delineate successful performance. The modeller searches for an underlying signature of sport performance which is a reliable predictor of future sport behaviour. Stochastic models have not yet, to our knowledge, been used further to investigate sport at the behavioural level of analysis. However, the modelling procedure is readily applicable to other sports and could lead to useful and interesting results."

Franks and McGarry (1996)

The purpose of this paper is to provide a summary review of literature written on modelling in competitive sport and also outlines other possible means of modelling that could be developed further in sports, such as chaos theory. Teams and performers often demonstrate a stereotypical way of playing and these are idiosyncratic models which include positive and negative aspects of performance. Patterns of play will begin to establish over a period of time but the greater the data base then the more accurate the model. An established model provides for the opportunity to compare single performance against it. Coaches and performers should always have input as to the aspects which should be used in modelling performance.

Mosteller (1979) set out guidelines when he developed a predictive model:

1. Use the past to predict the future -use only past scores to predict future ones.
2. Use weights - weigh recent games much more largely than games earlier in the season. Develop method from data for several years.
3. Use last year's data - for early games one would weigh up last year's last few games. As season progressed last year's games would be weighted less and less.
4. Estimate both strengths and weaknesses.
5. Adjust for home and away and for trends such as injuries, strengths found out.
6. Develop scores for injuries.
7. Consider morale.

Fuller (1988) developed and designed a Netball Analysis System and focused on game modelling from a data base of 28 matches in the 1987 World Netball Championships. There were three main components to the research - to develop a notation and analysis system, to record performance, and to investigate the prescience of performance patterns that would distinguish winners from losers. The system could record how each tactical entry started; the player involved and the court area through which the ball travelled; the reason for each ending; and an optional comment. The software produced the data according to shooting analysis; centre pass analysis; loss of possession; player profiles; and circle feeding.

Fuller's (1988) intention of modelling play was to determine the routes that winning, drawing and losing teams took and to identify significantly different patterns. From the results Fuller was able to differentiate between the performances of winning and losing teams. The differences were both technical and tactical. Fuller identified nine quantifiable benchmarks:

1. Shooting efficiency for GS for winning/drawing teams bettered 73%.
2. Shooting efficiency for GA for winning/drawing teams bettered 65%.
3. GA attempted 42% of all shots with winning teams.
4. Shooting efficiency bettered 54% for winning/drawing teams from inner region.
5. Winning/drawing teams created 57% of shooting chances directly from own centre plays.
6. Winning/drawing teams scored 70% of shooting chances from own centre plays.
7. Winning/drawing teams lost on average 72 and 53 possessions per match respectively.
8. Winners lose 20% of possessions in the defending and centre third areas.

The research was an attempt to model winning performance in elite netball and more research needed in terms of the qualitative aspects i.e. how are more shooting opportunities created. the model should be used to monitor performance over a series of matches not on one-off performances.

Morris (1981):

Every match is a contradiction, being at once both highly predictable and highly unpredictable.

Treadwell, Lyons, Potter (1991) expressed that match analysis in rugby union and other field games has centred on game modelling and that their research was concerned with using the data to predict game content's of rugby union matches. They found that clear physiological rhythms and strategical patterns emerged. They found that at elite level it was possible to identify key "windows" i.e. vital "moments of chronological expectancy where strategical expediency needs to be imposed." It appears that international matches and successful teams generate distinctive rhythms of play which can exhibit a team fingerprint or heartbeat. Lyons (1988) had previously analysed 10 years of Home Nations Championship matches to build up a database, and from this was able to predict actions for a match within 3 passes and 2 kicks. Franks et al (1983) had previously stated that they felt that one of the most important uses of quantitative

analysis was the formation of a data base of past games to provide the possibility to formulate predictive models.

Soule (1957) reported on work carried out by the team statistician of the Brooklyn Dodgers baseball team. Roth noted half a million symbols per year and prior to each match would work out the probability of the team winning on a given park, on a given day, with a given pitcher.

