MANAGING GOLF GREENS: ALIGNING GOLF GREEN QUALITY WITH RESOURCE INPUTS

STEWART BROWN

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ABSTRACT

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STEWART BROWN

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Golf course managers need to manage their facilities efficiently for both economic and qualitative reasons. Golf greens are the most significant area on the golf course for play, intensity of maintenance practice, and player judgement of quality. The gap in knowledge lies between measurement of golf green performance and operations efficiency. Performance measurement is the process of controlling management operations to achieve optimum resource input efficacy but in considering existing performance management systems it was found that none provided a definitive tool that could be used to monitor operations for golf green management. This research aims to determine whether a performance management system can be developed for golf green management.

Four golf courses were selected to collect management data for operations practices and qualitative tests of golf green performance. Interviews provided operations data for the core practices, identified from literature, including material inputs. The comparison of maintenance inputs and their costs against playing quality allow objective comparison and determination of management efficacy. A survey of golf course managers and review of industry operations practice also informed the key parameters in the development of a performance management framework.

Research data for maintenance intensity, cost, and quality have been plotted onto analysis framework graphs which indicate the quality golf course managers are achieving within golf green culture with known levels of resource input. This research proposes a performance management framework for golf course managers to enable them to better manage their golf greens.

The adopted research methodology and methods have produced a performance based management framework for golf green management. Mapping key parameters of quality, costs, and inputs in a benchmarking radar chart reflects the efficacy of golf green management in a way that allows stakeholders to identify and adjust operation variables. In a survey of Golf Course Managers in the UK, 73% of respondents stated that they would find a performance management framework beneficial for their work.

Key Words: **Golf Greens, Quality, Performance, Measurement, Operations, Management, Framework**

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Published Work

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Chapter 1   Introduction

Introduction

This introduction provides the contextual background for the research undertaken and the identified aim, objectives and key research question. It provides an overview of significant areas pertinent to the research beginning with the golf industry before discussing aspects of golf course development, management and the significance of golf greens which are the main focus for this research. After introducing these key areas, the research strategy is briefly discussed and then the outline of the thesis structure is provided.

Golf is reviewed as a worldwide sport and identified as a significant contributor to the economy of England where this research has been conducted. Although this is still the case participation in golf in many countries, including those of the UK, has declined especially since the economic downturn of 2008 and this has impacted on golf club revenues. In the UK there has been an overall decrease in club memberships and an increase in players who still play golf but do so on a pay and play basis. Golfers have become more discerning in where they choose to play and club income is no longer assured. Golf greens are seen as the most significant playing surface on the golf course and the hallmark of course quality. Surveys have shown golfers expectations for golf course standards and especially golf green quality. Golf course managers are also operating in an environment where maintenance budgets have been reduced but player's expectations for quality surfaces are as great as ever. Golf courses also face pressures from organisations such as The Royal and Ancient (R&A), the games Governing Body outside Mexico and the USA, to manage their courses sustainably which it promotes as *"Optimising the playing quality of the golf course in harmony with the conservation of its natural environment under economically sound and socially responsible management"* (The R&A, 2010). Performance measures have been developed for golf greens as a means to assess their playing qualities, however no performance management framework exists where such measurements can be used to manage both resource inputs and the playing quality of golf greens. Reducing inputs whilst maintaining quality is seen as the primary goal in operations efficacy and is the focus for operations managers. This research addresses this gap in knowledge.

1.1 The Origins of Golf

The exact origins for the game of golf are unknown (Hurdzan, 2004), but most agree that the modern game we know today originated in Scotland in the 1500's. (The R&A, 2015; Beard, 2002). It is believed that the game evolved from the Dutch game of "Kolven" which involved striking balls with implements resembling clubs. At that time there was significant trade on the east coast of Scotland with Dutch merchants (Arthur and Isaac, 2015) who found the links land ideally suited to their game (Hurdzan, 2004). It is also believed the windswept dune land and coastal strips of grazed grass offered ideal terrain and that shepherds anyway were probably hitting small stones into rabbit holes whilst managing their flocks on this free draining land. In truth the modern game has evolved over many hundreds of years and as Beard (2002) maintains its origins can be traced to earlier stick and ball games such as the Roman "Paganica", England's "Cambuca", and "Jeu de Mail" in France and even "Shinty" in Scotland. The word "Golf" is derived from the Dutch "kolf" which is related to "kolbe" in German and "holbe" in Danish which mean club. The game developed slowly at first until a boom in the 1800's when it spread quickly throughout the British Isles, the British colonies and Europe (The R&A, 2015). The first rules of golf were established in 1741. In 1857 there were 18 places to play golf, mostly in Scotland, and this had increased to 59 by 1880. The next 120 years were to see significant developments in sites for golf, courses, techniques, rules and equipment (Hurdzan, 2004).

1.2 Golf: A Global Sport

Golf is a global sport. In a survey by The R&A published in 2015 (The R&A, 2015) there were 34,011 golf courses to be found in 206 countries around the world. The R&A report identifies that the vast majority of courses are found in developed golfing countries such as the USA, Canada, England (sic), Australia and Japan. The USA accounts for 45% of the world's facilities with Europe having the second largest supply with 22% of the world total. New courses are being constructed in parts of the world where golf has not been present. In countries such as Belarus, Azerbaijan, Georgia, Macedonia, Sao Tome and Principe golf courses have been constructed recently and countries such as Bolivia, Cyprus, Egypt, Iran, Oman, Qatar and UAE are adding to existing supply. The picture is one where currently golf is still strongest in the developed nations but the game is growing around the world. The R&A report does, however, recognise that in countries including the USA, England, Canada and Australia supply has outpaced the demand for golf and there has been a decline in participation. The R&A,

who are concerned with growing the game globally, believe that the closure of some courses in the developed nations has been more than offset by the expansion of the sport in new territories thus maintaining a worldwide growth in the sport. England's 2,084 golf facilities constitute 28% of the 7,403 in Europe (The R&A, 2015).

1.3   Golf and the Economy in England

Golf is a significant contributor to the economy of England. The England Golf Partnerships (2014) survey of golf facilities in England found golf (in 2011-2012) to be a significant contributor to the economy with a contribution of £3.4 billion. Of this amount just over 3.2 billion came from direct industries of golf supplies, capital investments, golf events and facility operations. 56% of revenue (£1881.06 million) came directly from the management of golf facilities. Golf real estate and tourism contributed £115.02 million of the £3.4 billion total. Further this figure of £3.4 billion is 65% of the total for Great Britain and Ireland – England being the dominant nation in the British Isles with 67% of its golfers within its 61% of golf clubs. In England golf generates £61 for every man, woman and child. The report also states that in the same year, 2012, 3.7 billion was spent on NHS dental care which at that time constituted 3.5% of all NHS expenditure. Thus the significance of golf to the economy is immediate and needs to be sustained for the wider benefit that it brings to society.

In terms of direct employment, England's, golf facilities employ 48,491 people at a cost of £779.63 million averaging £0.40 million per facility. Golf course maintenance accounts for £360 million spent annually which entails all costs for materials, repairs and renovations but excluding staff costs. A further £82.85 million is spent by golf clubs on course maintenance machinery and irrigation equipment. Among the major land-based sports, golf has probably the strongest interaction with the environment. Certainly no other sport exclusively occupies and manages such large areas of green space. Golf dominates the professional turfgrass industry (Adams and Gibbs, 1994).

1.4   Golf Participation

In the period from 1985 until 2010 there was a steady growth in supply and demand for golf with an approximated 5% year on year increase in the European golf market. From the start of the economic crisis participation in golf and the number of golf courses began to decline and became negative in 2010. During the last four years the average decrease in the number

of golfers was 1.2% per annum peaking at 2.4% in 2013 and slowing to 2% in 2014. During 2014 the number of registered golfers in Europe fell by 1.8% or approximately 77,000 golfers (KPMG, 2015).

As well as the total number of golfers declining in Europe's established markets the number of registered golfers in the UK and Ireland has fallen by 51, 826 (4.4%) in 2014. This is a significant factor as in these countries golfers do not need to be registered at a particular club and can choose where to play on a greens fee basis. According to the KPMG survey (2015) there are an estimated 2.84 million "casual" golfers in the UK and Ireland. There was a 3.5% increase in the number of rounds played in 2014 so it is obvious that golfers are choosing more where to play and are not remaining affiliated with one single club as was historically the case. 80% of the 3.5 million non-registered golfers in Europe can be found in the UK and Ireland. Registered golfers and golf courses for the UK and Ireland are shown in Table 1.

Table 1 Registered Golfers and Standard Golf Courses in UK and Ireland 2015 (after KPMG 2015)

Country	Registered Golfers	% change from previous year	Change in the number of golfers versus previous year	Participation rate	Golf courses	% change from previous year	Change in the number of golf courses versus previous year	Population per golf course
England	678372	- 4.8%	-34,018	1.3%	1849	-0.4%	- 8	29,032
Scotland	199764	- 4.8%	-10,048	3.8%	545	-1.1%	- 6	9,762
Ireland	194,151	- 2.7%	-5,399	4.2%	413	-0.2%	1	11,116
Wales	49,084	-4.6%	-2,361	1.6%	151	-1.3%	-2	20,384

This situation of golfers (in England) reverting to independent unaffiliated play was confirmed in the report by England Golf (2014) in their Golf Club Membership Survey who went as far as to state that golf club memberships are in a precarious position due to this and the contributing factor of fewer people taking up the game. In their survey they found that on average there was a net decrease from 85 to 77 members (8) between those leaving a golf club and those joining. Overall this is a net deficit of 34% in English golf clubs.

1.5   The Financial Situation for Golf

England Golf (2014) believe that there needs to be investment in golf facilities, particularly the course itself, to attract and maintain members and that ensuring quality and value for money is a key factor in encouraging golfers to renew memberships. This view is supported by Syngenta (2013) who had conducted their own survey previously in 2013 which included both current and lapsed golfers. They found that it was the condition of the golf course itself which was the most important factor for golfers with golf greens being the main factor by which players judged overall golf club quality. Golf Clubs must ensure that the golf course and its presentation are given sufficient priority and resources. Again, significantly, in the Syngenta survey most respondents (70%) were pay and play customers reflecting the shift from single golf club memberships. The Syngenta survey did ask why golfers were leaving the game with 67% of respondents saying it was because of the cost or the time it takes to play. The cost factor is a direct contributory factor why many golfers are choosing a pay and play as opposed to renewing annual club memberships which can be expensive. This is a very real problem for golf clubs as their income revenues are less certain (England Golf, 2014).

The effects of the economic downturn on golf clubs were reported by KPMG in 2010 (KPMG, 2010) in their report reviewing the economic performance of golf clubs throughout Europe, the Middle East and Africa. In this survey nearly 50% of clubs had seen their revenues and profitability fall with them making cuts to staff costs or making redundancies. The situation was confirmed in 2011 when KPMG (2011) in a follow up report that stated that rounds played in 2010 had decreased by 43% which a following negative impact of 44% on revenues. This later report also found that 65% of courses had cut costs and 45% had made direct cuts to staffing levels. KPMG (2011) reported that the situation was comparably worse in the UK and Ireland where less than 50% of clubs reported good or excellent financial results and 17% declared results to be poor or very poor so the optimisation of playing quality and management input is more important in times of recession than at any other time if golf is to retain its market share.

1.6   Golf Course Maintenance Budgets

This situation has impacted directly on golf course maintenance budgets. Vavrek (2010) confirms that golf course managers have seen little, if any, increases for turf maintenance

during the past 10 years, and many budgets have been significantly cut by as much as 10% to 20%. Maintenance budgets have decreased despite increasing maintenance costs, which is due to higher oil prices and players' ever-escalating expectations for perfect course conditions. The budget and course economy then become of more concern to members and to the people who earn their living with golf, such as the golf course manager (Buchanan, 1980), the golf professional, and the club manager. Vavrek (p10, 2010) further believes that too many golfers consider that budgets for course maintenance will always seem unreasonably expensive, regardless of whether the facility spends $200,000 or *$2* million per season for course conditioning and *"after all, from their point of view, how much can it actually cost to mow grass, rake sand, and press a button to turn sprinklers on once in a while?"* Vavrek (ibid) asserts that course maintenance budgets account for only 18 to 20% of the total budget at most golf clubs and Buchanan (1980) had already considered that the course maintenance budget should be last to be examined. Buchanan did, however, maintain that golf clubs could definitely reduce costs if they would place more emphasis on maintaining a quality playing surfaces as opposed to a vast expanse of manicured acreage that is better to look at than to play over. Maintaining quality playing surfaces requires substantial expenditure but, as shown recently in the Syngenta survey of 2013, is necessary to fulfil player demands and expectations. This thesis explores this relationship to provide managers with methods to verify and monitor their efficacy.

1.7   Golf Course Development

Adams and Gibbs (1994) describe how in the early days of golf there was minimal management or interference by man as it was the land that shaped and dictated how golf courses were. The natural lie of the links land along the coast featured undulations and contours through which fairways were "found" leading to closely grazed areas from rabbits and sheep which made sites for golf holes. The sandy soils encouraged fine grasses and areas blown out by the wind became natural bunkers. These areas were bordered by longer grass areas which made for areas now termed "roughs". They later explain how in the early 1700's people began to manage courses and influence the layout and development of golf courses. Beard (2002) confirms that the first greenkeepers were established by then and charged with making things better for the golfer. The first record of a payment being made to a greenkeeper was by the Royal Burgess Golfing Society in 1744. In 1754 the Society of St Andrews Golfers agreed to pay for course maintenance – a significant event as it showed that golfers were concerned about the state of the golf course (Beard, 2002). The first recorded greenkeeper is reputed to be "Old Alick" in the 1780's at the Society of Blackheath Golfers

(Hurdzan, 2004). Beard (2005) has documented the key practices in the development of greenkeeping as a profession from earliest golf times to shortly after the 2nd World War at St Andrews.

Hurdzan (2004) recounts two significant events in the development of the greenkeeping profession. Firstly, the invention of the cylinder lawnmower in 1830 by Edwin Budding which led to a major improvement in grass surfaces and the return in 1863 of "Old Tom Morris" to St Andrews. Old Tom was to remain at St Andrews until his death in 1904 and is widely considered by many to be the father of greenkeeping and golf course architecture as we know these professions today (Hurdzan 2004). Old Tom is thought to be responsible for the introduction of several greenkeeping practices still conducted today including sand topdressing of greens, irrigation, drainage improvements and significantly course design and layout. He was responsible for changing the number of holes at St Andrews from 22 to 18. This has become template for all golf courses today as have many of the features originating at St Andrews (Adams and Gibbs, 1994). During his tenure at St Andrews the greens became the standard by which all other greens at other courses were judged (Hurdzan, 2004). As was the case for many greenkeepers at the time Old Tom was also a club maker and ball maker. He was responsible for the layout of many other golf courses and not least was golfer of some repute himself winning The Open Championship on four occasions. Although greenkeeping management became recognised as early as 1863 no theoretical approach to optimising management has yet been published. This is further explored in sections 1.10-1.12 below.

1.8   The Golf Course

Golf is different from other sports played on turf in that it is not confined to a precisely marked-out area such as the rectangular fields used for football, rugby, tennis and hockey (Adams and Gibbs, 1994). Golf is played on more extensive landscape areas which are typically highly variable from each other due to local landscape topography, situation and climate. Typically, an 18-hole golf course (the standard size) will occupy 60 hectares of land (Adams and Gibbs, 1994) but only about 24% of this is made up of the primary playing surfaces, tees, fairways and greens (Beard, 2002). Bordering these areas are areas of longer grass (rough) which may extend to include coarser scrub, woodland and or water and which approximate to natural habitats (Adams and Gibbs, 1994). Golf courses vary in length from 5670m to over 6400m for championship courses. Holes are classified by Par, the number of shots allocated to complete that hole, as either 3, 4 or 5. (Adams and Gibbs, 1994).

1.9   The Significance of Golf Greens

A golf green is the area specially prepared for putting surrounding the hole into which the ball is played. Originally greens were areas on links land characterised by low growing grasses, usually on elevated plateaus, which were kept short by grazing rabbits (Beard, 2005) providing natural surfaces for putting. Although golf greens generally occupy less than 1.5-1.8 hectares of land (Adams and Gibbs, 1994) or about 1.6% of the course (Beard, 2002) they are the most critical of all the playing surfaces as they are primarily how golfers judge the quality of a golf course (Emmons, 1995; Syngenta,2013). Hurdzan (2004) confirms this point and considers that as well as being the focal point for each golf hole, greens are the hallmark of the golf course itself and the cause of much debate by agronomists, designers and architects, green keepers as well as by players. This situation can be explained when one considers the role of the green in play. In play two shots per hole are allotted to putting for example on a Par 5 hole three shots are allotted to reaching the green (one of which will be the approach shot onto the green) and then two further for putting the ball into the hole. On a typical PAR 72 18-hole golf course therefore 50% of shots are for putting. The fact is that although golf greens are a very small component of the golf course (typically each being only between 500 and 700m^2 in size), they can be the focus of 75% of the shots a golfer will make assuming a par round (Beard ,2002). Beard specifically says that the proper design, construction and maintenance of golf greens is therefore essential and goes so far as to say that the goal is perfection without being able to substantiate what proper and perfection actually mean. Beard also maintains that the closer to perfection that golf greens become, the more accentuated minor imperfections in the playing surface are revealed, and these are generally more costly and difficult to correct. Beard therefore implies an unhelpful tautological dilemma.

1.10   Contemporary Golf Course Management

Golf course condition is the most important factor in determining how the game is played (Beard, 2002; Syngenta, 2013). The golf course manager is the most significant person in that it is they who determine the maintenance for the course which in turn affects play. Golf is a unique game in that the playing surface itself is as important and as variable as the game itself. Each course manager determines their own philosophy for course management based on their own education and experience over time (Beard, 2002). Some individuals espouse

the so called English or Scottish philosophy as far superior to the American system which typically utilises more fertiliser, pesticide and water inputs (Beard, 2002). Arthur and Isaac, (2015) maintain that the best British golf courses are found on links, heathland and downland landscapes typified by their open exposed situations and firm, fast putting greens and wiry grasses. In the US, from the 1950's through to the 1970's, excessive inputs of fertiliser and irrigation led to increased thatch and disease problems and practices such as "fence-to-fence" mowing meant that there were few "natural" areas on the course (Beard, 2002). The focus in UK (at least for links courses) was to maintain traditional bent grass and fescue swards without pesticides and excessive inputs. Beard (2002) acknowledges that course management is varied across the world due to differences in climate and soils and that there is no one best turfgrass management programme. Beard though also recognises that in the US there still persists a problem termed "green grass syndrome", where dark green grass, derived from high fertiliser inputs, is the expectation: if established at UK golf courses this would probably lead to increased costs and premium fees. Arthur and Isaac (2015) adopt a harder stance when considering maintenance practices for golf courses when they assert that there are no valid alternatives or opposing schools of thought. There is only good greenkeeping, based on encouraging bents and fescue grasses, and bad greenkeeping favouring agricultural grasses and annual meadow grass. Arthur and Isaac (2015) state that any opposed to this premise are wrong and that such people rely on agricultural teachings, have little knowledge of golf and do not understand how much the quality of the turf is so important to the game. Canaway (1994) has affirmed that many working methods and practices on golf courses have arisen from agronomists trained in agriculture leading to a feed, spray and water approach to green keeping following the agricultural model of crop production. Arthur and Isaac (2015) further maintain that golf is not played on colour [alone] and that [colour] has nothing to do with quality as grass which is not green is not necessarily dead, and dry summers often mean khaki coloured grass that recovers quickly. Regarding course maintenance philosophy: Arthur and Isaac (2015) say the best practice is to adopt the principles of greenkeepers from the past who found from observation that that the best turf was found on the poorest soils, provided such soils were free draining. Furthermore that the secret of good greenkeeping is to replicate those infertile conditions, avoid phosphate fertilisers, use nitrogen only, and aerate deeply on greens and other areas of the course.

Arthur and Isaac (2015) stress that such practices have been confirmed by research since and are even more dismissive of many advisors who they state are no more than thinly disguised salesmen often confused about coarse-leaved agricultural grasses and the management of fine-leaved grasses. An issue here though is that Arthur and Isaac are relying on practices derived from mainly links golf courses which have naturally free draining land and

fine grass specie dominated swards. The majority of the golf courses in the UK, and indeed, worldwide are found inland on heavier soils and with very different climates. Beard (2002) agrees that not all areas of the golf course need intensive management and many areas can be left to be more natural. He considers that an equally significant factor is the level of surface quality the golfer desires and, perhaps, more significantly, is willing to pay for in terms of maintenance budgets. There is a need to find a balance between the golfer's needs, course agronomy and the integrity of the architectural design or course layout.

