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Experiences in Selling Mathematics and Statistics to the Cricketing World: Market Penetration of the Duckworth-Lewis Method

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ABSTRACT

This paper briefly outlines the problems associated with interrupted matches in one-day cricket and the mathematics behind the Duckworth/Lewis method that provides a viable solution. Recent updates in the light of experiences from the Twenty20 format of the game are also discussed. Considerable emphasis is placed, however, on the experiences gained from trying to persuade the adoption of a method based on mathematics and statistics into a world, although familiar with summary statistics, is generally mathematically challenged.

Keywords: Average Run Obtainable (ARO), T20 cricket

INTRODUCTION

The cricketing world was introduced to the Duckworth/Lewis (D/L) method of target resetting in one-day cricket in 1997 (Duckworth and Lewis, 1998 and 2004). It has since become the standard "rain- rule" of the International Cricket Council (ICC) for adjusting targets in interrupted matches, and in almost all of the major national competitions of countries affiliated to the ICC.

In this paper, it is assumed that readers are familiar with the game of cricket and also of the nuances of one-day cricket. Some discussion of the basics of the game can be read, however, in Lewis (2005) and the authoritative rules and regulations can be read in Engels (2009).

One-day, or limited overs cricket, typically having between 40 and 60 overs per side, was introduced in the 1960s to satisfy an audience of spectators who desired to see a result to a match in one visit to the ground. This also suited the scheduling requirements of the growing television market. A problem arose, however, when weather interrupted the match and a reduction in the number of overs was necessary in order to complete the game in a day. The paper commences with a discussion of

the early and simple attempts to solve this problem, with illustrations of disasters along the way that led to the game trying out alternatives, which were just as flawed in other ways.

The paper summarises how Dr. Frank Duckworth and Dr. Tony Lewis became involved in this problem and how they began to work together in producing their method, which has a more mathematically and statistically based methodology than earlier attempts to solve the problem. A brief summary of the methodology is provided along with their initial presentations and their experiences of audiences with the cricketing authorities and their reactions.

In recent years a much shorter version of the one-day game has emerged, called Twenty20 (T20) cricket, in which each team receives only 20 overs. A game is completed, therefore, within about 3 hours and has become hugely popular both with spectators and TV companies. The Duckworth/Lewis methodology is applied in these matches also but, following the results of some high-profile matches, the applicability of the D/L method in such shortened matches has been called into question. Based on a previously scheduled review of recent data, the question is addressed in this paper.

Finally, the paper concludes with some reflections on the actions that Duckworth and Lewis have taken over the years that have lead to the establishment of the D/L method as part of the fabric of the modern one-day game.

Early Examples of Target Adjustment in Interrupted Matches

These follow several cases which illustrate the problems of handling interrupted one day matches and several attempts to handle their inadequacies.

Case 1: England v New Zealand, Perth, 5th February 1983

Lewis was present at this 50-over one-day international (ODI) in which England had reached 45/3 in 17.3 overs when heavy rain sent the players from the field for a few hours. On resumption, the match was reduced to 23 overs per side. In their remaining 5.3 overs England scrambled 43 more runs to finish on 88/7 in their reduced allocation of 23 overs. As New Zealand also had 23 overs available, there was no adjustment to the target. Clearly, however, England had been disadvantaged by the unexpected shortening of their innings, whereas New Zealand knew in advance that they were to receive only 23 overs and so could bat more aggressively

from the start. New Zealand scored their 89 runs well within these overs and won easily. This was recognised as being an unfair contest but the cricketing world had no mechanism to make any adjustment. Lewis had no thoughts at the time either but the match made an imprint which was recalled later.

Case 2: Australia v West Indies, Sydney, 18th January 1989

Due to early rain, this match was reduced before it started to 38 overs per side. There was no inequity in this because both teams knew in advance of the reduction. Australia scored 226/4 in their 38 overs. Before it could start, further rain reduced the West Indies innings to 18 overs, a valid length of innings at the time.

Since cricket is very familiar with batting and bowling averages, as summarised in Engels (2009), the logical process at the time was to reset the target for West Indies' 18 overs using Australia's average run-rate (ARR). Since Australia in their 38 overs scored at an average rate of 5.947 runs per over then 18 overs at 5.947, rounded up gave a revised target of 108 in 18 overs. This had been the standard process for target resetting in one-day matches since the 1960s. Everyone knew it was unfair generally advantaging the team batting second (Team 2). The logic being that with 10 wickets still available a team can be more aggressive with fewer overs to bat and can score at a generally higher average run rate than in a full ODI or, as in this case, the 38 overs that Australia actually had. In the match West Indies won easily scoring 111/2 in only 13.2 overs.

It is believed that this match had two effects. One was to usher forward a minimum-overs rule of 25 per team for a match to be viable. (This was later reduced to 20, following the success of the D/L method). The second effect, in Australia at least who were the victims of the inadequacies of ARR in this match, was the invention of a revised rain-rule intended to negate the advantage to Team 2. Dubbed the Most Productive Overs rule (MPO), the West Indies target would have been determined by the 18 most productive overs of Australia's innings. From the scorers' perspectives there was a substantial amount of bookwork necessary in order to rank the overs by their scores before Team 2's innings began.

