Institution: Oxford Brookes University		
Unit of Assessment: 17, Business and Management Studies		
Title of case study: The formula that changed cricket		
Period when the underpinning research was undertaken: 2004		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Dr Anthony Lewis MBE	Senior Lecturer	[text removed for publication]
Period when the claimed impact occurred: 2014–2020		
Is this case study continued from a case study submitted in 2014? Y		

1. Summary of the impact

Cricket is the second most popular sport in the world with its number of fans estimated to be over 1 billion throughout the globe. The Duckworth Lewis (D/L) method establishes that, in the event a match cannot reach its own natural conclusion, there is a fair means by which a winner is decided The updated D/L method Stern Edition (D/L/S) is the method for adjusting targets in interrupted, limited overs cricket matches, firmly established within the rules and regulations of the International Cricket Council and implemented at all levels of the game throughout the world.

2. Underpinning research

Dr Anthony Lewis' research interests were in the application of operational research techniques and methodology to performance measurement, decision making and strategy planning to individual and small-group human endeavours. The impact claimed within this case study is derived from research undertaken at Oxford Brookes University that built upon the innovative and acclaimed original Duckworth/Lewis (D/L) method. The original D/L method published in 1998 saw Lewis collaborate with Dr Frank Duckworth, whilst he was employed by the University of West England. In 2004, employed as a Senior Lecturer at Oxford Brookes University, work by Lewis (co-authored with Duckworth) reviewed the robustness of the original D/L method whilst providing fuller details of the model behind the method. Although there is no simple way to explain the formula's workings, in essence it treats overs and wickets in hand as "resources" available to a batting side and makes proportionate adjustments to the target in the event of those resources being lost through interruptions, such as rain delays. The 2004 paper confirmed the D/L method's suitability for use in interrupted limited-overs cricket matches but also indicated a need to update the model's parameters.

The original model is a simple two factor exponential relationship:

$$Z(u,w) = Z0\,F(w)[1 - \exp\{-\frac{bu}{F(w)}\}]$$

Where Z(u,w) is the average further number of runs made when there are u overs remaining and w wickets down. Z0F(w) is the asymptotic value of further runs expected with w wickets down as u tends to infinity, F(0) being set to unity. The parameters, b, Z0 and the nine values of F(w) were estimated from an analysis of a one-day database. The Duckworth and Lewis (2004)[1] paper drew

on several years of data from international matches and demonstrated that the original model was representative of average runs scored in limited overs cricket matches. However, the original model relied on the assumption that performance was proportional to the mean, irrespective of the actual score. In the majority of matches, the assumption held true but when very high scores were involved, the simple approach started to break down and consequently targets could be less equitable for both sides. Data indicated that certain parameters of the original model required updating to reflect the changing nature of the game since the method's inception. Data also indicated a need to upgrade the model to cope with high scoring matches where the original model's assumptions no longer hold. The upgraded formula (the D/L Professional Edition) proposed was:

$$Z(u,0,\lambda) = Z0\ F(w)\lambda\mathrm{n(w)} + 1\ \{1 - \exp(-\frac{bu}{[\lambda\mathrm{n(w)F(w)}]}\}$$

The additional parameter, λ, had to be determined for every Team 1 innings, allowing for any stoppages in that innings. This gave fair targets even at the very highest score made but could no longer be implemented manually.

3. References to the research

1. Duckworth, F.C., Lewis, A.J. (2004). A successful operational research intervention in one day cricket. *Journal of Operational Research Society*. Vol. 55 No.7. pp 749-759. DOI: 10.1057/palgrave.jors.2601717

Journal article that upgrades the original D/L method and led to the Professional Edition adopted by the International Cricket Council from 2003. At the time, Anthony Lewis was employed as a Senior Lecturer at Oxford Brookes University. Indeed, this article was included as one of Lewis' four outputs submitted to RAE2008, UoA36 - Business and Management Studies [AJ Lewis, RA2, Output 2] (the Association of Business Schools journal quality list rating for this journal is 3-star).

4. Details of the impact

The D/L method created by Duckworth and Lewis has endured for over 20 years as the International Cricket Council's (ICC) official method of recalculating the target score for a team batting second in interrupted limited overs cricket matches. Its use by Cricket's international governing body and by those at the very top of the game through to local junior leagues demonstrates its global reach, relevance and significance.