1.11 Sustainability and Golf Course Management

There is genuine public concern about environmental quality and the golf course is often seen as an environmental polluter (Gange, Lindsay and Schofield, 2007). Monitoring environmental issues has therefore become a legitimate concern on golf courses (Peacock, 2007) and a move towards sustainability is seen as one way of addressing public concerns. The R&A believe that managing golf courses in a sustainable manner is not an option, but a necessity (Isaac, 2007; Park, 2006) and fundamental to the future success of golf. Ormondroyd (2007) considers that the debate concerning sustainable golf course management has benefited all course managers by raising awareness serving as a catalyst to review current management regimes. Economic factors are, however, having a greater impact on practice.

Golf courses have to adapt to ever changing demands from the golfer, climate change and environmental regulations. Golfers demand exceptional playing surfaces all year round, and this will influence the management decisions that are made (Windows, 2005). Not all golfers' demands are agronomically sound: their demand for green colour and fast ball speeds have eliminated most of the fine grasses on golf greens in the UK (Isaac, 2005). A balance is needed as ignoring golfers' wishes is economically unsustainable as most golf clubs need members to survive (Danneberger, 2006; England Golf, 2014). Meeting these demands can also be hindered, however, by budget constraints, increasingly stricter regulations on water and pesticide use and problematic weather conditions (Windows, 2005). Any model that serves to optimise such parameters must do so in a way which informs effective management decision making.

1.12 Performance Standards for Sports Turf Surfaces

Professionals working in the sports turf industries have developed performance or playing quality standards for different sports over many years but not everyone in the industry is agreed about the use of these. There are different viewpoints regarding their value or even need in contemporary sports turf management. Arthur (1994) maintained that there should be more focus on minimum standards for materials and construction methods rather than an emphasis on playing surface standards when in use. This belief is based on the assumption that if playing surfaces are built with quality materials to precise specifications then surfaces will provide good playing conditions. Dury (1994) argued that performance standards can be used to develop and maintain surfaces better when in use; that their implementation will raise standards of management and subsequently playing surface quality. The diverse range of surfaces on which golf is played makes a description of performance criteria difficult. Hayes (1990) summarized the attributes of good playing surfaces (Table 2) for golf, some of which can be analysed quantitatively, for example those relating to ground cover and drainage characteristics.

Table 2 – Characteristics of Good Playing Surfaces for Golf (Hayes, 1990)	
Surface	**Quality component**
Greens	Fast, true, firm surfaces Uniform grass cover Dry surfaces Suitability for year-round play
Approaches and surrounds	Dry surfaces Freedom from wear patterns Good cover of grass
Tees	Large, level, firm, dry surfaces No wear pattern on and off tees Uniform grass cover
Fairways	Free drainage Suitability for year-round play Good cover of grass Lies uniform

The Institute of Groundsmanship (IOG, 2003, p5) offer several benefits for having performance standards on golf courses including that of allowing managers to make realistic comparisons between courses and to counter comments from players about one course supposedly being better than another. The IOG (2003, p6) have also proposed some standards for golf greens (and other areas) but these have not generally been adopted in golf course management and

tend to focus on structural properties as opposed to objective measurements of presentation or playing quality. The Sports Turf Research Institute have developed some objective assessments for the playing quality of golf greens (Windows and Bechelet, 2009). These are really the only objective measurements of playing quality available to golf course managers. Standards for other areas of the golf course are not developed to any real level. Today most people utilising any form of performance standard are doing so from the standpoint of increasing the quality of playing surfaces in use, in an attempt to increase standards of provision or increases in surface 'carrying capacity'.

1.13 Identifying a Gap in Knowledge

The introductory sections of this thesis demonstrate that there is a need for golf course managers to manage their facilities more efficiently for both economic and qualitative reasons. Golf greens are the most significant area on the golf course for both play and intensity of maintenance practice (Beard, 2002; Hurdzan, 2004). They are also one of the few areas of the golf course for which there are objective measurements of quality. Quality of greens being one of the (if not the) most important factors by which players judge golf course "quality". Measuring the quality of golf greens has been described by Windows and Bechelet (2009) who advocate the "Performance Measurement and Development" system developed by the Sports Turf Research Institute (STRI) but this does not measure inputs or attempt to align quality measures to resource management.

The major question is at what level of input one can achieve quality surfaces. It may be that quality can be achieved with lower resource inputs, a view held by The R&A (Isaac, 2012), but this needs objective assessment and measurement. Such measurements can be benchmarked for different golf greens on a given golf course and with other golf courses. Such benchmarking can inform management for decision making and resource utilisation for more effective management (IOG, date not known, p4). If golf course managers can achieve quality surfaces with reduced inputs this will have positive benefits for both environment and golf club finances. Another view of this situation is that of what is the cost of sustainability? Can we achieve sustainable greens without compromising on playing quality? Golf greens need to have maintenance inputs to maintain them as golf greens as they are man-made surfaces and not wholly natural although they are made up from naturally occurring materials such as soils, sands and grasses. Reducing inputs will affect playing quality and the very essence of the golf greens function is compromised. Reducing golf green quality will undoubtedly have a

detrimental impact on player satisfaction and ultimately revenues as golfers elect to play elsewhere. One key question is how can we satisfy golfer's expectation/requirements at a level which is economically and environmentally sustainable? There is also a question of performance management here and that of providing a quality product at an affordable price for the customer. In the past many golf courses have often been managed intensively with large inputs of fertiliser and water in an attempt to create the verdant courses demanded by players – the "Augusta syndrome" (Beard,2002). The R&A advocate moving away from this concept towards sustainable practice (The R&A, 2010) but there is no industry consensus as to what standards we should provide or strive for or how such factors can be achieved in practice.

The perceived gap in knowledge at the outset of the study is that which lies between those who advocate the measurement of golf green performance as a tool for management (Windows and Bechelet 2009) and those who espouse the benefits of a reduced input approach including the R&A (Isaac, 2012). One can measure maintenance inputs for golf greens and the quality of surfaces but as yet no one has looked at these two factors together. The development of a performance management framework for assessing maintenance inputs, costs and playing quality will potentially allow us to determine what level of management efficacy managers are achieving for golf greens.

1.14 Research Strategy, Aim, Objectives and Key Research Question

The gap in knowledge is proposed from professional experience, verified in preliminary studies and will be explored further in literature and industry practice. The research adopts a phenomenological review of managers' attitudes towards management practice and triangulates these against literature with a positivistic study of green-playing quality indicators. Thus the mixed method paradigm aims to provide a contextually prioritised system to explore how managers balance their resources and achievement using a theoretically informed conceptual framework described in chapter 5.

AIM – to develop a performance management framework that enables golf course managers to target better use of resources in golf green maintenance strategies and achieve optimal surface performance quality.

OBJECTIVES:

1. Critically review existing golf green management theory and practice to verify a gap in knowledge perceived through professional experience.
2. Critically review existing operations and performance management theory and practice to establish new ways to challenge and enrich existing golf green management strategies.
3. Identify the primary factors and inputs that affect golf green quality and playing performance to enable new golf green management strategies.
4. Determine the parameters that influence resource optimisation and therefore enable golf course managers to identify strategies that positively affect the efficacy of lean-input golf green management.

KEY RESEARCH QUESTION

How can golf greens be better managed for playing quality performance and optimum resource efficiency?

1.15 Structure of the Thesis

This introduction is followed by three theoretical chapters. Chapter 2 discusses aspects of Golf Green Maintenance, Chapter 3 considers Operations Management and finally Chapter 4 reviews Performance Measurement and Management from literature. These are used to form the theoretical foundation and inform a Conceptual Model for empirical research which develops in Chapter 5. Research Methodology and Methods are discussed in Chapter 6 where the case for mixed methods combining both inductive and deductive approaches and utilising both qualitative and quantitative methods is made. Chapter 7 presents the findings from the data collection and discusses these together with the research objectives. Chapter 8 then concludes the thesis with a final review of the aim objectives and research question. A personal reflective account is provided on the Professional Doctorate in Chapter, 9.

Chapter 2
Principles and Practice of Golf Green Culture

Introduction

The primary aim of this research is to develop a performance management framework for golf greens. In doing so it is necessary, firstly, to understand the agronomic practices required for golf green maintenance and how these can impact upon decision making by golf course managers. This chapter discusses the key practices identified in a variety of literary sources and does so from both a theoretical standpoint and also as applied to actual golf green culture. In doing so it helps to inform the first identified research objective and forms the basis for later empirical investigative research. This chapter determines the most significant golf green practices from secondary references in order to identify and prioritise those practices likely to inform a performance management framework.

2.1   Sports Turf Management

Managing grass swards for sport and recreation is an established practice based upon plant, soil science and applied technologies (Adams and Gibbs, 1994). Turfgrass management is the range of activities for establishing and maintaining turf for a particular use at a desired standard (Turgeon, 2002). Management priorities in turf maintenance range from providing an acceptable cover of grass at a minimum cost to that where very high quality surfaces are required irrespective of cost (Adams and Gibbs, 1994). There is some truth in this view but resources are rarely infinite and frequently limited in practice. Thus turfgrass management involves determining a specific cultural programme for the desired quality of surface (Turgeon, 2002) but it must be one which is sympathetic to the physiology of the grass plant (Adams and Gibbs, 1994). In essence turfgrass culture involves the selection of particular plant genotypes and then sustaining these in a modified environment through imposed cultural practices to attain a specified end product and level of quality. As the intensity of culture increases so do the levels of technical expertise and operations capability and this is the case with golf greens (Turgeon, 2002). The turfgrass manager determines and implements turfgrass management programmes drawing on their own practical experience, empirical observations, technical and scientific knowledge and their own ability to manage operations and personnel.

Significant cultural practices in maintaining turf surfaces for sport include mowing, irrigation, fertilizer application, aeration and topdressing. Turgeon (2002) believes that mowing, irrigation and fertilizer application are the most important practices as they are decidedly interrelated and changes in one impacts upon the others. These activities have their basis in agriculture where feeding, watering and controlling growth are essential to production. Arthur and Isaac (2015) warn of the dangers, and are positively against, agricultural practice informing golf course management as the two disciplines have very different objectives. Turgeon (2002) terms these primary cultural practices and believes in many established turf surfaces additional cultural practices are rarely needed if their management is satisfactory (Turgeon, 2002). Additional cultural practices, termed supplementary by Turgeon (2002), include aeration, topdressing and rolling. Turgeon (2002) acknowledges that these practices may be required where problems arise or are anticipated because of unfavourable developments in the turf. The reality is that for sports turf, which is subjected to wear and damage through play, these practices are generally essential to maintain cover and suitable playing surfaces and so they are likely to be key parameters in the management framework.

2.2   Mowing

Mowing is the cultural practice which most influences other cultural practices (Turgeon, 2002) and has the most profound effect on plant growth and physiology (Fry and Huang, 2004).From a botanical standpoint mowing is detrimental to the grass plant as it severs plant tissue, primarily leaves, which are the main photosynthetic structures of the plant responsible for carbohydrate production essential to sustain plant growth and physiological processes (Turgeon, 2002; Fry and Huang, 2004 and Christians, 1998). Mowing causes a temporary cessation in growth reducing carbohydrate production and the severed ends of leaves temporarily increase water loss as well as being sites for entry for disease causing organisms which impacts upon practice and decisions for managers (Turgeon, 2002 ; Christians, 1998). Turf grasses persist under mowing as they have evolved over millennia to tolerate defoliation from grazing animals (Turgeon, 2002; Fry and Huang, 2004 and Christians, 1998). Christians (1998) considers that grasses are the best equipped plants on earth to tolerate mowing but even they have difficulty tolerating mowing which is more recurrent than grazing. Christians further stresses that less than 50 grass species are adapted to the continuous defoliation imparted by mowing. Scientists (grass plant breeders) have selected grasses for use in turf culture based upon their ability to tolerate mowing and developed cultivars which perform exceptionally well under mowed conditions even tolerating heights of cut lower than 5mm (Fry

and Huang, 2004). In practice there are fewer than a dozen grass species utilised in sports turf surfaces in the UK and golf greens are most frequently made up of *Agrostis*, *Festuca* and *Poa* species.

Grasses grow by cell division and elongation at their base where meristematic tissue forming the 'crown' of the plant generally survives mowing (Adams and Gibbs, 1994; Christians 1998). Thus the oldest part of a leaf is its tip and the youngest its base. Although mowing may not damage the basal meristematic tissue of grasses it removes active photosynthesising leaves leaving stem bases and immature leaves. Recovery and new growth requires the plants use of carbohydrate reserves which are small in rapidly growing turf. The advice of Adams and Gibbs (1994) here is very valid in that mowing should be sufficiently regular to minimise stress and that this is primarily determined by the amount of leaf tissue removed. Continual removal of plant tissue by mowing causes a number of effects on the grass plant which appear to be the plants attempt to maximise photosynthesis under mowing pressure (Fry and Huang, 2004). Shoot density and tillering increases with lower cutting heights but this increase does not allow for the same level of carbohydrate production as would be the case with higher mowing heights (Fry and Huang, 2004). There are optimum heights, however, above and below tillering decreases which are less than 10mm for fine turfgrass species. The manager must be familiar with the species and cultivar being grown and their tolerance to mowing. Mowing in this optimum range will ensure the maximum rate of tillering and sward infilling with new growth (Adams and Gibbs, 1994). Grass leaf blade width is reduced at lower mowing heights as a likely response to increased density and competition amongst plants. Shoot turgor (water content) also increases with plant cells having thinner walls. This increased turgor is commonly associated with increased susceptibility to foliar diseases and environmental stresses. This is thought to explain the reduced tolerance of mowed turf to biotic and abiotic stresses (Fry and Huang, 2004). Here, again, mowing practice has wider ramifications for overall turf management. Because maximising plant leaf area enhances photosynthesis, changes to mowing practice and particularly in heights of cut should only be done with due consideration. At higher cutting heights the plant is not only able to meet its daily requirement for maintenance but is also able to store carbohydrates for later in the season and possible adverse environmental conditions (Fry and Huang, 2004). Higher cutting also allows the development of a plant that is a more efficient water user primarily because it has a deeper root system which enables it to draw water up from moist subsurface layers when the surface is drying down (Fry and Huang, 2004).

Another significant effect of mowing is that of the plants ability to grow laterally. Many turf grass species have rhizomes and/or stolons which enable them to recover from wear and in

turf culture enhance rapid recovery and coverage of the sward. Again mowing at a higher height generally promotes such growth (Fry and Huang, 2004). Grass stems and leaves depend upon roots for their supply of water and essential mineral nutrients and root development requires energy from sugars produced in the leaves. The loss of photosynthetic tissue, as a consequence of mowing, directly impacts on root growth. (Adams and Gibbs, 1994; Fry and Huang, 2004). Severe mowing will often lead to a rapid loss of plant roots and in turn severe defoliation (Adams and Gibbs, 1994). Regular close mowing is less damaging to living root mass (Adams and Gibbs, 1994) but even small reductions, relative to usual mowing height, such as 1mm can cause a significant decline in total root length and root depth (Fry and Huang, 2004). Low mowing also increases the likelihood of root death in periods of high temperature stress which most cool season grasses experience in the summer.

The exact range of cutting heights for mowing tolerance in specific species is difficult to estimate due to the variability of genotypes, growing environment and culture (Turgeon, 2002) and indeed, there is variability in practice. Turgeon also confirms that there are ranges within which a grass species can provide a satisfactory turf below which the plant will be stressed and above which the grass will be limp, puffy and failing to provide a satisfactory turf. Closeness of mowing tolerance varies between species and even within cultivars of the same species. Fine leaved fescue and bent grasses can be mown at 5mm, which is why they are used in golf greens, whereas most cultivars of perennial ryegrass and smooth-stalked meadow grass will be severely stressed if mown closer than 20mm (Adams and Gibbs, 1994). Grass species having a prostrate growth habit are more tolerant of close mowing (Adams and Gibbs, 1994). Creeping bent grass can be found on golf greens at mowing heights as low as 2.5mm as can grasses such as annual meadow grass , widely considered to be a weed, which can even produce seed at this height (Christians 1998).

Turf which is close mown, such as that on golf greens, is less tolerant of environmental stresses, more susceptible to disease and more dependent on careful management (Turgeon, 2002; Christians, 1998). Such turf requires more resource inputs, frequent irrigation and fertilizer, to compensate for the plants reduced ability to source nutrients and water from the soil (Turgeon, 2002) which thus impact on operations decisions and costs for managers. Turgeon (2002) believes that close mown turf requires more technical expertise to manage than is the case for grass maintained at higher cutting heights. Grass is, also, generally mown for aesthetics, to improve the appearance of the area, or to provide a playing surface for sport (Christians, 1998). In the latter case it is the particular sport which determines to a large degree the height of cut required (Adams and Gibbs, 1994). This may lead to maintenance problems such as when turf is mown too close which can lead to annual meadow grass (*Poa annua*)

encroachment and disease on golf greens (Christians, 1998). Mowing stress can be reduced by removing no more than 50% of the standing height of the grass plant (Adams and Gibbs, 1994). Christians (1998) affirms the 'one-third' rule where it is recommended that no more than 33-40% of above ground tissue should be removed in a single mowing. Anymore can result in cessation of root growth for up to two weeks and possible scalping of the turf which exposes leaf sheaths and results in a bleached appearance of the turf canopy (Fry and Huang, 2004). Mowing frequency is the number of mowing's per unit of time (Turgeon, 2002) and is directly related to mowing height as turf maintained at higher heights requires less mowing to maintain it at that height (Fry and Huang, 2004 ;Christians, 1998). Turfgrass managers are familiar with the one-third rule (Fry and Huang, 2004) and this is the best guide for determining mowing frequency (Christians, 1998). In practice mowing frequency can vary from daily for golf greens (Turgeon,2002; Christians, 1998) to several mowing's per growing season on some amenity areas. Establishing proper mowing frequency is a key operations decision for the golf course manager (Christians, 1998) as its effects on the turfgrass sward and plant health are pronounced.

When using cylinder mowers on closely mown turf it is desirable to vary the direction of cut with successive mowing to encourage upright shoot growth and eliminate a condition termed 'grain' (Turgeon, 2002; Christians, 1998). Grain is where grass blades and stems lie procumbent in the direction of cut and is particularly objectionable on golf greens as it can affect ball roll and putting green quality (Turgeon, 2002; Christians, 1998). Mowing in the same direction each time can also lead to compaction and wear. Alternating mowing direction can help to prevent 'grain' and is common practice for maintaining areas such as golf greens (Christians, 1998). On surfaces where grass clippings would interfere with play such as on golf greens it is essential that grass clippings arising from mowing operations be removed (Turgeon, 2002; Christians, 1998). Turfgrass quality and reduced incidence of disease are also claimed to be improved by clipping removal (Turgeon, 2002). Turgeon and Christians both state that clippings, if not collected, have been claimed to contribute to thatch layers within the turfgrass soil profile. Both authors refute this theory and consider that the real contribution of clippings to thatch development is minimal since leaf blade remnants readily decompose. Grass clippings are a source of plant nutrients particularly nitrogen which be found in concentrations ranging from 3 to 5% in dried clippings. Returned grass clippings can contribute an estimated 10 g/m^2 to the sward (Christians, 1998). The removal of clippings necessitates the application of additional fertilizer, at cost, to compensate for nutrients that have been removed (Turgeon, 2002). Clipping removal can help to reduce populations of *Poa annua* and other weeds in turfgrass surfaces (Fry and Huang, 2004; Christians, 1998) but it does increase operations time, costs and an issue for the disposal of arising's.

On surfaces where an even and uniform turf is required an appropriate height and frequency will not guarantee such an outcome. Grasses produce lateral growths such as aerial tillers and stolons which need to be raised to affect their cutting at the general mowing height (Adams and Gibbs, 1994). There is a range of equipment from mechanical scarifiers to vertical cutting units which can be used to varying degrees to sever such plant tissue and rip out debris from the turf surface. The frequency of use for such implements varies according to the depth of treatment required whether it be light cutting on a weekly basis to more severe scarification to remove debris on an annual basis (Adams and Gibbs, 1994). Such practices can have a negative impact on surface quality. On balance cutting height and frequency are therefore likely to be the key parameters in the management framework.