Whereas the logic of the method would appear to have merit in reducing the advantage to Team 2, it was based on the premise that interruptions to play only occur between the two innings. There were other technical difficulties that could arise such as Team 1 being all-out within their overs, but for stoppages at times

other than between the innings, especially one to terminate the match, the rule was a disaster waiting to happen.

Case 3: England v Sth. Africa, Sydney, 22nd March 1992

The disaster occurred at the most inconvenient and embarrassing time possible for the Australian administrators; the semi-final of the 1992 World Cup in Sydney. In this match, which began as 50 overs per side, England scored 252 in 45 overs when the time for South Africa to bowl their overs ran out. Subsequently Sth. Africa suffered financial penalties for their slowness, but they began their innings with the match reduced to 45 overs, as though from the start, with a target of 253; England received no compensation.

After seemingly in trouble, Sth. Africa recovered through Richardson and McMillan and were well in the match at 231/6 in 42.5 overs. 22 runs were required to win from 13 balls when rain interrupted play for a very short time. On resumption, applying the (rather inflexible) rules of the day, the umpires declared that the time lost represented two complete overs, and so play would resume for one ball! After some confusion it was declared that the target was still 253 and that 22 runs were still required from that one ball. This was because Sth. Africa, through M Pringle, had bowled two maiden overs. As a result of their own good bowling, when fielding they then suffered badly as the batting side from the MPO rain-rule.

The result, of course, was a win to England and a place in the final, but the match tolled the death knell of MPO and the launch by Australia to find a better method. In addition, cricket fans around the world came forward with their suggestions to improve the target resetting process.

One notable effort came from a Sth. African schoolboy, Wayne do Rego (do Rego, 1995). It was adopted by his home country and came to the attention of the CEO of the ICC through Sth. Africa's representative on the ICC's committees. It is significant in that it represents recognition that mathematics, other than the simple average, might have a role to play in the target resetting process. Using data from the English 1991 domestic season do Rego produced a formula $y(x) = 7.46x - 0.059x^2$ that represented the average score $y(x)$ from x overs. These averages were called 'norms'. It will be noted that $y(50) = 225.5$, close to the average ODI score of the time of 225. The mechanism of target resetting, subsequently adopted as the ICC(1995) rain-rule, first converted the 'norms' to percentages of the practical average of 225 in ODIs. Then Team 1's score in its 50

overs was revised by multiplying by the percentage appropriate for the reduced number of overs, x, available to Team 2.

Case 4: Victoria v Western Australia, Melbourne, 7th February 1998

This match again illustrates that the thinking of many cricket fans was still based on the between-innings interruption. Victoria scored 223 in their 50 overs and Western Australia (WA) had scored 188/1 in 43.2 overs when rain caused the match to be abandoned. Using the ICC (1995) method, the score at the end of the 43rd over was the basis for deciding the winner (fractions of overs were ignored). The percentage norm was $y(43)/225=94.1\%$ and the benchmark for 43 overs would be 223*94.1% = 209.81. Thus, WA need to have been at 210 or better to have won. In the event, much to dismay of the Western Australians who were clearly well on course for victory, Victoria were declared the winners – and by 22 runs!

Had the stoppage been between innings then 210 would have been eminently fair, but the late termination had exposed the deficiencies of the parabola and ICC's method as in the 1992 World Cup.

Enter Frank Duckworth

Duckworth tells the story that comments by the BBC cricket broadcaster and writer Christopher Martin-Jenkins (CMJ) on air in the 1980s galvanised him into thinking about a rain-rule mechanism that answered the many criticisms of the ARR method. He quotes CMJ as saying, after a particular disaster, "surely somebody somewhere can come up with something better". Duckworth realised that it was a mathematical problem that required a mathematical solution, and devised a relationship of average runs scored not only in overs available, but also taking into account of wickets lost; a feature not even contemplated by earlier approaches. His formula required inputs from real cricket data but without considerable research, these weren't available and so he made estimates of those inputs. The target re-calculation also needed many computations so he wrote a programme called Cricket: One Day Analysis shortened ever after to CODA.

His ideas reached the academic community through the 1992 conference in Sheffield of the Royal Statistical Society (RSS). Duckworth was the organiser of the "Statistics in Sport" stream. At the last minute one of his speakers pulled out. Rather than leave a gap in the programme, he wrote up his rain-rule ideas into a paper which he entitled "A fair result in foul weather". The delegates were impressed with his solution to the rain problem and urged him to contact the

cricketing authorities. He obtained an audience with Tim Lamb, Cricket Secretary of the England Test and County Cricket Board (TCCB). Lamb was impressed with the ideas, but balked at the thought of the need for computers. "Cricket", he said in 1992, "is not yet ready for computers". Consequently, Duckworth's meritorious ideas lay fallow for a while. But the importance of that first contact with the administrators of the game of cricket cannot be overstated.