Cricket is the second most popular sport in the world, with over 1 billion fans and more than 300 million participants[1]. With the introduction of T20 cricket in 2003, the popularity of the game has reached a new level with a number of high-profile T20 leagues established around the world. Despite its global popularity, it is a rare sport in that play is regularly abandoned due to rain which, prior to the introduction of the D/L method, would mean that matches ended with no result or an unfair result. The D/L method (now updated to the Stern Edition - D/L/S) establishes that, in the event a match cannot reach its own natural conclusion, there is a fair means by which a winner is decided and, since 1999, it is the International Cricket Council's (ICC) official method of recalculating the target score for a team batting second in interrupted limited overs cricket matches.

The ICC adopted the D/L method in 1999 to replace previous approaches to setting targets. The traditional method used proportions of overs to revise targets (Average Run Rate) e.g. in a fifty over match the team batting second because of rain only had thirty overs to chase the required score, they would have a revised score to beat of 60% of the original. This method was generally

more favourable to teams batting second though and made it a lot easier to chase scores down. The Australians adopted a method (Most Productive Overs) which saw economical bowling overs from the first innings removed to increase the difficulty of chasing. This though ended in farce, as South Africa playing England in the 1992 World Cup went from needing 22 runs in 13 balls to requiring 22 runs from one ball because of a short downpour[2,3]. Subsequently the ICC adopted the upgraded D/L Professional Edition (based on the 2004 paper by Duckworth and Lewis, Reference 1). Retrospective application of the D/L Professional Edition to this match shows that South Africa would have needed four runs to win from that final ball – an achievable and fair target[4]. In June 2012, the ICC went on to confirm its continuing commitment to the method, following a challenge from a new approach (the VJD method). The ICC said in a statement "The committee unanimously agreed that there was no evidence of any significant flaws in the D/L method nor did the committee believe that any improvements could be offered by the VJD method. Therefore, the committee decided to continue with D/L,"[4].

Following the retirement of Duckworth and Lewis in 2015, Professor Steven E Stern (QUT, Australia) became custodian of the formula in 2014 extending the methodology to address extreme scoring rates observed in modern forms of the game (Twenty20):

> Stern, SE. (2016). The Duckworth-Lewis-Stern method: extending the Duckworth-Lewis methodology to deal with modern scoring rates. *Journal of the Operational Research Society*. Vol 67 No 12. pp 1469-1480. DOI: abs/10.1057/jors.2016.30

We do not claim this research as our own but cite it to demonstrate that through continued academic rigour and, indeed its impact within the academy, its relevance and importance is continuing. From October 2014, the Professional Edition of the Duckworth/Lewis method was updated to the Stern Edition of the Duckworth/Lewis method (D/L/S) and was adopted by the ICC[5]. The ICC firmly set out in their rules and regulations that "the Stern Edition of the Duckworth-Lewis Methodology shall be used in all matches… using the latest version of the 'ICC Duckworth-Lewis-Stern Calculator' as distributed by the ICC…"[6].

In 2018, the ICC introduced an updated version of the D/L/S System[7] following a detailed ball-by-ball analysis of scoring patterns, including Powerplays, in all limited overs internationals played during the previous four years. This means that the current analysis is based on information from 700 One Day Internationals and 428 Twenty-20 Internationals, which comprise over 240,000 outcomes of individual deliveries. The study confirmed that, for both One Day International and Twenty20, while overall scoring rates are obviously different, wicket-adjusted resource utilisation rates are essentially identical, and further confirmed that D/L/S was compatible with all forms of the game.

The D/L/S method enables a multi-billion-dollar international sport to determine fair results for interrupted limited overs matches. Within the game, the most lucrative and widely viewed series is the Indian Premier League (IPL) (T20), valued at $5.3 billion in 2017[8] and considered to be the third most expensive sport property in the world after the English Premier League and National Basketball Association, representing 0.6% of India's Gross Domestic Product. During the first week of the IPL in the 2018 season, the first week pulled in 371 million viewers and attracted crowds in the various stadia of ca. 322,000. The IPL operates under the regulations of the ICC and deploys the D/L/S method as and when it is required. During the first week of the 2018 season, D/L/S was used on three occasions[9] to determine fair results to the satisfaction of the teams, sponsors, broadcasters and fans, which otherwise would have been in doubt due to the weather.