2.3   Mowing Practice for Golf Greens

Having considered the principles for mowing including its affects upon the turfgrass plant the course manager must decide upon actual practice for the surfaces they have direct responsibility for. Beard (2002) advocates mowing on a daily basis for golf greens to achieve optimum surface conditions required by players especially during periods of active growth. This is frequently the practice in summer when grass growth is at its peak. This is further supported by Ryan (1999) who also adds that mowing frequency should be in line with expected standards of golf green surface presentation. Mowing less frequently results in less turfgrass shoot density and coarser leaf texture which would negatively impact on surface quality. Frequency of mowing is often recommended to be decided by actual turfgrass growth which is, of course largely affected by environmental conditions (Adams and Gibbs 1994; Ryan 1999 and McCarty 2001). McCarty (2001) considers that in reality mowing frequency is most often decided by what is considered best for the grass and what is practical for greenkeepers. Minimum frequency is most often considered to be three occasions per week (Adams and Gibbs 1994; Ryan 1999 and Turgeon 2002) to the maximum seven occasions per week (daily cutting) suggested by Adams and Gibbs (1994); Beard (2002) ; McCarty (2001) and Turgeon (2002). Beard (2002) and Ryan (1999) discuss the operation of double mowing (one mowing pass immediately following another), an extreme practice, for tournaments where this is done to enhance golf green ball roll speed. Height of cut for golf greens range from 2.5mm (Beard, 2002; McCarty, 2001) up to 7mm suggested by Adams and Gibbs (1994). Again, environmental conditions, should influence actual heights of cut and there is general consensus that mowing heights should be seasonally adjusted in response to growth. Turgeon (2002) states that cutting heights below 3mm are possible on golf greens which receive little

traffic but this is not universally accepted or adopted. Mowing direction should be varied as much as possible with each successive mowing (Turgeon, 2002) using at least four different directions to reduce turf grain (Adams and Gibbs, 1994; Beard, 2002). Mowing patterns, from varied directions, also serve to enhance aesthetic qualities in surface presentation (McCarty, 2001) which is considered important by players. Vertical cutting units can be used from 5 to 14 day intervals to control grain (Adams and Gibbs, 1994; Beard, 2002). Turf groomers and a variety of brush and comb attachments are frequently used with cylinder mowers on golf greens to control grain and ensure procumbent grass growth is lifted for effective cutting (Ryan, 1999; Turgeon, 2002). Grass clippings should always be removed in the mowing operation for golf greens (Adams and Gibbs, 1994; Beard, 2002; McCarty, 2001 and Turgeon, 2002).

When mowing golf greens there is a choice whether to use pedestrian operated or ride-on (triple) machines. The first ride-on greens mower was introduced in 1968 by Jacobsen (the *Greens King*) and such machines were rapidly taken up by golf course managers (Adams & Gibbs, 1994; Randquist, 2004 and O'Brien, 2013) with their use widespread by the mid 1970's. These ride-on machines, with three cutting units, allowed one man to mow 18 golf greens in under 3.5 hours whereas it would take three men 3 hours to do the same (Randquist, 2004). This factor, together with the convenience afforded by ride-on machines, led to the dominance of such machines for cutting golf greens (Adams & Gibbs, 1994; Randquist, 2004 and O'Brien, 2013). Despite the popularity of ride-on machines many greenkeepers identified issues with increased wear and compaction around golf green perimeters with resultant deterioration in turf quality. Issues with quality of cut and hydraulic oil leaks also led to many greenkeepers reverting to pedestrian machines again. (Adams & Gibbs, 1994; Arthur & Isaac, 2015; Randquist, 2004). Many greenkeepers still maintain that pedestrian mowers give a better quality of cut and surface presentation than ride-on machines (Arthur & Isaac, 2015). The rear roller of a pedestrian mower allows the machine to sit closer into the turf sward enabling lower cutting and affording a light rolling action which smooths the surface enhancing golf green surface performance. O'Brien (2013) states that there has been a resurgence in the use of ride-on mowers for golf greens which is attributed to developments in mower technology but also, notably to economic factors and labour costs. The golf course manager is faced with decisions of green quality and operational costs. The use of pedestrian mowers is still advocated by many for tournament preparation and still seen as the hallmark of quality for greens presentation (Adams & Gibbs, 1994; Arthur & Isaac, 2015).

Mowing is the most time consuming practice and requires expensive machinery. It is, therefore, the most costly of turf management operations and will most certainly be expected to be a key parameter in the management framework.

2.4   Irrigation

Irrigation is the input of water principally to supplement, when necessary, that received from rainfall to maintain adequate soil moisture levels and sustain turfgrass growth (Adams and Gibbs, 1994, Christians, 1998 and Turgeon, 2002). Many amenity and sportsturf surfaces may be maintained without any additional water to that received from rainfall, however, irrigation is needed to maintain high quality turf and automated irrigation systems are common on golf courses (Christians, 1998). Adams and Gibbs (1994) and Turgeon (2002) identify several other uses for irrigation on turf surfaces stating that it helps maintain turf colour (verdure), prevents the development of 'dry patch', to wash in fertilisers and some pesticides into the surface and also wash out accumulated salts from the soil profile. Here, again, turf colour is seen as important for presentation to players. Arthur and Isaac (2015) are strongly opposed to irrigation as a means of achieving colour which they see as the antithesis of good playing conditions. Adams and Gibbs (1994) also warn of the dangers of using irrigation purely for cosmetic reasons claiming that this will favour invasion of *Poa annua* and possible overwatering leading to waterlogging and anaerobic soil conditions. They advise that maintaining turf at moderate soil water levels will better sustain more desirable turfgrass species and stress undesirable types such as *Poa annua*. Greenkeepers, however, often irrigate copiously to promote grass growth and recovery from wear.

A feature of many sports turf surfaces, especially golf greens, is that they are constructed on sand dominant soils which characteristically exhibit poor water retention and are frequently quite shallow in depth overlying a drainage layer. This and the shallow rooting frequently found on close-mown turf, exacerbated by overly low cutting heights, means that the effective soil depth for water retention is often no more than 150mm (Adams and Gibbs, 1994). Given a water holding capacity of approximately 20% such a soil could hold a maximum of 30mm of water which in UK summer conditions would be exhausted in less than a week (Adams and Gibbs, 1994). On all sand dominant sports surfaces irrigation will be required on several occasions a year. Rooting depth frequently determines the volume of soil that serves as a water reservoir and deeply rooted turf should have a lower irrigation demand than one with shallow roots. Shallow-rooted turf requires more frequent but less intensive irrigations than deep-rooted turf (Turgeon, 2002). As well as inherent plant genetic traits grass rooting depth

is frequently affected by cultural factors including close mowing, soil compaction, poor aeration and excessive fertiliser use.

In addition to that lost through drainage water is primarily lost from established turfgrass swards by direct transpiration from the plant (Fry and Huang, 2004) and also from the soil surface (evaporation). These are frequently referred to together as evapotranspiration or ET (Turgeon, 2002; Fry and Huang, 2004 and Christians, 1998). Some water from lower soil depths may move upwards through capillary action but may frequently not be sufficient or timely to prevent turf grass stress or death thus irrigation is required. (Turgeon, 2002). Several factors have an influence on evapotranspiration which will increase with solar radiation (Turgeon, 2002; Fry and Huang, 2004) and increases in air and soil temperature, day length and wind (Christians, 1998 and Fry and Huang, 2004). The turf manager's role is to select grasses and cultural strategies which result in the lowest possible rate of ET and still allow for the desired level of turf quality to be maintained (Fry and Huang, 2004). Environmental factors impacting on ET are outside the control of the turfgrass manager but cultural practices are not.

Irrigation frequency on golf greens is a function of the rootzone and the amount required a function of ET (Lodge, 1994) but there is no easy answer to how much water turf needs as variability in grass species, soil type and environmental conditions all affect water use. These factors interact in complex ways that require turfgrass managers to make constant onsite decisions (Christians, 1998). Managers have a variety of science based tools which combined with a common sense approach provide an integrated approach for determining irrigation requirements (Fry and Huang, 2004). Soil type is a major determinant in deciding amounts of water required as fine-textured soils (clays) retain water whereas coarser textured soils (sands) drain rapidly due to larger pore spaces between the sand particles. Clay particles also have internal porosity which retain moisture (Turgeon, 2002). Coarser soils also have greater rates of water infiltration which allows for irrigation water to be applied more rapidly but less water is needed to moisten a given soil volume. In a season, though, greater quantities of water will be needed for coarser soils as they drain quicker and lose more water through evapotranspiration than do fine-textured soils (Turgeon, 2002). For cool season grasses water use rate in periods of active growth will range from 2.5 to 8mm per day (Fry and Huang, 2004). Christians (1998) states that in normal maintenance conditions turf will require between 25mm and 38mm of water per week from rainfall, irrigation or a combination of the two but that grasses use only about 1% of this amount for actual growth and development.

The application of water at a proper frequency is an important part of turf management and varies with local conditions and it is clearly possible to overwater leading to shallow rooting

and turf which will be poorly adapted to stress conditions (Christians, 1998). Adams and Gibbs (1994) concur and state that a soil cannot be moistened to a uniform water content when the water input does not achieve field capacity meaning that small amounts of water applied to a dry soil will result in uneven wetting which may sustain grass growth but will encourage shallow rooting. Fry and Huang (2004) discuss the debate regarding turf irrigation and whether deep, infrequent or light frequent irrigation is best, a long running argument in turfgrass management. They define deep, infrequent irrigation as wilt based irrigation as water is applied to replenish the soil at the first signs of the plant wilting. The opposing form being field capacity irrigation where water is applied lightly but more frequently to maintain soil moisture status. Fry and Huang (2004) state that research has demonstrated that the plant is probably best served by using wilt-based irrigation but that field capacity irrigation has benefits. Positive benefits of wilt based irrigation include reduced clipping yield, shoot growth, enhanced rooting, lower leaf water and osmotic potentials, better turf quality and leaching of growth-inhibiting salts. Benefits of field capacity irrigation are stated as less potential for nutrient and pesticide leaching, fewer problems with localised dry spot on sand-based soils, maintenance of turf quality when water availability is restricted, and potential reduction in some turf diseases. Lodge (1994) in discussing irrigation frequency rightly points out that a little and often approach to irrigation can encourage shallow rooting and encroachment of *Poa annua* on permanently moist surfaces and also that the alternative, deep irrigation to field capacity may not suit play.

Turgeon (2002) reports that golf course managers who irrigate daily do so in the belief that this improves turfgrass growth and quality and that this trend has been rationalised on demands for higher quality turf with closer mowing requirements and increasing golfing traffic. Excessive irrigation rates, however, render soils more susceptible to compaction and surface wear from play. Frequently this leads to shallow rooting which then necessitates more frequent irrigation. These problems can be reduced by cultural practices such as aeration and installation of drainage systems (Turgeon, 2002). A sound cultural programme including efficient use of irrigation water can provide a turf of adequate playability without excessive irrigation. Adams and Gibbs (1994) strategy for irrigation being to irrigate to field capacity at infrequent intervals during long dry spells and to supplement this with light irrigation (1-4mm) daily or every second day. Christians (1998) justly states that water conservation should be the concern of every turfgrass manager. Factors to consider include grass species, mowing height, fertilizer programmes, aeration and chemical usage such as plant growth regulators. As long ago as 1994 Adams and Gibbs identified that irrigation of turf will become more expensive and less available (Adams and Gibbs, 1994). This is still a resource and

environmental issue for golf course managers but would only be useful in a management framework if detailed irrigation records are maintained by managers.

2.5   Irrigation of Golf Greens

The application of water to golf greens is one on the most critical and difficult decisions of the golf course manager (Beard, 2002). Irrigation should be applied as required to sustain turfgrass growth (Turgeon, 2002) and not to increase ball holding or fulfil a cosmetic purpose (Adams and Gibbs, 1994). This is good advice. There may be conflict, however, between the biological needs of the grass and golfers requiring moist surfaces to hold the ball as it alights on the golf green (Lodge, 1994). Ryan (1999) recommends that soil moisture levels for golf greens should be maintained between plant wilting point and field capacity. An issue with golf greens is that due to extremely low cutting heights, often practised in the pursuit of green surface speed, root depths are frequently shallow resulting in reduced water absorption capability (Beard, 2002). As a result, golf greens frequently require greater irrigation intensity than other managed turf surfaces and areas (Turgeon, 2002). Irrigation requirement will depend on many factors including soil characteristics, rainfall, turfgrass species and how much water is lost through evapotranspiration (Adams and Gibbs, 1994; Beard, 2002; Ryan, 1999 and Turgeon 2002). In applying water with automatic irrigation systems, the norm on most golf courses, Adams and Gibbs (1994) identify how these do not enable the course manager to calculate how much water has actually been applied. Frequently they are operated on a time basis with no information regarding water flow rate. Irrigation programmes cannot be effectively planned and managed without knowing the quantity of water applied. Irrigation systems should be capable of applying the 25mm of water typically lost through evapotranspiration in UK conditions (Adams and Gibbs, 1994). There are a variety of equipment including weather stations and soil moisture sensors can be used to determine irrigation need and to control application (Ryan, 1999). Despite these Ryan reports, that at the majority of the world's golf courses irrigation decisions are based on the experiential knowledge of the golf course manager. In planning irrigation there is a lack of published data in terms of ET rates and other turf specific input requirements for UK conditions. Irrigation practice in the UK is more reactive and reliant on the course manager's experience than in agricultural crop production and presents an unreliable parameter for effective measurement especially for individual golf greens.

2.6   Turf Nutrition and Fertilizer Application

Grasses are green photosynthetic plants which use the energy in light to convert carbon dioxide into organic carbon compounds which are used as a source of chemical energy for the building blocks for the many diverse compounds that plants contain. There are thirteen mineral elements primarily derived from the soil that are recognised as being essential for healthy grass plant growth (Adams and Gibbs, 1994; Turgeon, 2002). Some authorities recognise Nickel (Ni) as another important mineral element for grass growth (Christians, 1998). These essential minerals are often divided into categories according to their concentration in plant tissues known as macro and micronutrients (Turgeon, 2002 ; Christians, 1998).Plant scientists define macronutrients as those found in plant dry matter at concentrations of at least 1000pm and this includes Nitrogen (N), Phosphorus (P), Potassium (K), Sulphur (S), Magnesium (Mg) and Calcium (Ca). Micronutrients, at concentrations of 100pm or less, include Iron (Fe), Manganese (Mn), Molybdenum (Mo), Zinc (Zn), Boron (B), Chlorine (Cl), Copper (Cu) and Nickel (Ni). If any nutrient is lacking a deficiency may be apparent as diagnostic visual symptoms within the plant, however, grasses do not generally exhibit symptoms as clearly as other plants (Adams and Gibbs, 1994). A deficiency has to be quite severe before any symptoms show and growth may be limited with no obvious visual effect. In grasses the nutrients which have been found to most frequently control growth are Nitrogen (N), Phosphorus (P) and Potassium (K) (Adams and Gibbs,1994) and these are also the elements most frequently lacking in soils on which turf is grown (Christians, 1998). For these reasons these nutrients are the ones most frequently used in fertilizer programmes and those found in commercial fertilizer products (Adams and Gibbs, 1994; Christians, 1998 and Turgeon, 2002). The concentration and ratio of N, P and K within grasses is fairly constant in frequently mown grass where all leaf tissue is of a comparable physiological age (Adams and Gibbs, 1994). The N, P, K ratio in grass clippings is around 8.5:1:6 which when transposed to normal fertilizer nutrient expressions approximates to a weight ratio of 4:1:3. This ratio defines the relative amounts of nutrients required by turf in fertilizers where grass clippings are removed (Adams and Gibbs, 1994) such as for golf greens.

Fertilizer application ranks with mowing and irrigation in turfgrass cultural programmes as a primary determinant of turfgrass persistence and quality but is one of the least time consuming and expensive components of turf grass management (Turgeon, 2002). Fertilizer application is an established practice in agriculture and horticulture and fertilizers have become so readily available and relatively cheap that they are frequently assumed to be essential (Adams and Gibbs, 1994). Turgeon (2002) contrasts this situation to grass culture where the extensive use

of chemical fertilizers is a relatively new practice, as historically turf grass managers did not have such products and relied upon nature and their own practical experience to sustain grass surfaces. This was certainly the case on links golf courses in the early 20th century and earlier. Turgeon (2002) states that today, however, the demands for fine quality turf under severe stress and frequently adverse environmental conditions require extensive knowledge of plant nutrition and fertilizer use. There has been a move by some course managers to revert to earlier practices and use more natural products such as seaweed for golf green culture because of environmental and cost considerations. An approach favoured by those who advocate sustainable or traditional greenkeeping (Arthur and Isaac, 2015).

The application of fertilizers is often required to replace nutrients lost to the air, drainage water or removed from the grass plant in clippings. Frequently nutrients are removed more rapidly than they can be replenished by weathering of soil minerals, biological fixation of nitrogen and deposition from the air (Adams and Gibbs, 1994; Turgeon, 2002). In agriculture, crops are harvested which contain plant nutrients, in turf culture the equivalent is that of grass clippings removed in mowing. This is often the major factor in determining fertilizer programmes for turf. Where grass clippings are not removed, as for many amenity areas and some sports turfs there may be no fertilizer input (Adams and Gibbs, 1994). Intensively used sportsturf, such as golf greens, cannot be sustained satisfactorily though without relatively high fertiliser inputs as grass clippings are removed and wear reduces the plants uptake of nutrients (Adams and Gibbs, 1994).

It is difficult to determine precise nutritional requirements for turfgrass swards as there are no direct criteria which exists to measure turfgrass response and measures such as quality, often judged an appearance or colour, are largely subjective (Turgeon, 2002). Nitrogen is the plant nutrient which most frequently controls growth in turfgrasses (Adams and Gibbs, 1994) and required in the greatest amounts (Turgeon, 2002). Potassium is the second most required nutrient and then phosphorus (Turgeon, 2002). As the ratio of N, P and K removed in grass clippings is fairly constant then a reasonable ratio for fertilizer would be 4:1:3 for of N: P_2O_5: K_2O as the forms these nutrients are taken in by the plant. This has been the basis for many commercial fertilizer products used in turf care (Adams and Gibbs, 1994) but is in reality rather poor practice. Another approach is of applying nutrients separately, Turgeon (2002), recommends that nitrogen should be applied according to turf grass growth whilst phosphorus and potassium applications should be based on soils tests. Here nitrogen response can be assessed by turf colour, clipping yield and grass density. Turgeon (2002) maintains that nitrogen application is as much of an art as a science and conducted by 'feel' when one has sufficient experience of a particular surface. This is a view shared by Christians (1998) who

goes further in stating that it is the nitrogen fertiliser programme that will quickly separate the experienced from the inexperienced manager. Experiential knowledge then, informs operations decision making. Soil tests for phosphorus and potassium should only be used as guides in developing fertilizer programmes as no one has determined with any certainty optimum levels required for turfgrass growth (Turgeon, 2002). There are also no reliable soil tests for determining the nitrogen needs of the grass plant (Christians, 1998).

Adams and Gibbs (1994) recommend that there is a good scientific basis for the strategy of applying phosphorus occasionally, which Arthur and Isaac (2015) refute in golf green culture, as it is retained in soils, and to apply nitrogen and potassium more frequently as growth dictates given that these are lost in large amounts in clippings and more readily leached from sand dominant soils often used for sportsturf surfaces. Adams and Gibbs (1994) consider that a policy of maintaining supply of all other essential nutrients and of using nitrogen as the control for grass growth the most effective approach to fertilizer management. Christians (1998) supports this approach and states that it is the amount of nitrogen applied which is the critical factor in fertilizer programmes. The actual amounts and timing of fertilizer applications depend on many variable factors including soil type, grass species, time of year and local environment. Turgeon (2002) considers that most turf surfaces will require at least two fertilizer applications per year to maintain satisfactory growth and appearance. Adams and Gibbs (1994) recommend that water soluble nitrogen fertilizers should be applied at intervals not greater than two to three months during the growing season (May to September) on very sandy soils at a rate not exceeding 60 kg/ha. This is due to the issue of such fertilizers being leached from the soil if over applied. Turgeon (2002) asserts that no more than 50 kg/ha of nitrogen should be applied and in hot weather no more than 25 kg/ha. Few authors give more specific guidance on nitrogen application given the variability of site and environmental conditions and nitrogen inherent mobility in the soil. Christians (1998) stipulates that nitrogen fertilizer programmes need to be adjusted to specific local conditions and that there is always a need for an experienced turf grass manager to finalise a fertilizer programme. Both Turgeon and Christians base their recommendations on golf greens in the USA which do not reflect growing conditions and practice in the UK.