Alexander et al (1988) used the mathematical theory of probability in the game of squash. Mathematical modelling can describe the main features of the game of squash and can reveal strategical patterns to the player. Squash is an example of a Markov chain mathematical structure:

The probability that A wins a rally when serving is	$P_a$
The probability that A wins a rally when receiving is	$Q_a$

The probability that B wins a rally when serving is	$P_b = 1 - Q_a$
The probability that B wins a rally when receiving is	$Q_b = 1 - P_a$

If two opponents are of the same standing then	$P_a, P_b, Q_a, Q_b = 0.5$
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The probability that A winning a point when serving is the sum of each winning sequence of rallies:

$$P_a = 1/2 + 1/2^3 + 1/2^5 + 1/2^7 + \dots = 2/3 \quad (\text{geometric series})$$

$$P_a \text{ wins } 9-0 = (2/3)^9 = 0.026$$

If A is stronger player with  $P_a = 2/3$  and  $Q_a = 3/5$  then:

Probability that A wins when serving is  $5/6$ ; when receiving is  $1/2$ .  
Probability of A being in a serving state is  $3/4$ .

The probability of winning a game is the sum of all the probabilities of each possible score, i.e. sum of  $p(9-0)$ ,  $p(9-1)$  . . . .  $p(9-8)$ ,  $p(10-9)$ .

Franks and McGarry (1996) cited Charles Reep's work in soccer since the 1950's, and how the statistical analysis of this data reveals mathematical functions and consistencies of certain behaviours. The conclusions drawn from their work suggested that it would be of benefit to a side to maximise the probabilities of certain actions at the expense of others. Reep and Benjamin (1968) found that the goal:shot ratio was 1:10 and thus it would seem fair to suggest that an increase in the number of shots would lead to an increase in the number of goals. Since they also found that most shots came from passing movements with very few passes then the "long ball" or "direct style" of play becomes important.

Work by Franks (1988) found that passing movements leading to goals were even shorter than passing movements leading to shots, hence suggesting that there lies a sub-group within the shots on goal group.

Another of Reep and Benjamin's (1968) findings was that over 50% of shots arose from regained possessions in the final third of the field. This finding was reinforced by Partridge and Franks (1991) who found that West Germany, winners of the 1990 tournament, lost the ball most regularly in the final third (61%). Reep et al (1971) expanded their previous research to see whether the negative binomial distribution was also applicable in other sports. They used the analogy of Greenwood and Yule's (1920) model for accidents to industrial workers to prove that in Poissonian situations then good fits were obtained but that these fits diminished when studying sports where individual skill played a bigger role.

Franks and McGarry (1996) described how sports analysis can move on from being a descriptive process to becoming a predictive one. If there is some level of consistency within the performance then future performance can be predicted from past matches through stochastic modelling. They sub-divide sports into two sections, those determined by score (squash, tennis, etc. where the result is win or lose) and those by time (soccer, rugby, etc. where the result is win, lose, or draw.) This is an important distinction when modelling aspects are to be discussed.

The characteristics of score-dependent sports are based largely on a structured sequence of discrete events where the relationship between each event is related to the opponent. Time-dependent sports are invasive and interactive and can be considered as relatively contingent in a temporary state. The structure of the sport is very important when it comes to deciding what method of modelling one should use to predict performance.

Score-dependent sports can be modelled by simply using discrete event models but the time-based sports need time models since the next event is always dependent on both event and time. Franks and McGarry suggested the so-far untried Poisson model for discrete events in time-dependent sports. They also discuss the importance of the number of competitors involved on the development of a model - the greater the number of competitors then the larger the scope for variability. This simply emphasises the problems facing coaches when they view a game. It would appear to be the case that the previous event only becomes of importance to the coach when a critical event has just occurred. The amount of data is one reason why little modelling has been directed into team games in a conceptual manner.

Grehaigne (1994) analysed the configurations of the game according to positions of the player, their speed, and their directions and proposed a model to analyse the transition between two configurations of play that enables one to take time into consideration as the match evolves.

## **Catastrophe Theory**

Kirkcaldy (1983) described catastrophe theory as:

" . . . a descriptive model . . . which allows us to better appreciate the manner in which *multi-dimensional* systems operate and to make predictions of the behaviour of the systems under scrutiny."

The mathematical model was originated by Thom (1975) and later modified by Zeeman (1975; 1976). Kirkcaldy (1983) used the model to provide a possible explanation of how explosive effects can accompany small changes in arousal to produce an optimum level of performance or a sudden decrement in performance. It is concerned with the methods of attaining equilibrium states in qualitative mathematical language.