Enter Tony Lewis

In 1992, Tony Lewis was a lecturer in the Faculty of Computing, Statistics and Mathematics (CSM) at the University of the West of England (UWE), Bristol. Dr Jeff Jones, a lecturer in Statistics and colleague of his, attended the 1992 RSS Conference and Duckworth's talk in particular. As is common in educational institutions, staff who attend conferences are required to circulate a report and copies of relevant papers. This is to maximise the benefit within the School of the often not-inconsiderable cost of conference attendance. Lewis, a keen cricket fan of course, seized upon Duckworth's paper not just from interest but also in connection with his responsibility for final-year student projects. Duckworth's admission that someone needed to undertake research into real cricket data in order to estimate the parameters of his basic formula struck a chord. Lewis formulated such a project which he supervised when Julian Adams, a keen cricketer himself, volunteered to undertake it. He obtained several years of data from the three English one-day competitions of 40, 55 and 60 overs per side.

Several months later, Adams graduated having done some estimation of the parameters and shown the viability of Duckworth's approach. Was that to be the end of the story?

Lewis decided it was too good an idea to leave there, so he contacted Duckworth to explore the possibility of developing the idea further and to raise interest with the cricketing authorities. It so happened that Duckworth lived (and still does) not too far from Bristol, so meetings were easy to arrange and a local pub called *The Pickwick Inn* became the regular meeting point.

90% Perspiration, 10% Inspiration

It is colloquially said that any invention is the result of 90% perspiration and 10% inspiration. The invention of the D/L method is no exception. During 1993-94, Lewis with the support of his CSM Faculty at UWE, did further analysis with as many datasets as possible and tried several variants to the relationship of average

runs to overs bowled and wickets lost. But the formula still needed CODA to undertake the calculations, or the use of a telephone directory sized set of tables. Duckworth and Lewis felt, however, that it was time to make a fresh approach to the cricketing authorities. In early 1995, writing to Tim Lamb at the TCCB on UWE notepaper seemed to carry considerable weight. It was learned in various exchanges that David Richards, the CEO of the ICC who were also based at Lord's at the time, was also looking into various rain-rules for the 1996 World Cup to be held jointly between Pakistan, India and Sri Lanka (PILCOM).

Various diary constraints, however, meant that a meeting could not be fixed until 12th October 1995. That delay worked against and for (in that order) Duckworth and Lewis. By the time the meeting was held, there was little time left to influence the decision on the rain-rule for the 1996 World Cup. Despite its faults the ICC (1995) rule was adopted. Fortunately for PILCOM, however, it was not called into use at any stage of the competition.

That delay gave more time for consideration of the runs/overs/wickets relationship. Duckworth was on holiday in Hawaii when a brainwave struck him that would substantially simplify the formula. A letter to Lewis summarised the structure of the formula as $Z(u,w) = Z_0 F(w)\{1-\exp(-bu)\}$, in which *Z(u,w)* represents the average runs scored in u remaining overs when w wickets had been lost, with b an exponential decay constant, Z_0 an asymptote and *F(w)* a monotonic decreasing step function of w with $F(0) = 1$. Whilst recognising the merits of the formula, Lewis realised that the decay factor needed to be a function of w also, *b(w)*, and faxed Duckworth accordingly. Further research determined that the nature of the decay factor could be represented by $b(w) = b/F(w)$ and so the final form of the D/L model became $Z(u,w) = F(w)Z_0\{1-\exp[-bu/F(w)]\}$. The parameters b and F_0 were estimated using the TCCB data with a weighted least squares approach, but data to estimate the *F(w)* were sparse and so these were determined more by cricketing commonsense in the first instance.

The next step was to produce a table of Average Runs Obtainable (AROs) in terms of u overs left (60,..,0) and w wickets lost (0,..,9) and his table could be used for all lengths of matches. This table, in conjunction with a pocket calculator, was all that were needed to revise targets. Everything could be done manually and without a computer. This was the "Eureka" moment!

The table was used to calculate the deduction in runs from the target for the reduction in overs of an average match. This was scaled according to Team 1's total in relation to the average for the competition and then rounded to the nearest integer.

The First Lord's Presentation

12th October loomed closer. Lewis, with his academic background and lecturing experience, led preparations and rehearsals for that important presentation. It was regarded as key to gaining recognition by ICC and TCCB that the mathematics was kept to a minimum but that examples of past disasters would illustrate how the method would work to solve the previous problems.

At this stage a new name for the method had not been settled upon. do Rego's Parabola Method had surfaced by this time and R. Clark, also in South Africa, had published the Clark Curves. Duckworth and Lewis, although living in Gloucestershire, were both from the English County of Lancashire. And so it was "*The Lancastrian Method*" that was presented to David Richards of ICC and Tim Lamb of TCCB with ICC's Cricket Operations manager, Clive Hitchcock, also in attendance at Lord's.

Richards, with an economics and management background appreciated the mathematical logic, however, and there was a general recognition of the logic and fairness of the method. Duckworth and Lewis were then charged with reviewing the inputs to the formula using just ODIs, which was ICC's major interest – and to think up another name for the method! An invitation was then extended to address the Chief Executives of the major ICC countries at Lord's in July 1996.