Phosphorus is relatively immobile in the soil and many compound fertilizers available for use on mature turf frequently have analyses (N, P, and K) similar to 18-5-9 and 20-2-15. Christians (1998) attributes the use of low phosphate fertilizers to the grass plants inherent ability to obtain phosphorus from the soil and not that they require any less than other plants. Application of phosphorus results in little visible response in the grass plant but it is considered to improve disease resistance, heat, and cold and drought tolerance. Fertilizers for turf have

generally included more potassium since research in the 1980's identified is role within grasses leading to analyses such as 20-3-15 and 30-0-30 being more common (Christians,1998). These form the basis of many fertilizers used in golf green culture to this day.

2.7   Fertilizer Application for Golf Greens

Fertilizer programmes for golf greens should be formulated to sustain grass growth and density in accordance with the required standards for golf green quality (Ryan, 1999; Turgeon, 2002). Quality, however, can be highly subjective, especially when judged as colour, and needs quantifying for management decision making. Specific recommendations for fertiliser application for golf greens are not possible due to the wide variation in soil types, turfgrass species and climate (Adams and Gibbs, 1994; Turgeon, 2002). Adams and Gibbs (1994) alleged that fertilizer application practice is a major area of controversy in golf green culture and related this to the incidence of *Poa annua* with high phosphate inputs, a view maintained by Arthur and Isaac (2015), they considered there were issues with high fertilizer inputs generally. Beard (2002) further identifies where excessive nitrogen inputs have been used to provide golf greens of a dark green colour favoured by golfers. Ryan (1999) advocates that all fertilizer programmes for golf greens should be linked to regular monitoring of nutrient levels within the growing medium as this will ensure adequate turf nutrition without wastage. In determining actual quantities to apply Adams and Gibbs (1994) state that a sensible approach is to adopt the 4:1:3 ratio input of N: P_2O_5: K_2O (this being the rate turfgrasses use these nutrients) and to adjust the level of nitrogen (N) input according to visual appearance. This, though, poses challenges for the manager as one is resorting to a subjective criterion. Levels of phosphorus (P_2O_5) and potassium (K_2O) are determined assessed by soils analysis, a quantifiable criterion. Beard (2002), McCarty (2001) and Turgeon (2002) all concur with using soil analysis to inform inputs of both potassium and phosphorus. Turgeon (2002) recommends that potassium input should be at least half that of nitrogen or more in sandy rootzones as it is easily leached. Beard (2002) however, states that it can be as much as 75-100% of the nitrogen applied. Adams and Gibbs (1994) affirm that golf greens with sand dominant soils typically require in kg ha of N, P_2O_5, and K_2O, 220, 50 and 150 respectively. Lodge (1994) identified that in recommendations for nitrogen the majority, in literature ,fell between 200 and 300 kg ha per year in a range from 140 to 500 kg ha year. Lodge (1994) recommends a minimum of 235 kg N ha year for soil constructions and up to 410 kg ha year for sand constructions golf greens. Light and frequent applications of nitrogen should be made throughout the growing season (Beard, 2002. McCarty, 2001 and Turgeon 2002) with no less

than 60% of the annual input applied before mid-June (Adams and Gibbs, 1994). McCarty (2001) recommends little or no applications of N after 15th November as its uptake in cold and frozen soils is limited and there is a need to reduce disease incidence at this time of year but prevailing weather conditions and growth should always determine actual practice. Beard (2002) supports the use of complete fertilizers (containing N, P_2O_5, and K_2O) in the spring and again in late summer in which both the annual P_2O_5, and K_2O are often made. This, in practice has little merit in applying actual nutrient amounts required as Adams and Gibbs (1994) rightly state. The management framework is likely to include nitrogen fertilizer application as the most significant input in practice.

2.8   Physical Properties of Soils and Turf Aeration

Soils are composed up of mineral particles, organic matter and also a network of channels and pore spaces which have a fundamental effect on soil properties including aeration and drainage (Jakobsen & McIntyre, 1999). The inorganic or mineral constituents can be classified according to size and mineralogy (Adams & Gibbs, 1994). Mineral particles are categorised as sand, silt and clay and the proportion or percentage of each of these can be plotted onto a 'triangle of texture' to give a soil class descriptor. This is known as soil texture (Adams & Gibbs, 1994; Jakobsen & McIntyre, 1999). Adams & Gibbs (1994) state that the term 'particle size class' is a better term to use than soil texture as there is frequent confusion between the terms soil texture and soil structure.

Soil structure describes the size, shape and arrangement of soil particles (Jakobsen & McIntyre, 1999). This is a significant factor for sportsturf soils as they are far more demanding than soils used for other purposes and it is for this reason they are frequently designed and created for specific sports (Adams & Gibbs, 1994).The movement of water through soils is determined by the arrangement of soil particles and aggregates which are frequently affected by play in adverse conditions leading to loss of structure, reduced porosity and poor drainage (Jakobsen & McIntyre, 1999). Poor drainage is the major problem in the management of fine turf surfaces and an understanding of soil-water relationships is necessary to remedy such turf management problems (Adams & Gibbs, 1994). Lodge (1994) also recognises the importance of assessing soil structure as it has more value in determining turf management practices than determination of particle size class. The complex arrangement of individual soil particles and aggregates create channels and spaces between them of differing shape and size. These spaces, channels and voids are collectively called pore spaces and their arrangement is affected by the degree of soil compaction and the stability of the soil

aggregates (Jakobsen & McIntyre, 1999). Pore spaces provide pathways for the movement of water, space for roots to grow and air space which are essential for turfgrass root growth. Water is stored in the smaller pores and these determine the water holding capacity of soils.

In natural soils macropore space, pores which are air-filled at field capacity, is created by aggregates of particles rather than by individual particles. In sports turf these fragile structures cannot persist in conditions of intense compaction and primary particles of an appropriate size must be used to control both total porosity and pre size distribution (Adams & Gibbs, 1994). Sands with a wide range of particle sizes have the potential to create a wide range of pore sizes when un-compacted and when particle distribution is random. However sands can inter-pack when compacted eliminating macropores and reducing total porosity. In considering particle shape rounded versus angular sands are discussed by Adams & Gibbs (1994). They affirm the benefits of angular sands in maintaining a more open framework of pores but suggest that such sands are rarely available as abrasion from weathering forces round sand particles. Sands with a large gradation index result in a reduced total pore space and reduced hydraulic conductivity (Adams & Gibbs, 1994) and therefore a narrow particle size distribution is advocated. As previously stated large pores are required for soil aeration, grass root growth and rapid drainage. There is no precise figure for the minimum air-filled porosity as this depends on plant species and oxygen demand in the soil, however, a figure of 10% (air-filled pore space in a soil volume) is often used as a minimum (Adams & Gibbs, 1994).

As Christians (1998) and Fry and Huang (2004) assert turf surfaces used for sport and recreation are frequently subjected to heavy traffic which subsequently present management problems, the most significant of which is that of compaction. The manager frequently has no, or only limited, control over when play occurs and number of rounds of golf played. There are two major problems which result from compaction. The first is that compaction eliminates free-draining macro spaces between particles leading to saturated soil and secondly pores within the soil are too small for turf grass roots to grow into (Adams and Gibbs, 1994). The degree of soil compaction can be measured as bulk density calculated as the weight of soil (g) ÷ volume of soil (cm³). The volume includes both soil solids and the pore space between them. When soil is compacted there is more solids in a given volume and less pore space. Bulk density increases as compaction increases (Fry and Huang, 2004). Soils not subjected to foot and vehicular traffic generally have moderate volume of macropores (pores greater than 75 μm in diameter) but in all but the sandiest soils this free draining pore space can be eradicated with compaction (Adams and Gibbs, 1994). Sandy soils are more resistant to compaction, as opposed to fine-textured soils (clays and silts), which is why they are frequently used in root zones for sports turf surfaces such as golf greens (Fry and Huang, 2004).

Soil compaction has several adverse effects on grass plant growth and development (Fry and Huang, 2004). The most immediate impact is on root growth. No turfgrass roots are smaller than around 60 μm in diameter and their ability to grow thus depends on adequate pore space and soil not so compacted that this is limited or non-existent (Adams and Gibbs, 1994; Fry and Huang, 2004). Not only will mechanical impedance affect root growth but also the resulting lack of oxygen as air-filled porosity decreases. Such anoxia will lead to root death and subsequently loss of shoots (Christians, 1998; Fry and Huang, 2004). Research has shown that shoot growth, root growth, carbohydrate levels and water use rates in grasses are all affected by soil compaction (Fry and Huang, 2004). Christians (1998) also states that compaction can result in excessively hard playing surfaces.

Compaction can be reduced by managing use and varying traffic patterns but this is frequently not enough on areas used for sport. Mechanical means of controlling compaction are an important part of turf grass management (Christians, 1998). Adams and Gibbs (1994) identify two methods of relieving soil compaction and improving aeration in established turf. These are to raise the soil surface so that the same mass occupies a greater volume or to remove soil cores so that the now reduced soil mass occupies the same field volume. There is a wide range of machinery available to relieve compaction and improve turfgrass growing conditions. The manager must decide means and method in aeration operations based on own knowledge and experience. The primary aim being to promote root growth, increase soil air porosity and facilitate soil water infiltration and drainage (Fry and Huang, 2004). Hollow coring utilises tines to extract cores from the turf and is an accepted turf aeration technique that relieves soil compaction and has the added benefit of removing thatch from the turf soil profile (Adams and Gibbs; Christians, 1998). Core size varies from 5 to 30mm diameter, depending on the size of the tine. Decompaction is achieved by soil removal (Adams and Gibbs, 1994) and root growth develops rapidly within the cores (Adams and Gibbs, 1994; Christians, 1998 and Fry and Huang, 2004). Core aeration, as well as directly removing some thatch, opens up the surface allowing moisture and oxygen into the turf root zone, the net effect being an increase in soil microbial activity which helps to breakdown thatch (Christians, 1998). Core aeration can be very disruptive to the turf surface and often the frustration of golfers (Christians, 1998). Its timing often subject to agronomical as well as internal political considerations. It is often done in conjunction with topdressing (Adams and Gibbs, 1994; Turgeon, 2002) which should always be compatible with the rootzone or at least comprise a material which will improve the root zone characteristics.

Application of sufficient material (most usually a sand or sandy loam material) will completely fill the core holes and the thatch layer is thoroughly infused with topdressing. Coring can provide a means to bypass surface problems, such as thatch, to link to the underlying soil (Turgeon, 2002). Another form of aeration is that of using solid tines. A solid tine penetrates the soil but no core is removed so it is less disruptive to the turf surface and recovery is quicker (Christians, 1998). Some solid tines are able to penetrate to depths of 30cm and as the tines move out of the soil heave and lift the surface thus increasing soil aeration such as the Verti-drain type machines (Turgeon, 2002; Adams and Gibbs, 1994). There are also a variety of machines with star shaped discs or knives which slice into the turf surface, to a variety of depths, leaving slits in the surface. Disruption to the surface is minimal and improvement in water infiltration is often seen and the severing of grass roots and rhizomes stimulates root and shoot growth (Turgeon, 2002). Slitting can be practised weekly during the growing season to mitigate soil compacting traffic as only minor disruption occurs to the turf (Turgeon, 2002). There also exist several specialist methods to relieve compaction by soil fracturing or loosening such as those which inject either air or water into the turf. Such equipment is often less mobile than conventional solid or hollow tine machines and therefore less useful for larger areas although the technology does shatter subsoil layers are relieving compaction (Adams and Gibbs, 1994).

2.9 Aeration of Golf Greens

On golf greens it is frequently necessary to improve or correct water infiltration and air entry into the rootzone (Adams and Gibbs, 1994). This can be achieved by spiking with solid tines at weekly or more intervals depending on need (Adams and Gibbs, 1994; McCarty, 2001 and Turgeon, 2002). Spiking may be required frequently from autumn through to spring, depending on the rootzone, as rainfall often exceeds evapotranspiration during this time (Adams and Gibbs, 1994). Spiking is less disruptive to the surface than other forms of aeration and can be completed at any time of year when there is active turfgrass growth (Turgeon, 2002). Solid tines, up to 450mm long, are effective for treating deeper compaction and aeration in golf greens (Beard, 2002). Slitting with flat tines, as a method of aeration, is used much less frequently on golf greens (Beard, 2002). Compaction is a common issue in golf greens especially those on fine-textured silt and clay soils , "push-up greens" , and the practice of hollow coring is the most widely used method to correct this problem (Adams and Gibbs,1994 ; Beard, 2002). Frequency of coring is dependent on intensity of traffic and factors such as the soil type and drainage capability (McCarty, 2001). Coring may be needed several occasions throughout the year (Turgeon, 2002 and Beard 2002) even proposes it may be required

monthly on fine-textured soils where traffic is intense. This is seldom practiced in the UK because of resource issues, differences in climatic conditions that do not support such growth rates, different grass cultivars, differing green construction standards, and the disruption it can cause to play. Adams and Gibbs (1994) recommend treatment in autumn and again in spring on intensively used golf greens and one annual treatment where such traffic is less intense. As coring is disruptive to the surface (Turgeon, 2002) and should only be done in periods where temperatures favour rapid growth and recovery (Beard, 2002; Turgeon, 2002). Aeration of golf greens is a key management practice which is essential to maintain soil air and drainage properties. In practice the golf course manager usually has to schedule this key maintenance practice around players and club events.

2.10   Topdressing and Thatch Control

Topdressing is the practice of applying a light layer of soil or other finely granulated material to an established turf surface (Christians, 1998; Turgeon, 2002 and Fry and Huang, 2004). It is also one of the oldest greenkeeping operations. Topdressing is one of the most important cultural practices in turf maintenance and one of the most difficult to conduct correctly. It is frequently abused which can lead to significant problems and may necessitate reconstruction (Christians, 1998). The principal reasons for its practise are to restore surface levels damaged through play, modify the turf grass soil or rootzone (especially when done with hollow coring) and reduce (dilute) thatch layers (Adams and Gibbs, 1994; Turgeon, 2002 and Fry and Huang, 2004). It is an expensive and time consuming operation generally restricted to high quality turf surfaces such as golf greens and professional sports pitches (Christians, 1998).

The choice of material for topdressing is one of the most important decisions in managing turf grass surfaces (Turgeon, 2002). An inappropriate material choice leads to one of the most commonly observed problems in turfgrass rootzones termed layering (Turgeon, 2002). Layering occurs where the topdressing material is incompatible to the in-situ soil or rootzone and instead of ameliorating with it forms a distinct horizon within the soil profile. This layering can restrict water movement leading to anaerobic soil conditions and deleterious effects on turf performance (Fry and Huang, 2004). Where the indigenous soil is favourable the topdressing material should be identical to it. For turf grown on sand-based rootzones a sand with the same physical properties should be used for topdressing (Fry and Huang, 2004). In practice sourcing compatible materials can be difficult as costs and availability of supply affect procurement. In golf course management many links golf courses use the indigenous material and often collect this from the beach. Sand is also a suitable medium for topdressing soils

where the objective is to modify the soil profile (Fry and Huang, 2004), most usually to improve water and air infiltration rates. Organic amendments are not usually a requirement for turf surfaces since turfgrass naturally generates sufficient organic residues and a primary purpose of topdressing in turf is to prevent excessive thatch accumulation (Turgeon, 2002). Fry and Huang (2004) recite the arguments relating to the use of topdressing as a means of thatch reduction. Thatch reduction occurs as sand topdressing dilutes thatch layers and this addition also creates a more favourable environment for thatch decomposing microbes.

Intensively managed turf grass swards frequently develop a layer of dead and living organic material at the interface between the soil surface and below the green living canopy of the grass. This layer is known as thatch and is composed of dead organic material derived from plant tissues including tillers, stolons, rhizomes, leaves intermixed with living roots, crowns and stems of grass (Christians, 1998; Fry and Huang, 2004). This accumulation of organic material is a natural phenomenon in grassland as the growth of grasses is a continual cycle of growth and death (Christians, 1998) however grasses that spread by rhizomes or stolons have a greater propensity to develop thatch (Fry and Huang, 2004). This organic debris is broken down naturally through the activity of a vast array of soil microbes (Christians, 1998; Fry and Huang, 2004). Thatch may become excessive, however, when rates of production exceed rates of degradation (Fry and Huang, 2004) which may occur in intensively managed turf where improper management and cultural practices which promote excessive production of vegetation (Christians, 1998; Fry and Huang, 2004). Causes of thatch include high nitrogen levels, excessive irrigation, low soil pH and the use of pesticides (Christians, 1998). Thus, a balanced approach in resource inputs and maintenance practices is needed.

Thatch is an issue in intensively managed turf used for sport as its presence, if excessive, leads to shallow rooting, often roots growing only into thatch when it is moist, but quickly succumbing to drought in dry spells as the thatch dries out. Thatch is hydrophobic and very difficult to wet again once dry. Thatchy turf is very susceptible to stress from low and high temperatures and drought. Thatch is also host to turf pathogens and can also lead to soft spongy surfaces and poor surface playing quality. (Fry and Huang, 2004). Moderate thatch layers of 12mm or less can be beneficial in some areas such as sports fields where such material provides cushioning for players; not a criterion required for golf greens. Thatch also is a good medium for beneficial soil organisms and can act as a natural filter in reducing movement of pesticides to groundwater (Christians, 1998).

Managers should focus on cultural techniques in controlling thatch including limiting nitrogen applications, managing soil pH, avoiding excessive irrigation and pesticide use (Christians,

1998). There exist, however, a variety of mechanical equipment to physically remove thatch and organic material from turf. Aside from hollow coring, mechanical methods for thatch removal are vertical mowing scarification. Vertical mowing is a mechanical procedure which uses vertically orientated blades mounted on a powered rapidly rotating shaft set to a desired depth to disturb the turf surface and, most often, the organic layer above the soil surface (Turgeon, 2002; Fry and Huang, 2004). Depth of blade (or knife) penetration can be adjusted depending on the objective of the operation when set to just cut surface grass tissue stolons and aerial tillers (shoots) are severed and promote lateral grass growth to produce a dense turf canopy. When set deeper physical removal of thatch material is achieved (Turgeon, 2002), a process usually known as scarification. Turgeon (2002) recommends that vertical mowing is best conducted when grass growth is vigorous to ensure recovery of the turf. Scarification is often practised with aeration, especially coring, as part of turf renovation procedures. Another commonly used mechanical aid is the use of 'groomers'. Groomers are attached to the front of mowing units to lift procumbent growth for cutting. This practice helps to eliminate 'grain' resulting from grass lying in one direction on fine surfaces such as golf greens (Fry and Huang, 2004). Grooming is not an aggressive procedure and so often conducted throughout the growing season.

2.11 Topdressing for Golf Greens

Topdressing golf greens is necessary to smooth the playing surface and frequently to amend the rootzone that supports turfgrass growth (Turgeon, 2002). The choice of material to use is one of the most important agronomic decisions to be made by the golf course manager (McCarty, 2001). Where the rootzone has good physical characteristics, drainage and porosity qualities the topdressing material should be of a comparable material (Beard, 2002; Ryan, 1999) to avoid layering (Ryan, 1999). The material of choice in recent times has been sand or a sand dominated soil to improve drainage and aeration in golf greens which have been poorly managed or deteriorated with age (Adams and Gibbs, 1994; McCarty, 2001). A sand with 80% or more fine-to-coarse particles (0.15 to 0.5 mm) is particularly suited to this purpose (McCarty, 2001) and as a primary function of topdressing is to reduce organic matter topdressing should contain no more than 2% organic matter (Adams and Gibbs, 1994).Frequent light applications of topdressings are preferred for golf greens (Beard,2002) at a rate where no more than one third of the standing height of the grass is covered so as not to smoother the surface (Ryan,1999). Adams and Gibbs (1994) recommend an annual topdressing of 2kg m^2 applied in four to six applications as good practice for UK golf greens. Where topdressing follows

hollow coring aeration heavier rates will be needed to fill the holes on the green (Turgeon, 2002). Topdressing is an essential practice in golf green culture and needs to be one of the parameters assessed in management framework.

2.12 Rolling

Rolling is an established cultural practice which for many decades was used to smooth grass playing surfaces, often to correct disruptions resulting from play. As technology led to advances in turf grass surfaces for sport the compaction effects of heavy rolling were recognised and rolling abandoned as both an unnecessary but most often a damaging practice. (Turgeon, 2002). Heavy rolling leads to compaction, destroying soil structure, limiting grass growth and impacting on surface quality. Beginning in the 1990's there has since been a resurgence in rolling with light weight units especially on golf greens where high standards of smoothness and ball roll are required (Turgeon,2002). Turgeon (2002) further asserts that such rolling is often seen as an alternative to mowing at very low heights of cut to achieve faster speeds on golf greens.