Whilst long established as the method for setting target in interrupted limited overs cricket matches, D/L/S continues to occasionally sparks controversy. For example, Kolkata Knight Riders' 9 wicket loss to Kings XI Punjab led their Captain Dinesh Karthik to question its continued use in the IPL. Karthik said "it was interesting that when play was stopped, they needed around eight runs an over but when it resumed it became run-a-ball….Ideally, in a 20-over game if we got two quick wickets, the run rate could have gone up. But then it became six-an-over. I didn't understand that but I am sure Duckworth-Lewis has been something people are trying to figure out…"[11].

Frank Duckworth and Tony Lewis's original research, which led to the D/L method and the D/L Professional Edition, continues to demonstrate impact not only within but clearly beyond the academy through the continuing advancement and application of the D/L/S method in modern forms of the game of cricket globally.

Sadly, Tony Lewis passed away aged 78 in March 2020. Geoff Allardice, General Manager of the ICC, paid tribute to him by saying "Tony's contribution to cricket is huge. The present-day system of resetting targets in international cricket is based on the one developed by him and Frank more than two decades ago. His contribution to the game of cricket will be remembered for years to come and we send our condolences to his family and friends". Simon Sharwood, APAC Editor, reflected "Few mathematicians' names are attached to work that enters the minds of so many people outside academia. Cricket's loyal global fanbase means Lewis's name will ring through the ages." Andrew Millar, UK Editor of ESPN CricInfo wrote "The impact that the two men had on the sport is best illustrated by the problems that rain delays had caused until they came forward with their algorithmic solution in the mid-1990s. Their calculations may have baffled generations of cricket lovers over the past two decades, but they have been universally recognised as the best solution yet devised to the sport's most intractable problem"[10].

5. Sources to corroborate the impact

1. 'First global market research project unveils more than one billion cricket fans', ICC Media release, 27 June 2018.
2. '22 off one ball', Andrew Miller, ESPNCricInfo, 12 February 2007.
3. The D/L method: answers to frequently asked questions (updated September 2012), ESPN CricInfo, Question 26 'What would have been the situation under the D/L method in the CWC1992 semi-final match between England and South Africa in Sydney?'
4. 'ICC decides to keep Duckworth Lewis and DRS', Reuters Sports News, 1 June 2012.
5. ICC DLS Methodology, Frequently Asked Questions (updated 29 September 2018).
6. ICC Rules and Regulations, section 6, Duckworth Lewis Methodology for recalculating the target score in an interrupted match.
7. ICC announces updated version of Duckworth-Lewis-Stern Method:
    - Wisden.com, 30 September 2018
    - Sports.ndtv.com, 29 September 2018
8. 'Why cricket is worth $5.3billion – in just one country', Darren Geeter, cnbc.com, 8 July 2018 (updated 1 August 2018).
9. Scorecards from matches in 2018 Indian Premier League season where the outcome was determined by D/L/S:
    - Rajasthan vs Delhi, 6th Match, 11 April 2018
    - Kolkata vs Punjab, 18th Match, 21 April 2018
    - Delhi vs Rajasthan, 32nd Match, 2 May 2018
10. Tributes to Tony Lewis:
    - 'ICC expresses sadness at death of DLS method founder Tony Lewis', Obituary, ICC,

includes statement from Geoff Allardice, General Manager of the ICC, 2 April 2020

- 'Cricket's average-busting mathematician Tony Lewis pulls up stumps. University lecturer and half of Duckworth-Lewis passes, aged 78', Simon Sharwood, APAC Editor, The Register, 3 April 2020.
- 'Tony Lewis, of Duckworth-Lewis rain-rules fame, dies aged 78', Andrew Millar, UK editor ESPNCricInfo, 1 April 2020

11. 'IPL 2018: Dump Duckworth-Lewis, says Dinesh Karthik after loss to Kings XI Punjab', Dhiman Sarkar, Hindustan Times, 21 April 2018