The Second Lord's Presentation

In the subsequent months, the ODI data were analysed and slightly different parameters for b and $F(w)$ found to be appropriate. But the basic structure of $Z(u,w)$ was no different. Since 50-over ODIs were to become the major focus, the final structure of the model thus became

$$Z(u, w) = F(w)Z_{50}\{1 - \exp[-bu / F(w)]\} / \{1 - \exp[-50b]\} \qquad (1)$$

when the asymptote Z_0 was represented in terms of the average score in a 50-over ODI, $Z(50,0) = Z_{50.} = 225$. The basic structure of the formula was not changed since that time.

In addition, it was realised that rather than presenting the target resetting process in terms of AROs, it would be expedient to have a table of percentages; equivalent to those which had become familiar in the ICC (1995) method. Thus came into being the idea of Resource Percentages represented by $P(u,w) = Z(u,w)/Z(50,0)$ and also presentable in the form of a two dimensional table, down to every ball of the innings as necessary.

The second task, as charged by David Richards, was to create a new name for the method. As Lewis had joined Duckworth, the very neutral name of the Duckworth/Lewis Method was decided upon with the intention of leaving it to the media if a shorter, catchier, name was deemed appropriate.

On 12th July 1996, Duckworth and Lewis presented themselves at the ICC offices at L'ord's and were taken to the Committee room in the famous pavilion. En route, the list of members of the committee was handed over. The Chief Executives of countries were not faceless administrators but were panoply of former famous cricketers, including Sir Clyde Walcott of 3Ws fame in the chair, Ali Bacher from Sth. Africa and Majid Khan from Pakistan. Already nervous constitutions turned somersaults!

The presentation and subsequent discussions went very well, however. By using simple examples as introductions, and previous disasters, particularly several involving Sth. Africa, as illustrations of how the method would solve the many and varied ways in which stoppages occur, a favourable reaction was obtained. The decision made was for the CEOs to take the papers back to their countries for further consideration and for action as felt appropriate. The considerable efforts in the development of the Duckworth/Lewis method and in the preparations for its selling were showing signs of paying off.

The Early Breakthroughs

In late 1996, the TCCB was in the process of being re-organised as the England and Wales Cricket Board (ECB). An invitation was received from the chair of its Cricket Committee, David Acfield, the former Essex spinner, to make a further

presentation to that committee at Lord's. As with the ICC's CEO committee, this committee consisted of mostly former county and international cricketers including Sir Colin Cowdrey, Brian Close, Bob Willis and Mark Nicholas. Following the same format of avoiding the mathematics, using simple examples as introductions and illustrations of how past failures of TCCB's ARR method would have been avoided, again a favourable impression was conveyed. Expecting the committee to debate the matter in private following our presentation it was a considerable surprise that there and then, David Acfield obtained a general consensus that the D/L method should be trialled for the 1997 domestic season. The Cricket Operations manager, John Carr (former Middlesex bat) was charged with its implementation. Several celebratory drinks were consumed in the nearby pub at Lord's afterwards!

At practically the same time, Ian Robinson, the CEO of Zimbabwe Cricket faxed a request to be able to use the method for England's forthcoming tour. It was a double celebration, but the full rules and regulations then needed to be written. This was soon realised to be not an inconsiderable task, as can be seen on ICC's website [http://icc-cricket.yahoo.net/rules_and_regulations.php].

The First D/L!

This happened on 1st January 1997 in Harare. Zimbabwe batted first and scored exactly 200 runs in their 50 overs. For the understanding the method it could hardly have been a simpler calculation. Table 1 shows an extract of the resource percentages applicable to the match.

Rain in the interval reduced England's innings to 42 overs. Whereas ARR reduces targets in proportion to overs available, the D/L method adjusts targets according to resources available. It is seen that Zimbabwe had all 100% resources and England had 92.5% resources, compared with a 50-over innings. Thus the calculation of the target is 200*92.5/100 = 185, a calculation that most cricket spectators could do even without a calculator.

Table 1: D/L resource percentage table for 1997-2002

	Wickets lost				
Over left	**0**	**2**	**5**	**7**	**9**
50	100	83.8	49.5	26.5	7.6
42	92.5	79	48.6	26.4	7.6
40	90.3	77.6	48.3	26.4	7.6

30	77.1	68.2	45.7	26.2	7.6
25	68.7	61.8	43.4	25.9	7.6
20	58.9	54	40	25.2	7.6
10	34.1	32.5	27.5	20.6	7.5
5	18.4	17.9	16.4	14.0	7.0

Whereas the calculation by match officials was done correctly, because of the integral nature of the result, it was not fully appreciated that this should have been the score to beat. The target should have been 186 with 185 to tie. But the target was announced as 185. Duckworth suggested sending a fax pointing out the error. Lewis suggested otherwise since it would not look good announcing an error on the very first use of the D/L method. This was a first lesson in public relations. So silence was kept and silent prayers made that the final score wasn't 185!

In the event England looked like strolling to victory but a typical collapse left England on 179/7 in 42 overs and losing by 6 runs, whereas they would have won by the old ARR method. It was a strange sensation listening to the radio and feeling "responsible" for England losing a cricket match.