2.13 Rolling For Golf Greens

Rolling golf greens is a practice to maximise surface smoothness and improve golf ball roll (Beard, 2002; McCarty, 2001 and Ryan 1999). Rolling can increase ball roll speed from 10 to 20% (McCarty, 2001 and Ryan 1999) and is important in tournament or championship preparation (Beard, 2002). Such lightweight rolling does not adversely affect turfgrass if practised three or fewer occasions per week (McCarty,2001) and its effects can persist anything from one to three days (Beard,2002). Turgeon (2002) asserts that such rolling is often seen as an alternative to mowing at very low heights of cut to achieve faster speeds on golf greens. Ryan (1999) makes a very valid comment in stating that rolling allows course managers to attain enhanced green speed without mowing excessively close which is detrimental to grass growth, however, it is commonly used in golf green surface preparation for play and as such needs to be apparent in the management framework.

2.14 Summary of Golf Green Maintenance Practice

This review confirms the researcher's professional experience that there are no absolutes in golf green maintenance and it is the responsibility of the course manager to design and implement maintenance programmes often based upon their own experience and local site conditions. It is, though, important that they also recognise both the requirements of the grass plant and that of the playing surface. Frequently one practice or activity has implications or has affects which necessitate other practices to be required. Operations are influenced by many factors. The golf course manager has to accommodate multiple maintenance practices in an environment subject to factors beyond their control including prevailing weather conditions and play. The key maintenance practices for golf green maintenance are summarised here in Table 3 in order that they can be used to review actual industry practice and inform the performance management framework proposed as the aim for this research. The data from the main literary sources reviewed has been tabulated for comparison and ease of interpretation. Recommendations for aeration and irrigation are frequently vague but one should remember that both these practices are subject to site variables such as weather and intensity of use. Data has been converted to English Metric from US Imperial where necessary.

TABLE 3   Summary of Key Golf Green Maintenance Practices and Indicative Parameters

AUTHOR	MOWING	FERTILISER	AERATION	TOPDRESSING	IRRIGATION
McCarty (2001)	HOC = 3.17mm – 16mm FOC = from daily to every 2-3 days	N = 1.8kg – 3.6kg per 929m^2 annually. K = based on N rate (up to 1-1.5 ratio of N to K based on soil analysis. P = 0- 1.8 kg per 929 m^2 annually.	Frequency and tines used dependent on traffic/wear. Every 4-6 weeks (9.5mm diameter tines) in active growth periods	Frequency and quantity based on objective. Typically 0.3825m^3 – 0.765m^3 every 2-4 weeks.	Based on Evapotranspiration rates- from 2.5mm -5mm daily.
Beard (2002) (figures relate to a *Poa* dominated green)	HOC = 3.2-6.4mm FOC = 6-7 per week	N = 0.15-0.35kg per 100m^2 per growing month. P = based on soil analysis. K = 75-100% of N for fine soils. 1.5-2.5kg per 100m^2 for sand soils.	Dependent on traffic – from 1-6 times per year. Spiking weekly in summer.	Apply 1-6 times per year. Minimum of twice (0.14-0.21 m^3/100m^2 in spring) and (0.21-0.35m^3/100m^2 in autumn. Can apply every 2-3 weeks during active growth at 0.07m^3 / 100m^2.	Maintain a constantly moist soil rootzone through daily light watering.
Ryan (1999)	HOC = 3.5 – 4.8mm FOC = 3-6 per week	Based on soil analysis. Minimum 100kg/ha. Per year for N. P = 20-40kg/ha per year. K = 10-20kg /ha per month in growing season.	Method and frequency dependent on situation	Frequency and quantity dependent on situation.	Frequency and quantity dependent on situation.
Adams and Gibbs (1994)	HOC = 5 -7 mm FOC = 3-7 per week.	N = 100 – 250 kg/ha per year. P = 20-80 kg/ha per year. K = 60-200kg/ha per year.	Frequency and method determined by need. Spiking 1 per month in growing season and more frequently from autumn to spring.	2kg m^2 – 4-6 times per year.	Matched to evapotranspiration rate – typically 25mm per week in summer.
Turgeon (2002)	HOC = 4.76mm – 6.35mm. FOC = 3-7 per week.	N = 0.34kg – 0.22kg 929 m^2 per growing month at 2-6 week intervals. P based on soil analysis. K = ½ or more of N based on soil type.	Hollow coring from 1 to several times per year. Spiking weekly in season.	Research methods to develop Rates and frequency dependent on conditions. Every 3 – 4 weeks. Typically 0.153m^3 per 929m^2.	As required to sustain growth.

These parameters for golf green maintenance will be revisited in the methodological and analysis chapters to inform the performance management framework.

Chapter 3   Operations Management

Introduction

To achieve the primary aim of this research and develop a performance management framework for golf greens one must consider operations management as it achieves organisational objectives by providing the product for the customer. Golf Course Managers can be considered to be Operations Managers charged with managing the operational process to achieve golf greens (amongst other commercial managerial responsibilities) that fulfil both senior management, and more critically, player/client requirements. This chapter reviews various aspects of this management discipline to inform the research objective and the later empirical investigative research. The most significant operations practices of cost effectiveness, planning work, work study operations improvement are discussed and summarised for this purpose.

Operations management is the activity of managing resources to create products or services (Slack ,Brandon-Jones and Johnston, 2013) or in more simple terms it is what an organization actually does (Brown et al, 2001). Every organization has an operations function which along with marketing and development makes up its three primary functions. These are supported by service functions including finance, IT and HR. Thus operations management is important for any business that uses resources to create something and is so irrespective of that organizations size or commercial station ((Slack, Brandon-Jones and Johnston, 2013). Large or small companies have the same operations issues, save for the fact that in larger organizations, with more staff, they often have greater flexibility to respond to changing requirements. Smaller operations may have staff with multiple roles. In not-for-profit organizations, such as the private members golf club, strategic objectives may be more complex due to a range of social, political and economic issues leading to conflicting objectives impacting on operations decision making (Slack, Brandon-Jones and Johnston, 2013). Operations management is critical in designing, managing and improving the organizations operations in an organised manner (Brown et al, 2001) and should be the fundamental motivation for any golf course manager.

3.1   The Inputs - Outputs – Transformation Model

All operations create products or deliver services by changing inputs into outputs in what is termed a transformation process (Brown et al, 2001; Slack, Brandon-Jones and Johnston, 2013). Although all operations conform to this general transformation model there are, of course differences in the specific inputs and outputs created (Slack, Brandon-Jones and Johnston, 2013). Inputs will usually include materials, whose physical properties may be changed, information for processing or customers themselves where their physical or psychological state may be changed. Outputs are the products or services resulting from the transformation process (Brown et al, 2001; Slack, Brandon-Jones and Johnston, 2013). In transforming inputs into outputs operations also require resources of facilities, including buildings and technology, and staff, the people who operate, maintain and manage operations. In operations management differences between product manufacturing and service provision operations is often discussed. Brown et al (2001) describe how manufacturing operations create tangible physical products with clear stages of production where in service industries finished 'products' are intangible. This differentiation, however, is becoming increasingly irrelevant (Slack ,Brandon-Jones and Johnston, 2013) as manufactured products are now surrounded by sophisticated service packages with manufacturing organizations now delivering services in association with their manufacturing core (Brown et al ,2001). Dury (1997) reports how, in landscape management, emphasis has been on management control on physical work to produce a product with little attention paid to managing all other input resources which are equally as important. Dury considers that there should be greater attention paid to management systems and costs as these will impact on final product costs for the customer. Sports facilities should always make a higher return than the cost of producing them even, if, as in the public sector there may be a degree of financial subsidy. Dury (1997) provides a very valid illustration for the customer experience in regards to sports surfaces and their provision here too. The product may not always be the surface produced as it can be the game itself according to how income is generated. If players are paying to use the surface, as most golf club members are, the product is the surface. However, if they are paying to watch, as golf tournament spectators, then the game is the product. There are, of course, different implications for cost and quality management with these two scenarios. Managing playing surfaces such as golf greens is a complex activity as product outcomes may be varied depending on the role or perspective of the observer. Controlling inputs though, does impact on the overall cost of the final product. The input-output model is too simplistic for golf green management as not all inputs can be quantified and customer expectations of output are varied so a more comprehensive system is required.

3.2   What do Operations Managers do?

Brown et al (2001) and Slack, Brandon-Jones and Johnston (2013) identify that operations managers perform three key functions in directing activities: designing products or services, managing day-to-day operations and developing ongoing performance. They bring together resources, knowledge and market opportunities to achieve deliverable products or services. Management of human resources, assets and finance are key to achieving competitive performance for the organisation. Continuous improvement is seen as critical (England Golf, 2014) in a global market where the best performing organizations strive to continuously improve their performance (Brown et al, 2001). Cobham (1990) identifies the key skills required for an amenity manager, akin to those of the golf course manager. Core expertise is required in horticulture (greenkeeping), recreation provision (golf), landscape design (golf course architecture), the ability to write specifications and work schedules, control finance, manpower and materials and a familiarity with work study. This latter management practice is not evident in golf course management. Cobham (1990) also recognises the need for manager ambidexterity in dealing with both the landscapes needs and satisfying the demands of customers who use such facilities and resources. This is a familiar principle for any golf course manager. Golf course managers are, foremost, operations managers and can adopt methods developed in other industries for their own practice although they are less concerned with product design and more focused on their primary aim of course maintenance activities.

3.3   Operations Performance

Slack, Brandon-Jones and Johnston (2013) and Cockerham and Van Dam (1992) identify five key objectives in managing operations performance, quality, speed, dependability, flexibility and cost, all of which can be related to golf green management. Quality is achieving consistent conformance to customer requirements and is fundamental to customer satisfaction. Slack, Brandon-Jones and Johnston (2013) also confirm that quality can mean fewer mistakes, cost reductions and better services and products. Dury (1997) and Cockerham and Van Dam (1992) discuss the issue of quality in respect to sports turf surfaces and the difficulties in measuring and quantifying quality for such. Dury (1997) maintains that there has always be variance in levels and standards of provision for sports surfaces together with variable expectations from site users. In golf greens measures of surface playing performance are the most frequently used criteria in determining quality. Speed is concerned with the period of time

between customers requesting and receiving services or products. Fast response is both desirable for customers and enhances movement of materials and information in operations processes (Slack, Brandon-Jones and Johnston, 2013). Players expect greens ready for play at all times and often operations are conducted to facilitate minimum disruption to throughput of play. Dependability is important in maintaining customer satisfaction (Slack, Brandon-Jones and Johnston, 2013) and is heavily influenced by management decisions including use of staff and machinery (Cockerham and Van Dam, 1992). It can be measured by such factors as number of complaints and downtime in operations. Players require greens that are available for play all-year-round and also give consistent performance. Operations with high internal dependability are more effective than those which are not (Slack, Brandon-Jones and Johnston, 2013). Flexibility is about operations managers being able to make changes to schedules, programmes and techniques in response to changing requirements and environments (Cockerham and Van Dam, 1992). It is also important that playing conditions, including course set-up accommodate players of different ability. Operations flexibility can assist in developing new products and services in wider variety, volumes as well as making cost savings (Slack, Brandon-Jones and Johnston, 2013). Cost is always an important objective in operations management even if the organization is not competing with others on product or service price (Slack, Brandon-Jones and Johnston, 2013), which is not the norm in golf. Cost has become an increasingly important driver in golf course operations and decision making.

Measurement of costs and values are important management activities which have long preoccupied economists and accountants (Cobham, 1990). Cobham (1990) discusses the concept of value in landscape management and suggests that the value of a commodity is measured by the price people are prepared to pay for it, even, if like amenity landscape it contains elements which are intangible. Parker and Bryan (1989) broadly concur with this view and also recognise that value for money is difficult to define in precise terms and frequently a subjective criterion affected by people's personal tastes or attitudes. Cobham (1990) identifies three aspects of value: Direct Use Value (DUV), Option Value (OV) and Existence Value (EV).

DUV is derived from the amenity in terms of its use for leisure and tourism activity and that ascribed for wildlife or environmental value. On a golf course, participation measured in rounds played can be measured to arrive at such a value. OV is where people consider the amenity worth conserving even if they are not direct users. Cobham (1990) considers this a real source of value as it can translate into people willing to pay to maintain the resource. Finally, EV relates to the value people attach to knowing an amenity exists and is there for others to enjoy. In golf course management comparison can be made for both OV and EV in situations such

as resort golf where property values often are aligned to adjacent golf courses. Cobham (1990) states that the sum of these three values gives a total economic value (TEV) for an amenity. Parker and Bryan (1989) propose that in the absence of any established framework it is frequently easier to base management decisions on cost alone and assume that low cost is the only desirable objective as outputs or benefits are often difficult to define in precise terms. Both Parker and Bryan (1990) and Dury (1997) again, discuss the issues in achieving value for money in the management of surfaces for sport. In maintaining sports surfaces it is relatively straightforward to measure operations inputs and ascertain costs for the user but complications arise from customer expectations – there is a massive difference in standards required for a local golf club and one hosting The Open. It is incumbent on managers to make customers aware of what standards can be achieved with available resources for that facility (Dury, 1997). All operations decisions should reflect the interests of stakeholder groups (Slack, Brandon-Jones and Johnston, 2013). In determining maintenance requirements ownership values for facilities must be recognised and understood (Cockerham and Van Dam ,1992).The owner is the controlling agent in deciding goals and objectives both aesthetic and athletic from which maintenance activities need to be decided. The function of the facility or surface is also key in establishing required inputs and maintenance practices, roadside verges are of low quality with comparatively low input whilst golf greens have very high inputs and quality requirements. This intensity of maintenance will impact on costs for the organization. More naturalistic and informal areas, (golf roughs) will be lower cost whilst more formal (golf greens) and man-made more expensive (Parker and Bryan, 1989).

Cobham (1990) presents a more complex picture for costs in managing costs for amenity landscape areas, which again, are relevant in the golf course sector. Cobham proposes the concept of True Social Costs (TSC) which is comprised of Direct Costs (DC), External Costs (EC) and User Costs (UC). DC are those associated with managing the facility including both variable and fixed costs. EC are those indirect costs arising from such effects as environmental damaged from pollution or the diminution of wildlife habitats. Often such costs are intangible and defy measurement. UC are those from use and exploitation of the facility or amenity. Too many rounds of golf or play in inappropriate conditions will result in damage requiring additional resource input and therefore cost to correct. Whilst user and external costs may be relevant to overall golf club management golf course managers are only responsible for costs of maintenance works and so only direct costs will be included in the management framework.

3.4   Cost Effectiveness

Evaluating cost-effectiveness is not easy within the sports turf and landscape industries (Dury, 1997). Estimations for cost: benefit ratios and cost-effectiveness can be made to determine whether financial inputs on the one hand are congruent with customers' requirements on the other (Cobham, 1990). At this point one is contrasting inputs with perceived outputs or benefits, thus there is a need to measure quality. Practice is more difficult than theory as the measurement of outputs is often extremely difficult and frequently subjective. Attempts to quantify such outputs have been made but rarely entirely successful (Cobham, 1990). Cobham (1990) maintains, however, that the difficulties in measuring inputs and outputs have not deterred those managing amenities and achieving cost effective results and that customers have always been vocal in expressing their views directly or with media support. The difficulty in accurate quantification of effectiveness requires managers to inventory customer needs which will include both qualitative and quantitative statements. Dury (1997) states that there needs to be a series of norms against which cost effectiveness and value for money can be monitored. Performance quality standards and number of products sold or opinions of customers in feedback could be used. Cost effectiveness , a key driver in golf course management today, should endeavour to provide value for money to the customer where this is not achieved profitability will be compromised (Dury, 1997). In seeking to keep costs low relative to quality objectives the measure most frequently used is that of productivity (Slack, Brandon-Jones and Johnston, 2013). Productivity is the ratio of what is produced in relation to what is required to produce it. Reducing input costs and eliminating waste in operations whilst maintaining desired output levels are accepted means in improving productivity and are integral to a performance management framework. Slack, Brandon-Jones and Johnston (2013) and Cockerham and Van Dam (1992) discuss the idea of the "trade-off" where comprises have to be made in operations. Trade-off decisions are among decision criteria for objectives of cost, quality, dependability, speed and flexibility (Cockerham and Van Dam, 1992). Improving the performance of one objective by sacrificing performance in another is often required. This can be achieved by repositioning performance objectives as it is accepted that in the short term the organization will not achieve outstanding performance in all operational objectives. The manager decides on inputs within resource limitations but needs a framework to capture operational performance.

3.5 The Landscape (Golf Course) Manager

The landscape, or golf course manager, is expected to achieve cost effective results and thereafter improve cost-effectiveness (Cobham, 1990). Managing resources of manpower, machinery, materials, and money and working methods are integral to operations management. Material inputs will vary from site to site and represent a small proportion of annual resource requirements. In landscape management labour accounts for between 66% and 75% of total resources required in cost terms (Cobham, 1990), this is directly comparable to golf course management. Labour is the resource requiring greatest scrutiny and management and is often the focus of attention in cost savings including where possible the use of mechanization and equipment to further reduce its cost. Achieving cost effectiveness, whilst important, should not be at the expense of achieving objectives set from consultation with user groups and management (owners) nor should it be detrimental to the landscape (golf course) itself (Cobham, 1990). Such influences can be frustrating for the manager who has to balance the demands of users with sound landscape management practices. Education of users in terms of what can be achieved is part of the manager's role (Parker and Bryan, 1989). The manager should present clear options to decision makers and users for them to make best judgements for management objectives and subsequent maintenance. Cockerham and Van Dam (1992) believe that in viewing the management of sports turf surfaces as a whole entity, as an input-transformation-output system, the decision making process for the manager is greatly assisted and it is particularly useful in problem identification and solving. The picture is far more complex though given the variables which can affect golf green management and customer expectations so any framework that includes these variables will help managers make and keep track of decisions in managing golf greens.

3.6 Planning Work

Regular maintenance of landscape areas has an acute impact upon its appearance and value as well as the plant community itself (this is analogous to sward composition in a golf green) (Parker and Bryan, 1989). Maintenance methods will vary from site to site dependent upon such factors as local terrain, topography and climate. Amenity landscapes, including golf courses, often have several functions to fulfil including physical, social, aesthetic, recreational, environmental and economic and it is incumbent upon the manager to manage operations to achieve these objectives (Cobham, 1990). Aligning maintenance practices with site requirements is a major part of landscape management but one which it is not possible to

prescribe standard specifications for particular landscape types (Parker and Bryan, 1989).Standards are implicit within the managers choice of operations and intensity of culture. The primary task of the landscape, or golf course, manager is to identify choices prior to carrying out landscape operations. Questions comprising levels of maintenance, standards, methods and techniques, labour, mechanization and options for achieving cost-effectiveness need to be considered and determined in a controlled and measured way. Amenity (golf course) managers are best qualified to decide both short and long term maintenance resources and also to analyse and advise on the most cost-effective combinations for landscape components, in both initial capital expenditure and subsequent expenditure over the landscape cycle (Cobham, 1990). In practice it is also affected by their philosophy or approach to golf course management (Beard, 2002; Arthur and Isaac, 2015). Cockerham and Van Dam (1992) recognise several preplanning requirements in the organisation of operations, these are inventory, sectoring, task identification and budgeting. Inventory includes surveying areas to be maintained as well as identifying staff skills levels and availability, materials and supplies and as maintenance programmes begin to be formed operating budgets. Sectoring allows for a facility to be divided into more convenient management areas. This can either be by operations function, e.g. mowing or irrigation, or by area where maintenance requirements are different, for example tees, fairways and greens on the golf course. In task identification Cockerham and Van Dam (1992) state that, in turf management, cultural practices such as mowing, irrigation, fertilizer application and spraying are separate jobs which need to be scheduled separately. In managing operations, the key to controlling costs is to control labour hours (Cockerham and Van Dam, 1992). The manager must identify weekly tasks and labour needs and then determine annual requirements for budget formulation. This will mean accounting for both seasonal variances in operations practices and therefore labour needs throughout the year. The cost per month for labour is most useful figure. Materials and other costs can be budgeted as for labour but since the latter is the largest budget item and the one easiest to lose control of it is critical to apply significant effort in making budget projections correctly (Cockerham and Van Dam, 1992).