Poston and Stewart (1978) state:

"Catastrophe theory may be expected to give useful analyses of more widely varying data than do the current linear models. Of course, it requires the development of comparable statistical expertise for the essentially non-linear case before that expectation may be fulfilled."

Thom's (1975) 3-dimensional model of catastrophe attempted to explain the relationship between cognitive and somatic anxiety and athletic performance, and predict performance from this. Catastrophe theory predicts a negative linear relationship between the cognitive anxiety and the performance, but that the somatic anxiety also plays a role. Hardy and Fazey (1987) hypothesised that if somatic anxiety increases towards optimum while cognitive anxiety is low then performance will be facilitated.

## **Chaos Theory**

The ability to predict performance is inherent in the process of effective planning., but is very difficult to do accurately. Errors in statistical methods of predicting are often attributed to forecasting error but chaos theory suggests that those errors imply that performances follow natural trends and are better explained by non-linear rather than the more traditional linear mathematics.

"Chaos theory is the science that discovers order in nature's seeming randomness."

In more recent times scientists have discovered that certain systems within nature have chaotic dynamics and have an infinite variety of unpredictable forms but through a systematic process of self-organisation. The disorder of nature produces orderly patterns such as snowflakes. Other examples of non-linear chaotic systems are:



weather, national economies, fibrillating hearts. It is possible to mathematically equate the beating of the heart that will provide values for the process over time. These solutions can be mapped through an "attractor" graph, which shows a chaotic system's solutions converge towards a specific path. A small change to the input will vary the pattern. Although this variation appears to be chaotic and random it is a reflection of a high order of complex events.

This provoked interest in whether this pattern of chaos and self-organisation could also be evident in human situations.

Stacey (1993) examined the possibility of using this new frame of reference in the management sector. His investigation was based upon the fact that the behaviour of some systems within nature is so complex that the link between action and outcome simply "disappears in the detail of the unfolding behaviour." Scientists see this notion of causality as being inherent within chaos theory and applies to most natural phenomena and is the reason why nature is always creative.

In the management of human organisations chaos theory points towards the need for managers to create an unstable environment for effective learning and hence new strategic directions to evolve. There are certain key points on the behaviour of dynamic systems and their applicability to human situations.

1. Chaos is a fundamental property of non-linear feedback systems. All human behaviour are non-linear because one action always leads to a subsequent one and people tend to over or under react. Therefore in any situation involving human interaction there is a possibility of chaotic behaviour as well as stable or unstable behaviour. The key question is which state leads to successful performance. Success will lie at the border between a state of stable equilibrium (ossification and team work) and an unstable state of equilibrium (disintegration and individual performance), that is in a non-equilibrium state between the two.
2. Chaos is a form of instability where the long term future is not known. When irregular patterns of behaviour operate away from equilibrium they will be highly sensitive to tiny changes and will completely alter the behaviour. Small changes leading to larger ones are common place occurrences in human situations. Stacey (1993) cited the example of VHS and Betamax.
3. Chaos has boundaries around its instability. Chaos is disorder and randomness at one level and qualitative pattern at another. When the future unfolds it often repeats itself but never in exactly the same way. "Chaos is an inseparable intertwining of order and disorder."
4. Unpredictable new order can emerge from chaos. Stacey (1993) highlighted eight steps to create order out of chaos:
  - a. Develop new perspectives on the meaning of control. Self-organising processes produce controlled behaviour although no one is control.

- b. Design the use of power. When power is used as a force it is consented to out of fear or not consented to out through rebellion. Groups in these states are not capable of the complex learning needed to develop new perspectives and models. In a business environment open questioning and public airing of views is to be encouraged.
- c. Encourage self-organising groups. Groups need to identify their own challenges and goals.
- d. Provoke multiple cultures. Rotate people between their tasks and from external sources.
- e. Present ambiguous challenges not clear long-term aims. Offer half-formed ideas for others to develop.
- f. Expose the group to challenging situations rather than run away from the unknowable future.
- g. Devote attention to improving group skills. "The route to superior learning is self-reflection in groups.
- h. Create resource slack through investing in additional resources.