Media Reaction

Although there had been some publicity of the new D/L method in the print media in the early part of England's Zimbabwe tour, it was with some trepidation that the newspapers were opened on 2nd January. Perhaps some sorts of congratulations were expected? The sports media had a field day with a selection of quotes as follows:

- "The players have to shoulder most of the responsibility for this particular failure rather than.... Messrs Duckworth and Lewis" Vic Marks, *Observer*
- "Academic responsible for England losing...." Hugh Richards, *Times Higher*
- "The new system is intended to be fair to both sides but only Zimbabwe were the beneficiaries" Simon Mann, *Guardian*
- "This system is so indecipherable (*sic*) that the Admiralty might be interested in it for a new secret code" Martin Johnson, *D Telegraph*

During the 1997 ECB season, media were also generally rather critical but basically uncomprehending of the rational and fairness of the method.

- Australia won after.... the dreaded Duckworth/Lewis calculation came into force" Simon Barnes, *Times*
- "..a much vaunted and complicated new system" Ivo Tenant, *Times*
- "The new system is bizarre", Peter Byrne, *BBC*

Offers to explain the method to the media were ignored. It was plain that the somewhat numerically challenged journalists preferred to rejoice in their ignorance, rather than make any effort to understand, and thereby inform their readers. Nevertheless there were many supporters, some of whom wrote in defence of D/L.

- "(D/L) will soon be an accepted part of the limited overs game", Keith Booth, letter to *The Times*
- "The Vera Duckworth?... it is much fairer than the old method, no doubt about that" Byron Denning, *The Guardian*

Denning's quote refers to a character in the TV soap opera *Coronation Street.* Although devising an alternative name to the D/L method was left to media, "Vera" was not was hoped for. But it was turned to advantage by representing VERA as an acronym for "Very Equitable Rain Adjustment"!

In general, retaining a dignified silence to the barbs of the scribes turned out to be the best strategy to some of the crass comments bandied about in the early part of the season; letting others speak (without prompting) was much more effective. In short, the inventors soon grew a few extra layers of skin.

This patience was rewarded when, after a few seasons of use and experience, comment mellowed, supported by quotes from high profile cricketers of the time.

- "It's the best method by a long way" *Steve Waugh* (1999)
- "I think it is probably the fairest system..." *Nasser Hussain* (2002)
- "The two rain-rule boffins have, by general consent, devised a fairer system" *Martin Johnson, Daily Telegraph* (1999)

Take Up the D/L Method

During the ensuing years the method became established within the cricketing community as whole, with the following landmark events as to when it was used:

- **1997:** Zimbabwe, ECB, ICC Trophy but a failure to persuade New Zealand & West Indies Cricket Board (WICB)
- **1998:** Commonwealth Games; ICC Champions Trophy, Dhaka, followed by other major countries - including WICB
- **1999**: World Cup followed by a full international 2-year trial
- **2000:** All countries under ICC, age level ODIs, club levels
- **2001:** Full adoption by ICC and full-member countries as standard 'rain rule'
- **2004:** "Winner" of a review of several competing methods

D/L Applied to Historical Cases

To complete the scenarios of Cases 1 to 4, the following would have been the targets and results based on the D/L tables as printed on the ICC website cited earlier.

Case 1: New Zealand would have required 109 in 23 overs instead of the 89; still not very demanding thereby rewarding New Zealand for the strength of their position at the interruption but providing some compensation to England for the unexpected shortening of their innings.

Case 2: West Indies would have required 137 at 7.61 runs per over against Australia instead of the ARR target of 108.

Case 3: Sth. Africa's requirement would have been 4 runs from that one ball and not 22!

Case 4: The par score at the termination would have been 171, so that Western Australia would have been declared the winners by 17 runs, instead of losing by 22 runs; a verdict reflecting the strength of WA's position.

Modelling Improvements

As stated previously the basic formula (1) has been unchanged since its final creation in 1996. There have been some significant improvements however in the way the D/L method has been applied in the intervening years.

- **1998**: Improved handling of Team 1 stoppages.

This was never visible to the users, but after the first year of operation the method of handling enhanced targets was improved to that as described in Duckworth and Lewis (2004).

- **2002**: Data review increases the 50-over average and better models the effect of wickets

After some years of operation with detailed over-by-over data available via the internet and commercial sports data organisations, the actual effect of loss of wickets on average further runs could be determined, replacing the "common-sense" values of $F(w)$ used initially. In addition, average ODI totals had increased to 233.1, with a standard error of 3.1 showing a statistically significant increase from the 225. The Z_{50} was raised to 235.

- **2003**: Introduction of the Professional Edition to handle matches better having well above average scores.

Whereas the ability to handle target calculations manually was a major selling point of the D/L method, the basic model is not a good fit in higher scoring matches, which were becoming more prevalent. A more refined model, making the graphs more linear in higher scoring matches had been previously been identified, but its use required computers which were still not ubiquitous although more prevalent. The tipping point for ICC was the 2003 World Cup final in which Australia scored 359 but India, at 145/3 in 23 overs looked as though they could undeservedly steal the cup had a number of not unlikely events come to pass in the next two overs and the match were abandoned to threatening rain.