3.7   Process and Job Design

Operations managers are responsible for designing processes whereby products and / or services are created (Brown et al, 2001). The design of products and services and the design of processes which create them are clearly interrelated and cannot be done independently (Slack, Brandon-Jones and Johnston, 2013). Changes in the design of any product or service will have profound effects on the operations to produce them similarly the design of a process

can constrain designers of products and services. This overlap between two design activities is generally greater in operations for services as they often involve customers in the transformation process. The service as far as the customer sees it cannot be divorced from the process (Slack, Brandon-Jones and Johnston, 2013). Cockerham and Van Dam (1992) see turfgrass management as a service with the design of processes for landscape maintenance similar to that found in manufacturing. Process flow is the sequence of operations used to achieve the desired outcomes and is the foundation for scheduling tasks in planning operations to arrive at the best turfgrass management operations system (Cockerham and Van Dam, 1992). Cockerham and Van Dam (1992) state, however, that operations research has been primarily conducted for the manufacturing sector and that turf maintenance operations do not fit neatly into an assembly line formula as there is much unpredictability with living plants, the weather, usage and other demands of the landscape. They do believe that it is still possible to develop better management tools for landscape areas but also that research in operations decision making, planning and job design and quality control systems for turfgrass management is wide open. They conclude that few turfgrass researchers have the background or interest to conduct operations research. There is little evidence in the literature of any such research since. Canaway (1994) stated that research in turf management has been slow in comparison with agriculture and horticulture due to a lack of government support. A situation that still exists today.

In operations management, capacity refers to the level of output that an organisation can achieve in a given time period and is a key area in decision making. It frequently involves making compromises or trade-offs between resource investment and their efficient utilisation (Brown et al, 2001). Capacity can be considered as theoretical, design or actual. Theoretical capacity is the level of output that could be achieved if all resources are fully used – akin to operating 24 hours a day, 7 days a week, and 365 days a year. A rarely possible situation in reality. Design capacity includes planned non-productive time but not, significantly, unplanned downtime as can occur with staff shortages, machine breakages and a variety of external factors including weather conditions and transport failures. A more practical definition might be that where the amount of resource inputs relative to outputs at a particular time is evaluated is the actual capacity (Brown et al, 2001). There is a need to quantify inputs against quality outcomes.

Measuring capacity includes assessment of time and money utilisation. In operations management time is frequently the most significant measure for outputs and money for inputs (Brown et al, 2001). In manufacturing capacity is usually measured in the number of physical

products created in a given time period. The situation is more complex in service industries where activities are initiated by customers or even managed by them such as the greens committee on the golf course. Capacity is often measured in terms of potential service provision since they may operate below capacity. The organizations ability in transforming inputs into outputs lies in its ability in transforming resources including facilities, technology, and labour and in resource procurement (Brown et al, 2001). In making capacity management decisions the efforts of each input type on the operations ability to perform work must be considered. In respect to facilities operations management is primarily concerned with determining the level of resources needed and to maximise outputs (or quality) at that level of input, the primary aim of this research for golf green management. Investment in technology, from machinery to communication systems, can add significantly to resource costs (Brown et al, 2001). The ability of an organisation or business to acquire resources and distribute its outputs is fundamental to its success. Financial resources in either, public or commercial sectors may limit capacity and are a very real issue in golf today. Hiring staff or purchasing equipment and supplies may be an issue. Staff are the organisations key resource in achieving its goals and objectives. Brown et al (2001) identify two staff groups termed direct and indirect workers. Direct workers are those involved in production or in contact with customers. Indirect includes support staff such as administrators. Brown et al (2001) state how in many organisations workers are trained in more than one task so that they can step in when needed for absent staff. This multi-skilling is very evident in golf course management where an 18-hole course usually has a staff base in single figures. Another factor Brown et al (2001) recognise is that of mechanisation in manufacturing industries where this has led to a decline in staff. The same is true within the golf course industry where mechanisation, following agricultural system changes post war and the developments in machinery and chemicals, has also led to fewer staff employed directly. Operations managers are responsible for capacity planning and must understand what levels of key parameters to be included in the framework.

3.8   Work and Method Study

Grounds maintenance is an inherently seasonal activity with busy periods in the summer and less intense activity in the winter (Parker and Bryan, 1989). This reflects the natural growing period for landscape plantings. In many amenity landscapes, and certainly in golf courses, summer is dominated by the need for grass cutting. The downturn in work required in the winter period may necessitate reductions in staffing. Most golf courses now employ additional seasonal staff in the summer to cater for the higher workload and operate with a reduced full-time staff in the winter. The winter shortfall in routine maintenance work can also be used for

renovation and construction works (Parker and Bryan, 1989) and this is also frequently the case in golf courses. Unlike machines and automated equipment workers tend not to work at a uniform and constant pace. People vary considerably in the level and amount of work output they can achieve in a given period. They also usually need time off work and other rest and personal breaks. People are, however, more flexible than machines in responding to changing needs and variations in the environment. Thus in estimating workforce capacity and labour requirements a special set of management tools is required. Time and work measurement describes such a set of tools used by operations managers to estimate times taken to perform tasks and subsequently staffing requirements (Brown et al, 2001). The goals are to identify and eliminate wasted time and to set standard times for tasks. Without estimates of how long activities take it is not possible to allocate work to teams or individuals or to monitor how much it costs or how overall work schedules are progressing (Slack, Brandon-Jones and Johnston, 2013). That said, measuring work times it is not without difficulty. There will be variances including staff skill levels and ability, motivation and environmental conditions. Accepting the weak theoretical basis for work measurement its systematic approach offers a common currency in the evaluation and comparison of all types of work and in also optimising management inputs (Slack, Brandon-Jones and Johnston, 2013).It offers the best solution for quantifying labour inputs for a performance management framework.

Work study in landscape management can be divided into two components – method study and time studies (Parker and Bryan, 1989). Method study attempts to analyse operations, identify any unnecessary actions, impediments and arriving at a blueprint for the most efficient method of work. It is valuable in a range of grounds maintenance tasks such as deciding upon different types of machinery or in organizing work schedules. Time study is the exercise of establishing how long specific jobs take to complete and is a precursor to planning staffing levels and budgets. Job times, to be of real value though, should be based on the most efficient working method derived from method study (Parker and Bryan, 1989).

Many experienced managers may be able to estimate likely job times and staffing levels however these are unlikely to be accurate enough for detailed planning or contract pricing as there is too much subjectivity involved. Standard times can be formulated from work study to allow more accurate forecasting of staff requirement and loading for teams and individuals. In arriving at standard times one should still consider standards of maintenance required and frequency of operations (Parker and Bryan, 1989). The outcome from work study is the production of standard minute values (SMV's) for specific jobs. Such SMV's for similar operations can vary greatly between different organizations (Cobham, 1990) due to differences in:

- The detailed nature of the job itself (e.g. size or shape of area)
- Tools and techniques used (e.g. machine used)
- Activities actually included (e.g. machinery checks or not)

Differences exist within published sources such as Spon's Landscape External Works and those of The Institute of Groundsmanship for turf maintenance operations. There is also a distinct lack of standard minute values for most specific golf course maintenance operations in published literature. Cobham (1990) states that managers should be aware of using SMV's and that they should formulate their own through onsite data collection and measurement. There is little evidence that this has or is happening in golf course management. Cobham (1990) encourages managers to do this as work measurement remains an invaluable management tool in determining workloads and labour requirements. Work study was used extensively in local authority landscape management as a means of managing labour efficiently.

Standard minute values do not provide the complete picture of labour requirements and adjustments will be required to cater for additional elements, termed allowances, in items such as:

- Lost time due to weather
- Breakdowns
- Machinery maintenance
- Travel time between sites
- Personal duties and rest periods
- Keeping records
- Contingencies and emergencies
- Receiving instructions and discussing operations with supervisors
- Clearing up after completing operations

There are several factors to consider in arriving at whole staffing requirements and productive working hours to formulate final work schedules and budgets. Losses occur in a working week for a variety of reasons. Parker and Bryan (1989) state that in a 40-hour week there may be, typically, loss in productive hours of between 18 and 30% - meaning an actual productive week of 28 - 32.8 hours. Losses here are attributed to wet time, breakdowns, sickness,

machinery servicing, staff training, planned leave and bank holidays. As discussed already landscape maintenance is subject to variations in work demands due to seasonal changes which may be planned for with the use of temporary summer staff. Another common strategy, certainly in golf course management, is to have flexible working hours across seasonal changes (Parker and Bryan, 1989). Working hours and pay are annualised but staff work longer hours in summer in return for reduced hours in winter. For example, staff employed on a 39-hour week contract would work 42 hours for the 6 months of summer and 36 hours in the winter. Pay is fixed throughout the year.

In determining staff requirements, workloads and programmes it is necessary to cost such activities for their effective management. The annual budget is the essential first step in any system of financial management and control. In an example of a grounds maintenance budget

Parker and Bryan (1989) state that a typical expenditure breakdown would be:

Expenditure	%
Employees (wages, salaries, training, allowances etc.)	63
Premises and Depots (maintenance, services, furniture, fittings, rent, loans etc.)	2.6
Supplies and services (equipment, consumables, PPE, contract services/fees)	11.4
Transport and machinery (running costs, renewals, etc.)	17.0
General office expenses (office staff, telephones post etc.)	6.0

Staff wages and machinery costs are clearly the most significant costs and this is true for golf course maintenance. This means that such resources require the most scrutiny and detailed analysis in operations management and are their costs are a key component of the management framework.

3.9   Work Programming

Work programming varies in terms of the size, timescale and scope of an organizations operations. The cyclical nature of landscape maintenance associated to seasonal conditions over a year make this a convenient time frame for planning, undertaking and reviewing work. Such programming lends itself to a systematic approach (Cobham, 1990) and typically comprises four principal components: planning, organizing, directing and controlling. Slack,

Brandon-Jones and Johnston (2013), whilst recognising that specific terminology for work planning and control varies with organizations, identifies four overlapping activities in loading, sequencing, scheduling and monitoring and controlling. Planning refers to the activities that take place for the transformation process to happen and control describes activities that take place in the conversion of inputs to outputs. In actual practice it is not always possible to separate planning and control activities (Brown et al, 2001). Loading is concerned with how much work there is to do. Actual operating time for productive working can often be significantly below the maximum time available as losses occur due to machine breakdown, idling time, set-up time and unplanned interruptions (Slack, Brandon-Jones and Johnston, 2013). Decision's about the order that specific tasks are undertaken to complete a job or process is termed sequencing. Often there will be pre-determined rules which dictate such sequencing of work activities (Slack, Brandon-Jones and Johnston, 2013) which is the case for many golf green cultural practices and course set-up for play. Turf operations such as coring which are particularity disruptive to surface quality often have to be scheduled around player event calendars.

Scheduling is concerned with the short-term control of activities, when things must be done, the output of which is an actual timetable for performing work (Brown et al, 2001). Golf course managers often utilise daily or weekly work plans for such immediate operations. Scheduling is one of the most complex activities in operations management as there are several types of resource to organise simultaneously (Slack, Brandon-Jones and Johnston, 2013) and in golf external factors such as the weather. Machines have different capacity and staff different skills when compounded with the possible number of activities and processes this can lead to millions of possible schedules for even relatively small tasks. In practice scheduling rarely attempts to provide optimal solutions but rather acceptable feasible ones. There are some mathematical techniques incorporated into commercially available software but, again, in practice, most scheduling problems are solved using heuristics (Slack, Brandon-Jones and Johnston, 2013) and there is no evidence of their use in golf course management. A simple and common method used for scheduling is the use of the Gantt chart (Brown et al, 2001; Slack, Brandon-Jones and Johnston, 2013). Gantt charts show start and finish times for activities and usually actual progress is also indicated. They can also be used to 'test out' alternative schedules but are not optimizing tools they merely facilitate the development of alternative schedules and communicate them effectively. Their simple visual representation of and ease of use in communicating schedules are seen as the key advantages of Gantt charts in scheduling operations (Brown et al, 2001; Slack, Brandon-Jones and Johnston, 2013). In turfgrass management operations scheduling can be used to determine the allocation of resources and supports decision making by managers. Shortages of resources, people,

equipment and time, are the norm in managing turfgrass surfaces and this inevitably places a heavy demand for their efficient use (Cockerham and Van Dam ,1992).

Once a plan for loading, sequencing and scheduling operations has been created it is necessary for managers to monitor and control what is going on and that planned activities are actually happening. An effective planning and control system should be able to detect deviations from planned activities in a timescale which allows an appropriate response (Slack, Brandon-Jones and Johnston, 2013). Deviations from the plan will require re-planning and interventions to be made to operations to achieve desired outputs. Operations control is relatively straightforward where objectives are unambiguous, effects of interventions are known and activities are repetitive. In golf green culture, whilst activities are repetitive the effect of interventions are not wholly known and there is a need for a framework for management. Operations discipline is needed to ensure that control procedures are systematically implemented (Slack, Brandon-Jones and Johnston, 2013). Cost control is significant in all operations management and Parker and Bryan (1989) describe the typical situation that occurs in managing sports fields. For a single sports field complex or golf course, grounds maintenance costs are fairly straightforward given a properly prepared budget and appropriate staffing and machinery levels. Typically, there will be few major changes in costs, except perhaps, major machine breakdowns, and so costs can be monitored against budget at three-monthly intervals. The seasonal nature of landscape maintenance means, however, that costs and income do not increase regularly from month to month in a straight line. Frequently neither costs nor income will have achieved 50% of budget in the first six months. Such factors as machinery costs may be low at the mid-year point as most major servicing will be conducted in winter when such resource is not in full use. These factors need to be considered when reviewing operations and their costs. Parker and Bryan (1989) state that the most useful indicators are: total income received against budget and totals of main cost items against budget in any given quarter or time frame. In golf most managers have responsibility only for a devolved maintenance budget and do not see income so only maintenance costs can be included in the management framework.

3.10 Operations Flow (Throughput)

An important objective for operations managers is to reduce throughput time, which is the time taken from order to delivery in products or services. Brown et al (2001) state that in manufacturing most materials spend more time in storage than being transformed into products and similarly in service provision customers may spend more time waiting than in

consuming or experiencing the service. There are differences, principally in tangibility, between products and services but the objective in managing throughput is the same for both. In managing throughput in operations process flow describes the sequence used to achieve the desired results (Brown et al, 2001; Cockerham and Van Dam, 1992). The decisions made about the operations process type affects the flow of materials, information and customers through the operation (Brown et al, 2001). Line, continuous process, flow is where the product moves sequentially from inputs to finished product. As line flow was conceived for continuous and repetitive assembly line tasks it is suited to turfgrass maintenance operations (Cockerham and Van Dam, 1992). To be effective though, procedures must be standardized and actually flow from one operation to the next. Routine maintenance can be programmed as a flow (Cockerham and Van Dam, 1992). Knowing how golf course managers actually plan and organise work may assist in formalising performance measurement. In project flow resources for work are brought together specifically for 'one-off' tasks such as landscape construction projects as operations here are not continuous (Cockerham and Van Dam, 1992).

Brown et al (2001) state that in the quest for improving flow in operations two of the most popular techniques have been in the application of Japanese manufacturing approaches and the use of computer technology. The earliest computerized systems were known as materials requirements planning (MPR) and were designed to manage mass production processes in operations where finished products were produced from a large number of components over several production stages (Brown et al, 2001). The major drawback with MRP is that it is based on mass production which is neither universally applicable nor relevant today. MRP encourages a static approach to process management and complacency among managers (Brown et al, 2001). Many western companies have adopted Japanese manufacturing approaches such as Just-in-time (JIT). The central principle of which is to produce exactly what is needed at the time it is required (Brown et al, 2001). This approach is considered most useful in repetitive manufacturing where there is a high demand for a standard product. Key elements of the JIT philosophy include minimising waste in all its forms and continually improving processes and systems. In critiquing MRP and JIT Brown et al (2001) state that although the two approaches are different, they can complement each other in practice. JIT can be used in managing day-to-day work and MRP for planning and control. A related theorem, termed LEAN, was originally called 'just-in-time' when it started to be adopted outside its birthplace, Japan, also focuses on operations planning and control (Slack, Brandon-Jones and Johnston, 2013). LEAN is seen by Slack, Brandon-Jones and Johnston (2013) as a management philosophy; a method of planning and a set of improvement tools. Slack, Brandon-Jones and Johnston (2013) state that one of the most significant parts of the lean philosophy is its elimination of all forms of waste which is defined as any activity that does not

add value to the product or service. Further, that studies show that as little as 5% of total throughput time is actually spent directly adding value meaning that for 95% of its time an operation is adding cost to its product or service and not value. Such systems often focus on operations when in action and less so with constraints prior to activity.

Brown et al (2001) discuss the 'theory of constraints' as developed by Goldratt and its relevance here for operations management. Its function is seen as identifying and removing any 'obstructions' or 'bottlenecks' in operations flow. Such obstacles impact on total output in terms of both timeliness and quantity delivered. Brown et al (2001) state that the theory of constraints offers useful insights for managing operations: simply changing input will not increase output; monitoring flow is continuous and it is not easy to identify all obstacles in complex processes; and finally, obstructions will change over time as do the products or services. Slack ,Brandon-Jones and Johnston (2013) state how LEAN supports the theory of constraints as its primary focus is concerned with smooth flow of items through processes and the elimination of any obstacles or 'bottlenecks' in operations. Making better use of throughput has been one of the great areas of organizational learning in operations management as western companies, in particular, have attempted to emulate Japanese practice and success (Brown et al, 2001). There is no published evidence where such methods have been used in golf course management at an operations level by course managers.

3.11 Operations Improvement

As well as achieving operations objectives of quality, speed, dependability, flexibility and cost managers are also judged on how they improve operations performance (Slack, Brandon-Jones and Johnston, 2013). Performance improvement is seen as the ultimate objective of operations management. There are a variety of reasons for this focus on continued improvement. Slack, Brandon-Jones and Johnston (2013) describe how changes in world trade, new technology and the interest and scope of operations management have all contributed to a growing concern for improvement. Golf exists in a leisure industry where changes in lifestyle and budget have impacted on golf provision. Approaches taken to improvement draw upon a common group of elements. One such element is the use of improvement cycles such as that devised by Deming, represented as a continuous cycle – Plan-Do-Check-Act, with a never ending process of repeatedly questioning and re-questioning the detailed working of a process or activity. Such cycles confirm improvement as a continuous activity. Slack, Brandon-Jones and Johnston (2013) discusses several other key elements common in performance improvement. Performance improvement is process focused,

includes aspects of evidence based problem solving, is customer centric and seeks to be inclusive with all staff involved in the process. In recent years the use of quantitative techniques and data collection with qualitative data derived from customer feedback has been an integral part of performance improvement. Slack ,Brandon-Jones and Johnston (2013) state though that, whilst important, what is good for the customer may not be the same as what is good for the business, operations management is a balance between what the customer wants and what the company can afford. In golf course management, managing customer expectations is an important part of the manager's role but the biological requirements of the grass in a playing surface must also be addressed. Whilst absolute perfection may not be achievable what is important in operations is that there is a credible target against which performance can be measured (Slack, Brandon-Jones and Johnston, 2013).

3.12 Approaches to Managing Improvement

There is no one universal approach to improvement and several systems have been developed including Total Quality Management (TQM), Lean, Business Process Re-engineering (BPR) and Six Sigma. Total quality management (TQM) was one of the earliest improvement systems whose general principles remain hugely influential (Slack, Brandon-Jones and Johnston, 2013). It is best thought of as a philosophy which stresses the 'total' of TQM and places quality at the centre of everything that is done by an operation. TQM focuses on meeting customer needs, getting things right first time, including costs in all quality and developing a systems approach. Lean was originally considered as an approach exclusively for manufacturing however, it has now become fashionable in service operation (Slack, Brandon-Jones and Johnston, 2013). Lean aims to meet demand instantaneously with perfect quality and no waste. It is concerned with achieving synchronised flow in operations reducing variation as well as waste. Business process re-engineering (BPR) is concerned with the radical rethinking and redesign of processes and methods in operations to achieve greater performance. Advances in information technology facilitated its adoption in operations management (Slack, Brandon-Jones and Johnston, 2013). BPR has been controversial as it has been seen to be too focused on work activities rather than on people. Studies show that BPR has been used to reduce staff when redesigning work activities and processes and that some companies used it for this purpose (Slack, Brandon-Jones and Johnston, 2013). Such radical redesign with downsizing can mean loss of essential experience from the operation. Six Sigma, first developed by the communications company Motorola, is a broad improvement concept which attempts to ensure products are delivered on time without defect. It includes customer driven objectives, use of evidence, structured improvement cycle, process design

and staff training for operations improvement. A criticism levelled at Six Sigma by Slack ,Brandon-Jones and Johnston (2013 is that it does not offer anything that was not available previously and all it has done is to package pre-existing elements together in order for consultants to sell it to gullible chief executives. Six Sigma's emphasis on improvement cycles comes from TQM, reducing variability from statistical control, and its data analysis is simply quantitative analysis. Its only contribution is the rather gimmicky martial arts analogy of Black Belt etc. for its practitioners.