Priesmeyer and Baik (1989) used chaos theory to describe the performance of companies. They describe their organisational heartbeat as "quarter 1, quarter 2, etc.". What chaos suggests is that a certain cycle will be followed over time but that there may be a divergence from this pattern in response to any environmental changes. One company, Toro, which manufactured snow-throwers experienced a change to chaos. In the winter of 1979 the USA had limited snowfall, shocking the company from a stable period one pattern to a chaotic behaviour pattern and then to a more stable one again. This transition back to a stable pattern represents successful dampening of the chaotic condition. i.e. through introducing a price incentive program.

### **Critical Incident Technique**

"The critical incident technique outlines procedures for collecting observed incidents having special significance and meeting systematically defined criteria."

Critical Incident technique was developed by Flanagan (1954) to identify why student pilots were exhausted at flight school. The technique was further developed at the American Institute for Research to continue "the systematic research on human behaviour in defined situations."

Some research on the pilots was undertaken by Miller (1947) and the conclusions were that pilots were eliminated for such reasons as poor judgement or insufficient progress.

The critical incident technique:

"consists of a set of procedures for collecting direct observations of human behaviour in such a way as to facilitate their potential usefulness in solving practical problems, with emphasis on observed incidents possessing special significance."

The incidents noted are those that the observer believes to be both crucial effective and crucial ineffective behaviours. These incidents are then categorised according to the behaviours to constitute the critical requirements. Flanagan saw the technique as a flexible one which should be modified to meet the specific needs of any given situation, and research has been made not only with pilots but also with nurses (Teig, 1953), teachers (Domas, 1952) and administrators.

Jensen (1953) found the critical incident technique to be a sound, objective way of collating information, as does Merritt (1954).

"The critical behaviours are derived from the reporter's description of actual teaching incidents, rather than their value judgements about critical teaching behaviours."

The critical incident technique is a powerful research tool but as with other forms of notating behaviour there are limitations inherent in the technique. Flanagan (1954) admitted that "Critical incidents represent only raw data and do not automatically provide solutions to problems" and Burns (1956) was even more critical:

"The indiscriminate use of the critical incident technique in the establishment of success criteria . . . can only result in fetish collection of data which describes everything and explains nothing."

Another limitation of the technique is the total dependence on the reporters' opinions and this subjective element inherent in the use of the technique is often stated as a disadvantage. but

Flanagan also pointed to the advantages of such a technique:

"The critical incident technique, rather than collecting opinions, hunches and estimates, obtains a record of specific behaviours from those in the best position to make the necessary observations and evaluations."

Barclay (1968) used the critical incident technique in teaching beginners to swim. His methodology included a questionnaire asking both the teachers and the students to identify, if possible, two specific critical incidents which they believed to have helped and hindered the instruction. In his pilot study of 30 students, 48 critical incidents (28 effective and 20 ineffective) were indicated.

A critical incident was used as long as the criteria laid down was met:



1. It described an actual happening observed or participated in by the observer.
2. It took place in beginning swimming instruction.
3. It included a clear description of teaching behaviour.
4. It showed a teacher behaviour/student outcome relationship.

Barclay tested for reliability by asking two judges to abstract critical behaviours from the same 50 incidents. Judge 1 identified 62 behaviours and agreed with the investigator on 85.5 % of the behaviours identified. Judge 2's corresponding figures were 68 and 88.9%. In the study a total of 1505 critical behaviours were extracted from the critical incidents - a 929 effective and 576 ineffective split.

Garis (1966) aimed to identify both ineffective and effective teacher behaviour in gymnastic instruction and thus establish specific guidelines for effective teaching. Over three thousand schoolgirls and over two hundred teachers from New York state were used in the research. The research undertook three major steps:

1. Testing the reliability of the abstracting process
2. Identifying and abstracting the critical behaviours from the incidents.
3. Categorisation of the critical behaviours.

This enabled Garis to establish a set of conclusions based on the critical incident technique which would provide a guideline of effective teaching for gymnastic activities to girls.

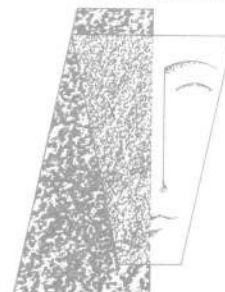
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