The Professional Edition (Duckworth and Lewis, 2004) is able to cope with high-scoring matches and then introduced into ODIs and national competitions, with authorities accepting that computers were needed at all such matches. But the original version, renamed the Standard Edition, continued for levels of the game where computers were not guaranteed.

With this greater ability to handle higher scoring matches, prima face, there was no real concern with the advent of Twenty20 competitions that the method could not be used for these also, until sufficient data were available.

- **2005**: Data review shows no changes necessary

The average ODI total had risen to 238.1 with a standard error of 3.3 but this was not significantly different from the Z_{50} of 235. It was decided that no change to the inputs to formula (1) was necessary, with the benefit of stability and rendering an update of the documentation unnecessary.

2009: Data review comparing ODIs and T20s leads to minor changes to inputs of the Professional Edition. The Standard Edition remained unchanged.

After the end of the 2008-09 season, a review of the previous 4 years of data was commenced in order to (a) review the scoring patterns of ODIs and (b) to test the assumption that D/L was valid for T20s.

It was in the middle of this review that the World Twenty20 Championships took place in England in June 2009. England lost their quarter final match to the West Indies via the Duckworth/Lewis method. England scored 161 in 20 overs when rain reduced the WI target to 80 in 9 overs. There was much comment that the target was too low for all 10 wickets. After 4 years of uncontroversial use of D/L in T20s suddenly claims were made, at high levels, that D/L needed to be revised for T20s.

It was pointed out to such critics that all 10 wickets are rarely required and it's the run-rate that's important, which is much more even in T20 matches. So to ask around 9 per over was not unreasonable

2009 DATA ANALYSIS

In order to answer the serious queries, the data over the past 4 years or so of both 50-over matches and T20s needed reviewing and how these data compare with the D/L formula. For this, average runs scored in the overs remaining for the wickets lost have been obtained over the two datasets outlined. For simplicity only the situations for no wickets lost are examined. Actual averages are compared with the expected values from the basic mathematical D/L formula (1), using the latest revised inputs to the formula. The formula for average runs $Z(u)$ for overs left when no wickets have been lost, represented by u, is given in (2) in which Z_{50} is the average runs in 50 overs.

$$Z(u) = \frac{Z_{50}\{1 - Exp(-bu)\}}{\{1 - Exp(-b50)\}} \qquad (2)$$

These data show that Z_{50} has increased significantly from 235 to 244.0 (with a standard error of 3.0) over the past 4 years. However, the Z_{50} was set at 245. The value for b, the exponential decay constant which best fits these data using weighted least squares, is 0.0395. These values are reproduced in the title lines of the graphs for the purposes of identification. The two graphs that compare ODIs and T20s are provided as Figures 1 and 2.