These four approaches (TQM, Lean, BPR and Six Sigma) constitute a representative sample of the most commonly used approaches for managing operations improvement (Slack, Brandon-Jones and Johnston, 2013). There is significant overlap in these approaches and they are best positioned on two dimensions. Firstly, whether the approach favours a gradual, continuous improvement or a more radical shift and, secondly, whether emphasis is placed on what changes should be made or how changes should be made. On this frame work BPR is very clear focusing on radical shift and on what should be done. Lean is the same, to a lesser extent, having its definite itinerary of things that processes should or should not be but with a more continuous improvement ideology. In contrast both Six Sigma and TQM focus far more on how operations should be improved with emphasis on continual improvement. To complicate matters further, Slack, Brandon-Jones and Johnston, 2013 (2013) concede that some organisations are now blending two or more approaches in operations management to form hybrids in an attempt to combine best characteristics. Lean Sigma is such a hybrid system approach. It includes elements of waste reduction, fast throughput from Lean and the data driven rigour from Six Sigma. Some organisations add other improvement elements such as continuous improvement and the error-free quality orientation of TQM to this concept. Such approaches have not been adopted by golf course managers. There is no literature whereby these systems are discussed, adopted or promoted for golf green management. This thesis will attempt to incorporate relevant philosophical ideologies above within the management framework for golf greens.

3.13 Organizing for Improvement

Improvement in operations needs organizing. Responsibility for its implementation needs to be allocated together with the necessary resources required to gather information and the identification of key issues. It must also be linked to the organisations overall strategy (Slack, Brandon-Jones and Johnston, 2013). At the strategic level operations improvement is about better commercial or market performance. There needs to be alignment between operations

performance and the requirements of its markets. Further, this alignment should be more 'sustainable' over time and there should be an increase in the 'line of fit' where the assumption is that high levels of market performance is directly attributable to a high level of operations performance (Slack, Brandon-Jones and Johnston, 2013). Before one can implement any improvement in operations it is necessary for managers to know how good they are already which a performance management framework could facilitate. The urgency, direction and priorities for improvement will be partly determined by the current situation. All operations need some kind of performance management system as a prerequisite for improvement (Slack, Brandon-Jones and Johnston, 2013) hence the need for applied research for the golf course management sector.

3.14 Summary of Operations Management

Operations management is a complex activity whereby a product or service is delivered to the customer or end user after input transformation. The product for the course manager is the golf course and in the case for this research the golf green itself. Inputs include materials and labour to create the golf green to expected player standards. Cost effectiveness in operations management is a fundamental responsibility of the golf course manager and the key to controlling costs is in managing labour (Cockerham and Van Dam, 1992). Managers are responsible for finite resources and producing the end product with the utmost efficacy. Work study is an established management practice for estimating workloads and then planning and scheduling operations. Times for operations are an integral part of allocating work to staff and teams and also for measuring outputs. Work study is an under researched area in golf course management, what data exists has been concentrated in amenity landscape management which does not include the specialist tasks required for golf course and golf green management. Scheduling work is another area where there is little research in golf course management and represents the multifaceted activity of organising work in accordance with management goals and directives. These can be challenging where there are differing objectives for management and user groups or customers or where these are confused such as may be found on the golf course where committee members are also the players or customers. Golf course managers are, foremost, operations managers who can adopt methods developed in other industries for programming and scheduling work. Operations practices such as work study will help to inform the performance management frame work by allowing the effective estimation of physical inputs and their costing. Reducing input costs and eliminating waste in operations whilst maintaining desired output levels are accepted means in improving productivity and are integral to a performance management framework.

Determining inputs and their costs is integral in resource efficacy in operations management. Questions comprising levels of maintenance, standards, methods and techniques, labour, mechanization and options for achieving cost-effectiveness need to be considered and determined in a controlled and measured way.

Establishing such resource inputs from practice is crucial in answering the research question of how can golf greens be better managed for playing quality performance and optimum resource efficiency? Ascertaining how golf course managers plan and organise their work and critically assessing industry practice will allow the formulation of recommendations for future practice. Several systems have been developed in operations management but there is no evidence of their uptake in the golf course management sector. Many of these systems reviewed above are complex and more relevant to strategic management rather than the operations level considered in this research. However, it can be concluded that these strategic operations models have not and are unlikely to be used in golf green management. Work study as a means of quantifying labour costs is the most useful aspect of operations management to develop a performance management framework which will be established after reviewing performance management in the next section. Thus golf green cultural practices and their costs form the first benchmarks of a performance management framework. Defining actual performance standards or measures for operations outputs, in this case golf green quality, will complete a framework focused on the key operations drivers of reducing input costs, eliminating waste in operations and maintaining output quality.

Chapter 4   Performance Management

Introduction

Managers are expected to make improvements within operations to improve output quality and also to assist in efficacy of resource utilisation. Performance management is an integral part of operations management but needs further exploration to develop a performance management framework. Commercial companies and organisations will only survive if they create and retain satisfied customers (Hoyle, 2007) and this is true for golf clubs (England Golf, 2014). Customers demand that products and services of a required standard are available when they want them and at a price that they believe gives value for money. Consumers need to be certain that they are buying a quality product or service and are more discerning with their cash in a competitive market place whilst producers need to fulfil ever-increasing user expectations and requirements in order to survive or prosper. The sports turf industry has not escaped this phenomenon and in recent years, there has been an increasing awareness, development and use of performance standards. Some of this has been prompted by the growth of contracting but also due to developments in technology, media coverage and increasing demands of players and coaches for better quality surfaces, particularly in professional sport (Brown, 2009).

4.1   Quality as a Concept

Quality is found in most organisations and businesses mission statements or objectives as no business strategy will succeed without sufficient focus to quality in today's competitive environment. (Cole, 1997). The concept of quality is elusive as it pertains to relative differences between one thing and another. When judging quality one usually has a standard in mind for products and services. Although few consumers could define quality if asked – all know it when they see it. Quality is in the eye of the beholder (Goetsch and Davies, 2010). This is true in the golf course sector where highly subjective measures such as visual appearance and course aesthetics often influence player perception. Quality is also judged in relation to price but also to such factors as reliability, suitability and safety (Cole, 1997).

The word quality has many meanings and there is no one universally accepted definition of quality, enough similarity does exist among the definitions that common elements can be extracted (Goetsch and Davies, 2010, p5). These are:

- Quality involves meeting or exceeding customer expectations
- Quality applies to products, services, people, processes and environments
- Quality is an ever changing state (i.e. what is considered quality today may not be good enough to be considered quality tomorrow)

Quality can be defined and measured and it is customers who ultimately decide their own parameters when selecting products or using services and it is a dynamic state. Certainly in recent years this has been the case in the golf course sector as affordability and player demands for course quality have become key drivers to participation. Any company that sets its own quality standards which do not meet customer expectations for products or services is bogus (Goetsch and Davies, 2010). Hoyle (2007) provides a useful figure to explain the concept of quality which is shown here in Figure 1
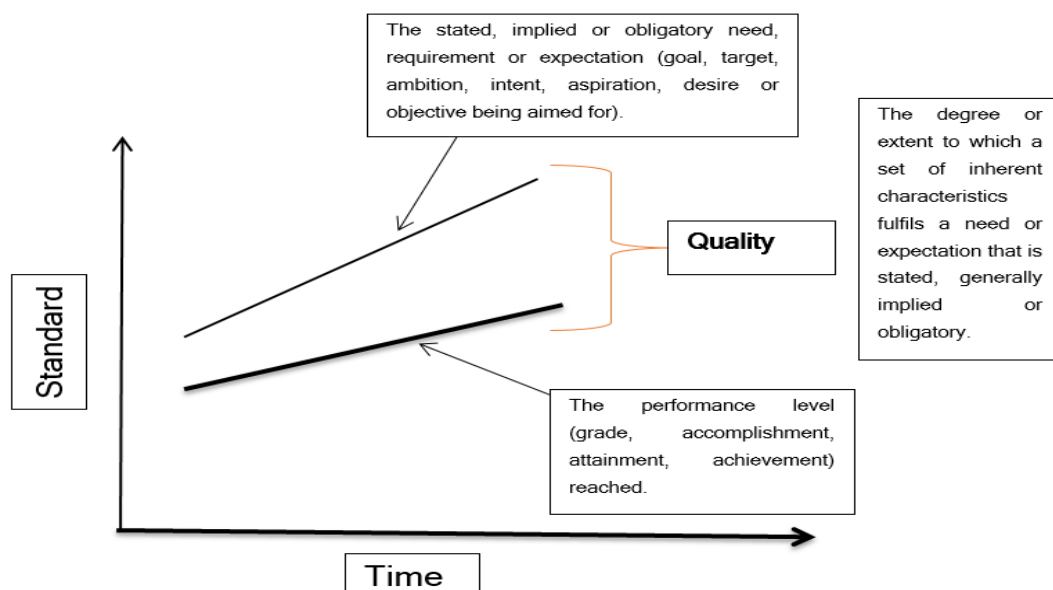
Figure 1   The Meaning of Quality - Hoyle (2007- page 11)

Hoyle considers that this figure expresses three truths:

1. Needs, requirements and expectations are constantly changing.
2. Performance needs to be constantly changing to keep pace with the needs.

3. Quality is the difference between the standard stated, implied or required and the standard reached.

These three truths all have relevance in the golf course sector and must be deliberated by any golf club seeking to retain and / or increase its business. Slack, Brandon-Jones and Johnston, (2013) discuss quality from both operations and customer perspectives. In operations quality is seen as consistent conformance to customer expectations and requires both a clear specification and consideration of customer views which may be influenced by price. Bridging the gap between customer (golfer) expectations and that product (green quality) or service actually delivered is seen as key in operations terms for organizational success. How many course managers have end user requirements central to their management practice when maintaining the course? It is easy to focus on agronomy and lose sight of player demands so this thesis redresses this balance and includes playing quality as a necessary emphasis.

4.2   Performance and Quality

There is a belief in some quarters that "performance" is an intangible and indefinable concept (Davies and Girdler, 1999). It is known to have something to do with quality, but some suggest that it is more than just quality. They tend to suggest there is a value added element to performance that is inspirational and spontaneous and therefore cannot be specified or quantified. In many ways one can accept the underlying logic of this argument. There is a legitimate case to accept that virtuosity and artistic performance, and even sporting achievement, can only be measured in terms of perceptive appreciation. However, it does seem illogical to suggest that all aspects of performance should be accorded the same type of regard. Conventional thinking previously endowed the notion of quality with the particular attribute of being better than something else. Quality was therefore comparatively measured in a rank order, albeit subjectively. Undoubtedly this comes about because some people believe they know quality when they see it. Most are convinced they can recognise performance when confronted with it. However, few can positively define what quality and performance actually means to them. Most also want to keep quality and performance as separate features when so often they are so closely linked that they become inseparable.

Within the working environment, and despite this potential for confusion, it is essential, where performance is a key feature of what is being done, to have a clear definition of what actually constitutes performance. Whilst this may be difficult, it is not impossible if a positive approach is adopted to determine what is really required. Davies and Girdler (1999, pp 20-21) offer a

number of propositions which may provide a framework for defining performance in realisable terms. Performance is able to be specified in a number of universally acceptable ways including:

- Performance is recognised within identified and prescribed limits.
- Performance is, and can only be, measured in comparison to some form of other.
- Performance and quality are tangible and achievable.

These propositions show that performance and quality can be defined at both the individual and organisation level. Standards can be set and measured so that they become the benchmarks of performance and the hallmarks of outputs.

4.3 Performance Measurement

Performance measurement is the process of quantifying action for operations management (Slack, Brandon-Jones and Johnston, 2013). Without such measurement it is impossible to control operations effectively. The measurement of performance in business and commerce is not a new phenomenon. Tangen (2004, p726)) cites a quote from Lord Kelvin (1824-1907) who said "*when you can measure what you are speaking about, and express it in numbers, you will know something about it (otherwise) your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in thought advanced to the stage of science*". This not only confirms that performance was being actively considered then but that such performance should be quantified to be of value. Towards the latter part of the twentieth century, and to this day, there has been a continuing interest from both academics and industry practitioners (Neely, Gregory and Platts, 1995) in performance measurement and management. This has arisen from the need for businesses to adapt to change and because they seek to gain or maintain a competitive edge over their competitors. Neely (1999) states that the arrival of national and international quality awards and the development of information technology have also fostered this interest but in reality there has been little developed or adopted in practice for operations managers in the amenity and sportsturf sectors.

Performance measurement is a complex subject for organisations as it can be viewed as incorporating at least three different disciplines – these being economics, management and accounting (Tangen, 2004). Neely, Gregory and Platts (1995) discuss how there are two fundamental dimensions of performance – efficiency and effectiveness and also how

organisations need to look at both internal and external factors. They consider that effectiveness is about meeting customer expectations and efficiency, how resources are used to achieve a stated level of customer satisfaction. In manufacturing, as an example of this, achieving a higher level of product reliability (an aspect of quality) leads to greater customer satisfaction (effectiveness) and thereby efficiency as potentially there will be a decrease in product failure and subsequent warranty claims. Neely, Gregory and Platts (1995) believe that performance measurement is often discussed and rarely defined, a charge that can easily be made at the golf course sector too. They define performance measurement as the process of quantifying action, where measurement is the process of quantification and action leads to performance. Thus there many facets of performance measurement to monitor and manage. Brown et al (2001) support the view that the complexity of performance measurement can make it difficult for companies to align this with their own organisational goals. A complexity that arises in golf course management is that decision makers are often the club members and players (customers). As with many disciplines there are different terms with different meanings to contend with in performance measurement. Neely, Gregory and Platts (1995, p80) provide some useful definitions:

- Performance measurement can be defined as the process of quantifying the efficiency and effectiveness of action.
- A performance measure can be defined as a metric used to quantify the efficiency and /or effectiveness of an action.
- A performance measurement system can be defined as the set of metrics used to quantify both the efficiency and effectiveness of actions.

Performance measurement is used to evaluate, control and improve production processes to ensure companies can achieve their goals and objectives Ghalayini et al (1996).

4.4   Traditional Approaches to Performance Measurement

Performance when viewed in operations terms is about making the best use of resources (meaning lowest cost) and achieving the highest level of profit. For any operation to be sustainable the economic value of inputs must be lower than the economic value of the output. (Brown et al, 2001). This input–output approach or model is the mainstay of so called traditional performance systems. There have been two distinct periods in the history and development of performance measurement systems (Ghalayini et al, 1996). From the late

1880s through until the 1980s the focus of performance measurement was on productivity, profit and return on investment. Post 1980s and continuing to the present time, there has been a fundamental shift in approach as academics and practitioners faced with new technologies and systems such as just-in time and total quality management began to consider a more holistic approach to performance measurement. It was viewed that traditional performance measurement (pre 1980) was too limited for contemporary success (Ghalayini et al 1996; Brown et al 2001). Certainly such approaches do not serve the more complex environs of managing golf courses with their myriad of internal and external influences and where product outcomes are less defined.

4.5   Criticism of Traditional Performance Measurement Systems

The major criticism of traditional performance measurement systems has been that they have been accountancy driven and cost focused (Brown et al 2001). They are based on management accounting systems with measures focused on financial data and where productivity has been the primary indicator of performance and labour is the cost driver (Ghalayini et al, 1996). Further that the objective is to minimise cost, increase labour efficiency and machine utilisation with no account of strategy (Tangen, 2004). Ghalayini et al (1996) also believe that the fixation with productivity and labour is no longer significant as decreasing labour costs mean that this is no longer as important in overall organisational performance. They further maintain that cost is no longer the most important factor as customer demands have changed and criterion such as quality and customer service are now more important. Cost and profit alone do not necessarily mean that operations, management and control systems are either efficient or inefficient. In golf course management course managers rarely have any responsibility for or involvement in the management of club income and generally only manage a devolved budget from more senior managers. Thus there may be disconnect between club and course objectives. In the golf industry sector, where business is heavily dependent upon a customer's disposable income and ability to pay there is evidence that cost of provision is impacting on the ability of course managers to operate.

Tangen (2004) declares that numerous other researchers have identified the limitations of using solely financial performance measures in performance measurement systems. Tangen further asserts that there are many aspects of organisational performance which cannot be quantified in financial terms that often financial reports are inflexible, restricted to a specific format, and based on past performance and decisions as they are produced at the end of a month or quarter – what Ghalayini et al (1996) term lagging metrics as they also concur with

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this view. Tangen (2004) claims further that reliance on financial measures can lead to problems. These include the fact that they focus managers on short term results and do not consider long term strategies or gaols. They also focus on controlling individual processes or functions in isolation without seriously considering the system as a whole. Today "shop floor" operators, golf course managers, have more autonomy and control and are therefore more influential in customer satisfaction. Traditional methods of performance measurement, such as the input-output model, do not suit newer methods of management or more complex operations such as golf green management.

Brown et al (2001) consider performance measurement from an operations perspective and state that inputs and outputs translate into operations performance measures of economy, efficiency and effectiveness. Economy here is about monitoring (reducing costs) as they state 70% of product or service costs are typically incurred within the operations function. This is indicative of golf course management where labour and machinery costs typically also make up such a percentage of production costs. Efficiency is about how well operations transform inputs into outputs and expressed as a ratio Input over Output. This has been, as already stated above, the traditional focus of performance with its emphasis on control and conformance reflecting the time and motion mentality of the mass production era. Effectiveness is seen as a better than ether economy or efficiency measures as it is concerned with whether the right products or services are being produced in the first place rather than merely how they are produced. Examples of effectiveness include customer service and product quality criteria. Tangen (2004) still maintains that although there has been some progress in developing performance measurement systems which include measures other than financial metrics many companies still focus on traditional financial performance measures. In golf course management the reverse is true as there has been some development of non-financial performance measures, such as those for golf green quality, but little, if any, consideration in objective financial performance measures, especially at the operations level.

4.6   Integrated Performance Measurement Systems

The shift in focus with performance measurement systems from the 1980s has led to the development of more organisation wide or integrated models that more accurately reflect product variety, quality and customer service (Brown et al, 2001). Researchers , in industries other than golf course management ,have focused on developing more complex performance

measurement systems including both cost and non-cost performance objectives argued to be more suited to businesses today (Tangen,2004).

Tangen (2004) states that the classical model for performance measurement developed by Sink and Tuttle in 1989 still has relevant criteria on which to build a performance measurement system today. Sink and Tuttle's model is a framework which argues that an organisation based on a complex relationship of seven performance criteria. These are effectiveness, efficiency, and quality, and productivity, quality of work life, innovation and profitability. Profitability is still seen as the ultimate goal, however, and it has limitations in not considering the customer perspective. Activity-based Accounting (ABC) was developed by Johnson and Kaplan in the 1980s to analyse the indirect costs within a company and to identify the activities that cause these costs (Tangen, 2004). It is claimed that this system is a more accurate method for determining actual costs which leads to better decision making in production (Brown et al 2001). As Tangen (2004) states though many researchers claim that this has never been proved and furthermore such improved accounting systems are not enough to gauge organisational performance.

Ghalayini et al (1996) describe the Performance Measurement Questionnaire system (PMQ) developed by Dixon in 1990. This method purports to assist managers in identifying the improvement needs of an organisation, evaluate its existing performance measures and ultimately to establish an agenda for performance measurement improvement. The system is based on a questionnaire which respondents complete, selecting answers from a matrix of options which are ranked on numeric scales. Analysis is grouped into alignment (how well a company's actions and measures complement its strategy), congruence (how well the measurement system supports an organisations actions and strategy), consensus (data is grouped by management level or functional group – effect of communication) and confusion (extent of consensus with each improvement area and performance measure).The major advantage of this system is that it attempts to review how current performance measures are working and identifying areas for improvement. Its major drawback is that it does not link performance measures to the "shop floor", where operations (golf course) managers must operate.