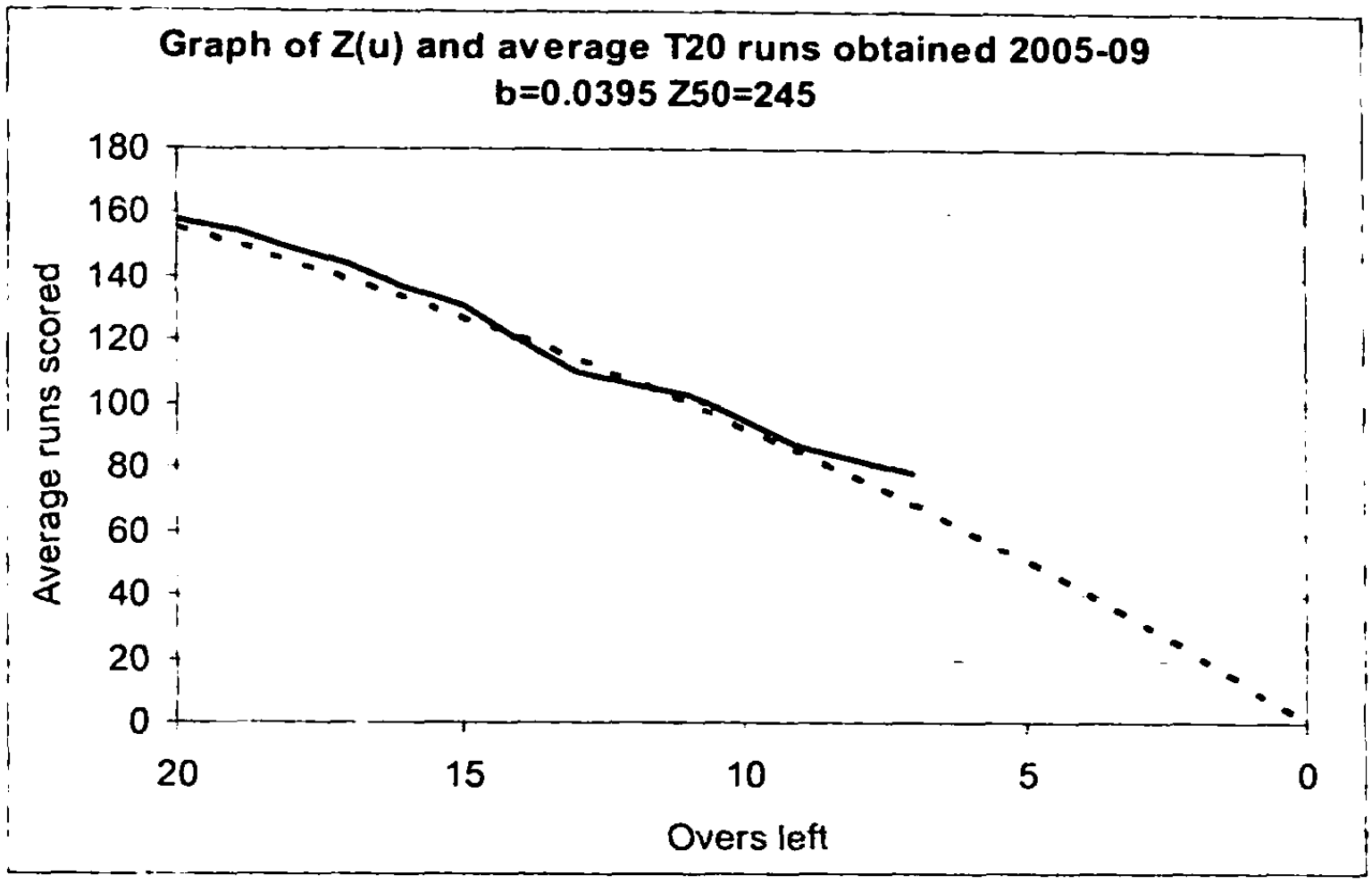

Figure 1: Graph of average runs for T20s

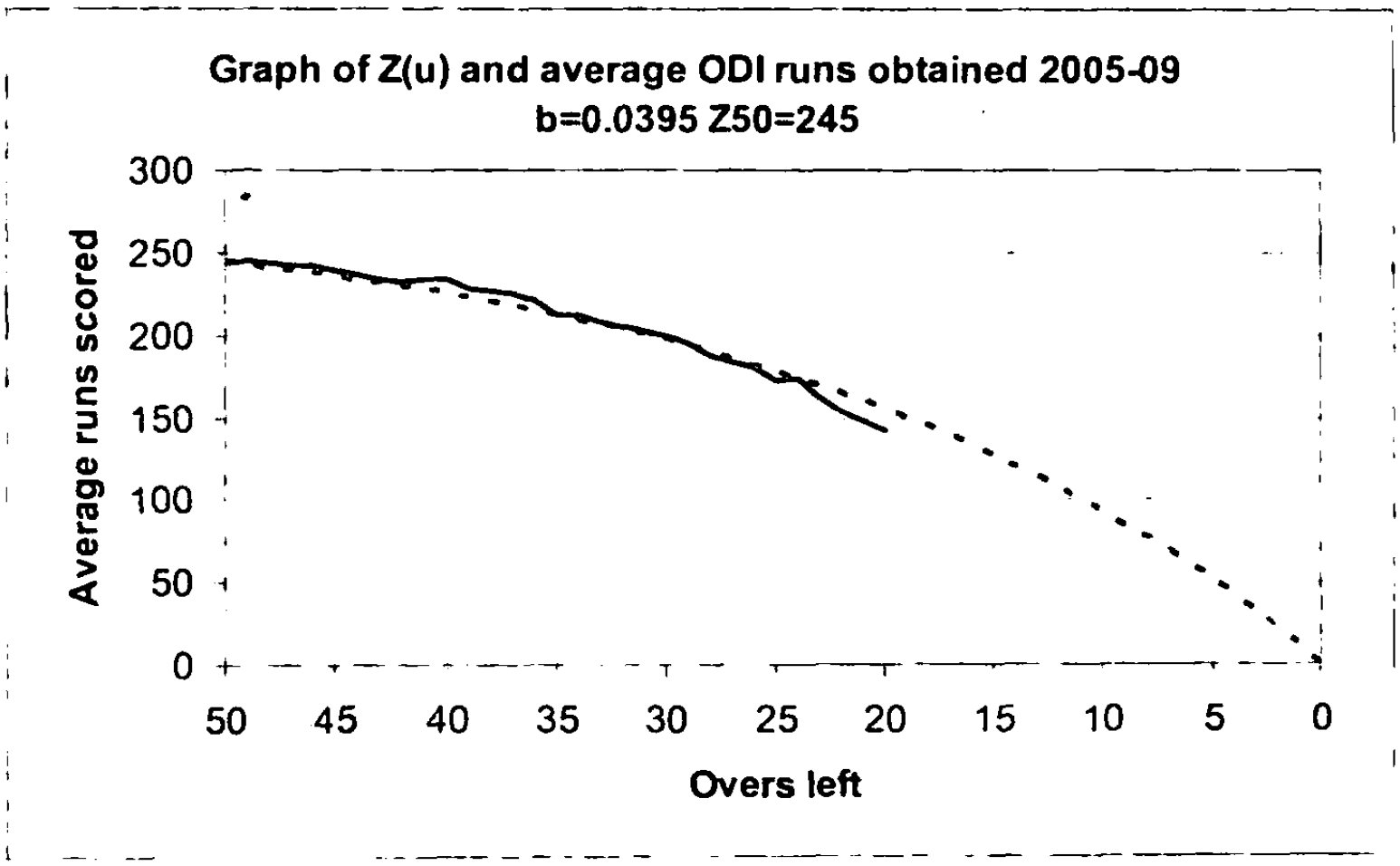

Figure 2: Graph of average runs for ODIs

It will be seen that, within natural statistical variation, the same inputs provide good fits to the actual averages (the wavy lines) by the D/L formula (2) (the dotted lines)

for both graphs. In other words, the same basic D/L formula explains the average scores in both ODIs and T20s. Hence the D/L method is equally applicable to ODIs and to T20s, and separate tables or methodology are not necessary.

Similar graphs for the average runs scored in remaining overs but with wickets lost from 1 to 9 (inclusive) are not presented here. However, they show consistency with the conclusion above.

The aforementioned data analysis has subsequently led to slight changes in the D/L tables, and hence targets, when compared with the tables applicable until end of the 2009 season. The new inputs to the Professional Edition came into effect for the 2009-10 season. As a consequence, and partly because of the introduction of the increased average 50-over total, the target for WI in that World T20 match would have been 84 in 9 overs.

SOME REFLECTIONS

Although it is not claimed that the success of the D/L method is any template, nevertheless it is felt that several things were done well in travelling down the long road to the implementation of the D/L method.

- **Identifying a "gap in the market"**

The cricketing world was desperate for a reliable rain-rule following the 1992 World Cup debacle in Case 3 above.

- **Development of a robust product to fill the gap**

The method devised has shown to provide sensible answers to reset targets in the many varied ways, and stages of matches, that these can occur, and some that were not considered before, such as in Case 1 above.

- **Getting the ear of key cricketing personnel**

Inventing the mathematically and statistically based method was one achievement, but more importantly perhaps was getting the cricketing authorities, generally not quantitatively inclined, to listen and to accept the methodology. It was good fortune that both ECB and ICC, at the time, had their offices in London, a modest train-ride

away from Bristol, so that personal contacts were not too difficult to establish, to foster and to maintain.

- **Pitching at appropriate levels and using familiar cases**

Lewis's experiences as a lecturer were invaluable when presentations were made to key cricketing personnel. The key acronym employed was *K.I.S.S* – keep it short and sweet. Although there were significant mathematical bases to the method, the strength of the method was in its simplicity in operation with the ability to undertake calculations manually. Simple examples illustrated the principles of handling stoppages at various stages, followed up by actual cases from the past which showed how more satisfactory outcomes would have been obtained. Cases in which specific countries suffered were particularly helpful in gaining acceptance.

- **Answering queries personally and promptly**

There have been many queries and questions, initially from several countries' authorities and later from many members of the public. The strategy has been to answer these promptly and personally. In general the questioner or discussant has gone away wiser, and content having received the human touch. Good public relations have been a key to gaining acceptance once the method had been introduced.

- **Patience and civility with a sceptical media**

As mentioned previously, the media have shown considerable reluctance to embrace the new methodology. Journalists are generally wordsmiths and tables of numbers are somewhat anathema to them. Comments about the "arcane" nature of the method have abounded, yet offers of providing explanations have been largely ignored. It has been good politics not rise to the bait of much ill-informed comment, but when face to face with some of the print and TV media relationships have usually been very cordial and constructive.

- **Stability with periodic updates**

The method was introduced in 1997, with some of the parameters of (1) based on "commonsense" because of the lack of appropriate data. Such data soon became available through the internet, but impulses to change the tables were resisted on the grounds of the need for stability, whilst the cricketing world was getting used to the method. It was not until 2002 that a thorough review of the data warranted a change to the tables. By this time the method had become established and there had been no

problems, and therefore adverse publicity, due to users referring to the wrong tables. A three-year cycle was instigated to maintain that stability but to keep up with the changing nature of the game.

It was expedient also to be "ahead of the game" when the upgrade to the Professional Edition became necessary. Duckworth and Lewis led the game into this rather being reactive to the scenario of the 2003 World Cup final as outlined.

- **Support of the academic community**

A significant factor in the acceptance of the D/L method by cricketing authorities has been the support of the academic community. The D/L method was first presented at the 3rd Maths and Computers in Sport Conference in Queensland Australia in September 1996, and Duckworth and Lewis (1998) followed soon after, which won the Operational Research Society's Goodeve Medal for the best published paper of that year. The cricketing community has been reassured thereby that the D/L method has firm mathematical and statistical foundations.

Subsequently, Lewis in particular with his academic connections has presented at many conferences in various parts of the world, particularly in those countries that were part of the old British Empire.

- **Good teamwork melding different strengths**

Finally, but by no means insignificantly, a major factor in the success of the D/L method has been the melding of the comparative strengths of Duckworth and Lewis. The former has had a bias in the technical skills, whereas the latter has had a bias in the communications skills, although neither is lacking in the skills of the other. Debate has been common on how to proceed, sometimes over a week or two before the path ahead has been agreed. Both have been equally enthusiastic in the project and in the subsequent satisfaction that has resulted from the project's implementation and acceptance by the cricketing world as a whole.

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