The "SMART" system (Strategic Measurement Analysis and Reporting Technique) proposed by Cross and Lynch in 1992 is one which does link an organisation's strategy with its operations by translating objectives from the top down (based on customers' priorities) and measures from the bottom up (Tangen, 2004). The model is represented as a pyramid with four levels or tiers. At the top is corporate vision or strategy – below this business units defined

as market and financial measures. At the third level more tangible business operating units such as customer satisfaction and productivity. The 4th level considers departmental and work centre operations objectives such as quality, process time and cost. The main strength of this model is that it does link operations at the shop floor with corporate objectives (Tangen, 2004 and Ghalayini et al 1996). Its weakness; however, is that it does not provide any mechanism for identifying key performance indicators and there is no inherent concept of continuous performance improvement (Tangen, 2004 and Ghalayini et al 1996).

One of the better known and more widely used performance measurement systems is that of the Balanced Scorecard developed by accountants Kaplan and Norton in 1996 (Brown, 2001). The Balanced Scorecard is a framework for integrated performance measurement and challenges managers to review the organisation looking at strategic, operations and financial measures (Tangen, 2004). As Ghalayini (1996) describes it forces managers to address four questions – How do our customers see us? (Customer's perspective); What must we excel at? (Internal perspective); Can we continue to improve and create value? (Innovation and learning perspective); and How do we look to shareholders? (Financial perspective). For each of these perspectives goals are set by managers and specific measures are specified in order to achieve each goal.

Again, the main criticism made against this model, which is true for golf courses, is that it is targeted at senior management (Brown, 2001) and that it is not relevant or applicable for operations managers on the shop floor where the golf course manager operates (Ghalayini, 1996; Tangen, 2004). Tangen (2004) further claims that it is a monitoring and controlling tool rather than an improvement tool and that it provides little guidance on how appropriate measures can be identified, introduced and used to manage the business. This is further supported by Gregory (1993, p296) who stated that *"Clearly much work would need to go on below the level of the 'scorecard' to provide systems which could deliver these generally rather aggregated measures"*. These systems are discounted for operational performance measurement in managing golf greens as they are not focused on actual operations.

4.7   Limitations of Integrated Systems

Ghalayini et al (1996) in reviewing several current performance measurement systems identify several common weaknesses or limitations of these systems for practice which are relevant for golf green management. They claim that these are:

- primarily concerned with monitoring and controlling without sufficient regard to continuous improvement
- lacking in specific performance measures or timeframes for their achievement
- only concerned with present performance and do not allow predictive or future performance
- not dynamic systems and are too focused on historic data, decisions and outcomes
- insufficiently focused on the importance of time as a strategic performance measure

These various approaches and frameworks have academic grounding and are "philosophically" sound and do provide some guidance on how an organisation can design its unique performance measurement system but, perhaps most significantly, none of them provide a specific tool that could be used to model, control, and monitor and improve the activities at the factory shop floor and therefore golf-greens. The measurement practitioner/golf course manager, still has to translate the framework into practical measures. He/she is still left to decide how each performance measure should be specified, how often it should be measured, and at what level of detail. Thus, these newer frameworks show what to measure, but give little guidance when it comes to the question of how to measure it (Tangen, 2004). This thesis aims to bring together the key operations parameters for golf green management and to provide a performance management framework for golf course managers.

4.8   Developing Performance Measurement Systems

Neely, Gregory and Platts (1995, p81) offer a useful framework for considering a performance measurement system in which they consider performance measurement at three different levels. These are the individual performance measures, the set of measures as a performance measure system and finally the environment within which it operates. Individual measures of performance include ones categorised as either quality (e.g. performance aesthetics, value), time (e.g. lead times, due dates, frequency of delivery), flexibility (e.g. material quality, new

product, deliverability) and cost (e.g. manufacturing cost, running costs). When selecting a set of specific performance measures Neely, Gregory and Platts (1995) state that these should be chosen from company objectives in consultation with the people involved and indeed should be controlled by those within the operations units being evaluated. Performance measures need to be clear as should data collection and analysis methods. It is recommended that such criteria should be objective rather than subjective with ratio based criteria being preferable to absolute number ones. They also recommended that they should allow comparison with other organisations in the same business.

When considering the system within its wider environment this consists of the organisations internal environment and the market within which that organisation operates – the external environment. Neely, Gregory and Platts (1995) believe that the system must be consistent with the organisations culture and that there exists the potential for conflict between different departments. This can be most markedly so with marketing and manufacturing arms of an organisation. This because these two functions are frequently evaluated on the basis of different criteria and receive rewards for different activities. Marketing judged on profitable growth (sales, market share etc.) whereas manufacturing is often judged on running operations at minimum cost. Within the external domain there are two distinct elements which are the customer base and the organisations competitors. A truly balanced performance measurement system would provide managers with information pertaining to both of these (Neely, Gregory and Platts, 1995). To meet customer requirements or demands one can devise and use customer satisfaction criterion within individual measures. When looking a competitor performance, a useful system is that of benchmarking.

Tangen (2004) offers more specific advice for developing the performance measurement system stating that the system needs to support strategic objectives with clear links from senior management to the shop floor. Further those measures should not be based on solely financial metrics and that all should be devised with clearly defined specifications and timeframes for achievement. There should be a limited number of criteria which are easy to understand and interpret. Maskell (1989, p32) offers seven principles for performance measurement system design which support many of the above and give further guidance:

- Measures should relate directly to the firm's strategy
- Non-financial measures should be adopted
- Measures may need to vary between locations (departments or sites)
- Measures may change as circumstances do

- They should be simple and easy to use
- They should provide fast feedback
- Measures need to stimulate continuous improvement rather than just monitor

In determining priorities for performance measurement Slack, Brandon-Jones and Johnston (2013) state that there are two major influences:

- The needs and preferences of customers
- The performance and activities of competitor organisations

The first factor here relates to winning orders from customers and indeed to enhancing such performance whereas the second recognises the significance of monitoring competition. Both are actually concerned with maintaining business and gaining market share.

4.9   Performance Measurement in Practice

Standards dictate what should be done but without measurement one cannot assess performance or the quantity or quality of an output. To manage quality one needs to be able to effectively measure it. Whether it be quality of a product, service, process or system without measurement we will not know if we are getting better, worse or staying the same (Hoyle, 2007). Measurement is a process whereby numbers can be ascribed to physical quantities and phenomena. Abstract characteristics such as quality need to be translated into quantities so that they can be measured. Standards expressed in measurable terms can be measured for conformity. For golf greens performance quality can be defined in measurable terms whereas other areas of the golf course this is often more subjective including aesthetic qualities which are difficult to even define let alone quantify.

Measurement is vital to the achievement of quality and this must be done with measures or tools that are fit for purpose. If measurement is done with instruments that are not fit for purpose results will be misleading or not valid. Valid measurements allow for decisions to be made on the basis of facts and whether standards or targets have been met. There must be a target value with which to compare results, measurements without such are meaningless (Hoyle, 2007). Measurement tells us whether there has been a change in performance. Make modifications to activities after analysis where: the activity is underperforming (leave target as

it is), variance is not significant (set higher target) or indicator is easily achieved (set higher target) (IoM, 1999).

The Institute of Management (IoM, 1999) state that measuring performance enables an organisation to:

- Understand its current position
- Determine whether improvements have actually taken place
- Ascertain where improvements need to be made
- Understand its processes more clearly
- Ensure decisions are made on the basis of fact
- Identify whether or not it is meeting its targets

The only drawback with performance measurement is that it does take staff and time to execute and this should not be forgotten by management. The whole process of collecting data and analysing performance should be continued. Goals and standards should be increased as performance improves, or changed as activities change.

Slack, Brandon-Jones and Johnston (2013) also recognise issues that may arise in implementing performance measurement within organizations. They state that from 50-80% of performance management programmes fail because of lack of support from senior management; lack of understanding; excessive or unrealistic expectations from the process and unforeseen implementation problems. Golf course managers may see performance assessment as a criticism of their practice and decision making. This is an area for which there is some anecdotal evidence but one which has had no primary research. This research aims to resolve this by empowering golf course managers in their decision making to manage golf greens with the greatest efficacy whilst maintaining the best possible quality golf greens.

4.10 Performance Standards

In trade and commerce standards have existed for thousands of years. They have become common place in all areas of society, business and science. Standards have become the means by which we judge whether performance or products are acceptable, whether outputs are of good or poor quality. Without standards outputs are only of interminable quality. In

management terms they are what should be achieved – what we should be doing. Without standards there is no logical basis for decision making (Hoyle, 2007). Both quantitative and qualitative quality factors and criteria need to have standard values against which measurements can be made to inform decision making. Performance indicators or standards are levels against which any area of management can be assessed (IoM, 1999). Such indicators should be realistic, understandable, adaptable, economic, legitimate and measurable to enable management to assess how efficiently, effectively and cost-effectively the operation is performing.

Standards are targets to aim for but they should also be reviewed and subject to change. Quality improvement takes place when standards are challenged and new levels of performance are achieved (Hoyle, 2007). Hoyle states that there is a vast array of standards for materials, products processes and systems developed for national and international use and that these cater for different companies and sectors. Standards have been developed for sportsturf but there are as yet no national or internationally agreed ones. The sports turf sector is quite fragmented as it embraces different sports played on grass as well as different levels of sporting provision from amateur club player to sports professional.

4.11 Performance Standards for Sports Turf Surfaces

In agriculture the objective in crop production is one of yield, the amount of usable or saleable produce from a given area. In sportsturf management the aim is to produce a playing surface for sport which cannot be defined in plant biomass terms but must be considered in terms of the actual quality of playing surface produced (Canaway, 1994). Professionals working in the sports turf industries have developed performance or playing quality standards for different sports over many years but not everyone in the industry is agreed about the use of these. There is difference of opinion regarding their value or even need in contemporary sports turf management. Arthur (1994) maintained that there should be more focus on minimum standards for materials and construction methods rather than an emphasis on playing surface standards when in use. This belief is based on the assumption that if playing surfaces are built with quality materials to precise specifications then surfaces will provide good playing conditions. Dury (1994), argues that performance standards can be used to develop and maintain surfaces better when in use; that their implementation will raise standards of management and subsequently playing surface quality. Today most people utilising any form of performance standard are doing so from the standpoint of increasing the quality of playing surfaces in use, in an attempt to increase standards of provision or increases in surface

'carrying capacity'. A further problem identified by Lodge (1994) is that golfers have differing views as to what constitutes a good or bad golf green. Performance standards, however, do provide a means of setting objectives and monitoring the condition of facilities so that management decisions can be made based on factual data rather than subjective observation. This is a more scientific approach and relies more on 'hard' measured data rather than the opinion of the players or grounds staff alone. This can only be a sound basis for management. Such standards can be used to identify any deterioration in surface quality and guide future actions. This in turn leads to more effective resource utilisation and management.

The visual appearance of a golf course is, for many, the key indicator of playing conditions. Assessment of green visual quality can be done by asking people to score according to their own subjective opinion which is basically market research (Lodge, 1994).Aesthetic appeal is , however, highly subjective and it is not uncommon for golf greens to be criticized without reference to the criteria which reward skill. Surprisingly, golf is not as advanced with performance criteria as with other games like soccer, bowls and cricket. A possible explanation for this is that research and development involving golf course agronomy in the UK has been fragmented (Adams and Gibbs, 1994). The diverse range of surfaces on which golf is played makes a description of performance criteria difficult. Hayes (1990) summarized the attributes of good playing surfaces for golf some of which can be made quantitative, for example those relating to ground cover and drainage characteristics. Most work on playing characteristics has concentrated on golf greens for it is these that by and large are said to determine the playing quality of a course. Playing quality can be defined as the characteristics of the turf surface which make it suitable for the sport in question, as measured by relevant technical tests or as perceived by players. The measurement of green speed is undoubtedly the most widely used assessment of performance for golf greens. The measurement of golf green speed is one of the few tests developed as a management aid in golf course maintenance. Apart from golf greens the only other areas that have been considered to any extent in the UK are bunkers. Visual impact is the first and often lasting impression. The primary standard is the 'expected' one, conditioned by the experience of player and spectator. Over and above this is a presentation outside common experience. Excellence as it is perceived can be achieved in different ways. Hacker and Shiels (1992) focus strongly on the way sound techniques in maintenance and attention to detail can raise the general standard of greens, tees and fairways.

The Institute of Groundsmanship (IOG, 2003, p5) offer several benefits for having performance standards on golf courses including that of allowing managers to make realistic comparisons

between courses and to counter comments about one course supposedly being better than another. This, though, is a contested concept. They also consider that such standards:

- Provide managers with an aide in budget negotiations (as evidence can be used to argue for a change in staff, materials or machinery if a different standard or overall quality is desired)
- Enable efficiency in staffing deployment (as staff utilise their time more effectively in achieving the desired results by having a well-defined end product)
- Provide a suitable basis for drawing up detailed work programmes (and allow for an accurate assessment of resource requirements)

The Sports Turf Research Institute (STRI) and, to a lesser extent, The R&A have further developed some objective assessments, including some from earlier methods and existing tools, for the playing quality of golf greens (Isaac, 2012). These are really the only objective measurements of playing quality available to golf course managers. Standards for other areas are not developed to any meaningful level. The Institute of Groundsmanship (2003, p6) have proposed other standards for golf greens (and other areas) but these have not generally been adopted in golf course management and tend to focus on structural properties as opposed to objective measurements of presentation or playing quality.

All of the above are performance standards related to the quality of the course and its surfaces, particularly the golf green, and are therefore key parameters to be used and further developed in this thesis. In a study of municipal golf in 2001 Mort and Collins looked at managerial aspects relevant to Best Value under which the courses were being managed at the time. They looked at three groups of performance standards:

- Access – showing the use by different groups and the effectiveness of policy to combat social exclusion.
- Financial – representing indicators of efficiency and economy.
- Utilization - showing the scale and nature of the use of the facilities, and indicating effectiveness and efficiency.

This is one of the few studies of its type and is limited to a few municipal golf courses in England and did not consider surface performance or quality. The study has little relevance to direct operations management and golf green management as it was limited to larger scale strategic objectives. Industry press in the UK has focused almost entirely on initiatives such

as the STRI's Golf Performance Management System (a collection of golf green quality assessment methods) which focuses entirely on golf greens. This, in itself is a weakness, if one is looking at overall golf course quality and management, a far more complex situation which is not the concern of this thesis.

4.12   Benchmarking

To support continuous improvement there are a considerable variety of quality management tools and techniques available for organisations to use (Dale, 1994) Benchmarking is an increasingly popular improvement tool (Goetsch and Davies 2010). The Institute of Management (1999, p6) define benchmarking as *"the ongoing structured process of identifying, understanding and adapting outstanding practices of industry leaders to help an organisation improve its performance and achieve and sustain competitive advantage".* Benchmarking is the process of learning from others and stimulating creativity in practice (Slack, Brandon-Jones and Johnston, 2013). Davies and Girdler (1999a) believe that Benchmarking is a rigorous and consistent system of comparing and measuring an identified section or element of operations with similar undertakings enacted by a selected other and ascertaining how improvements can be designed and implemented to improve the processes and outputs. Benchmarking therefore relies upon being able to measure both your own and other people's systems and work processes.

The aims of Benchmarking have been summarised by Davies and Girdler (1999a) as:

- Seeking improvement in performance and productivity.
- Striving for continuous improvement in work processes and output.
- Achieving 'best practice' in all activities.
- Advancing the cost effectiveness of each organisational activity.

Dale (1994a) identifies three types of benchmarking which can be undertaken in sequence:

- Internal Benchmarking – This does not have to mean comparison with another company. Benchmark against yourself.
- Competitive Benchmarking – can be used as a way of informing people how badly –or well- they are doing against direct competition. The main disadvantage is gaining information on competitive processes or targets – sometimes can be difficult.

- Functional/generic Benchmarking – compares specific functions EG distribution, logistics, service etc. with the best in the industry.

Slack, Brandon-Jones and Johnston (2013) suggest also that benchmarking need not be competitive where done with organisations which do not compete directly in the same markets. Goetsch and Davies (2010) argue that benchmarking must involve partnering with best in class so that you can adapt processes for your own operations without having to spend time and money trying to design a duplicate of the superior process. They believe internal benchmarking to be reengineering which should only be done only when partnering with best in class is not possible.

Personal experience in golf green management shows there is little point in entering into the benchmarking process unless there is a real desire by management to achieve these things. Benchmarking can be built into an organisations strategic planning as a mechanism for achieving continuous improvement. Organisations need to make resource and structural provision for implementing improvements that emerge from the benchmarking process. The philosophy of improvement needs to be owned throughout the organisation and most of all by management for this process to have real effect.

Inevitably in considering operations performance in facility management a benchmark to measure against is a first consideration. In fact, the word benchmarking is often used to describe performance measurement itself. "A benchmark is a reference or measurement standard used for comparison, whilst benchmarking is the continuous activity of identifying, understanding and adapting best practice and processes that will lead to superior performance." (IOG, unknown, p4) The Institute of Groundsmanship maintain that their own Performance Quality Standards are reference standards against which a particular facility can be compared and that Benchmarking provides a turf manager with a process that aids in identifying areas for improvement.

Isaac (2008) has likened benchmarking to human fitness when considering its relevance to golf course management. *"Benchmarking could be considered the golf course equivalent, whereby the impact of inputs on its performance are measured and compared year after year. In much the same way as we use tools to measure our fitness, e.g., devices to determine heart rate, blood pressure, the dreaded scale, and so on, implements are necessary to assess the health of our turf"* (p8). Golf course managers can measure drainage rates, organic content, and other factors relating to the physical condition of the grass, but must also assess how the turf performs for the golfer. Devices to measure the firmness of turf and the trueness of putting

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surfaces have been developed. These and other tools could also take their place in the turf industry as the Stimpmeter, for measuring golf green speed, has become part of the nomenclature of golf and turf management.

To achieve these objectives measurements must be based on both objective data and subjective data and consider both services and the general working environment. Bench marking is identified as one of the raft of measurement systems which will be used to measure the efficiency, effectiveness and economy of land related service provision and delivery.

A key part of benchmarking procedure is the analysis of results which should aim at identifying the reasons for any important differences between the benchmark operation and the operation being measured (Kincaid, 1994). This gap analysis then is the basis for a review and improvement of the processes involved in the operation. Action plans can then emerge from this analysis and following implementation further measurement to assess the changed process. The cycle then repeats. When this approach is allied to the involvement of staff in measuring and changing the process, benchmarking becomes a part of a total quality management approach to facility management. It should be obvious to all levels of management that benchmarking cannot therefore be properly undertaken in any covert way. The philosophy of improvement needs to be owned throughout the organisation and most of all by management. This means that any benchmarking project should be (Davies and Girdler, 1999a, p16-17):

- Realistically designed so that the objectives are clear and process of implementing the outcomes is known
- Accurately measured and assessed so that it is free from assumptions and unproven targets
- Honestly undertaken with a transparent agenda and clear means of communicating findings to the organisation and staff

Management also needs to accept that things always have the potential to go wrong. The key point is that management has to recognise they are unlikely to carry all people with them. This however should only stimulate managers to "accentuate the positive" elements by effective communication and "eliminate the negative" by efficient operations applications. Resistance to benchmarking is quite evident among some sections of the horticultural profession including golf course management. It is claimed there are too many variables associated with growing things, and with amenity usage, to enable any meaningful comparison to be made. Davies

and Girdler(1999a) state that It is difficult to fully accept this sort of argument when success has been achieved with other highly variable activities such as fish farming, dolphin training, ski-slope management and land reclamation which have retrospectively been benchmarked against car manufacturing, basketball training, fast-food enterprises and open-cast mining systems.

Slack, Brandon-Jones and Johnston (2013) argue that the fundamental flaw in benchmarking is that an organization is limiting itself, in comparing itself with others, to currently accepted limits of performance as well as relying on others to stimulate creativity. Best practice is best only in the sense that it is the best one can currently find and it does nothing to promote more radical shifts in practice. The R&A entered the benchmarking arena in 2010 with its own web-based benchmarking service for course managers to enter course management data and then compare their own course against others. This service has since been abandoned as it was seen to be overly complex and had little take up in the industry. Nevertheless, a performance management framework focused on operations management , which allows golf course managers to monitor green performance could be used for both own improvement with or without comparison to others. This thesis has not found such a framework to date and it is stressed that the emphasis should, however, be on the requirements of the specific course under consideration.

4.13 Conclusion: Developing a Performance Management Framework for Golf Greens

Neely (1999) argued the case for research into performance measurement within organisational settings and stated that there were four fundamental questions that this research needs to address or answer:

- What are the determinants of business performance?
- How can business performance be measured?
- How to decide which performance measures to adopt?
- How can the performance measurement system be managed?

In managing sport and recreational surfaces Dury (1997) states that there is a need to develop performance management systems for both existing facilities but also in developing new ones. Such systems need to be versatile and flexible to accommodate varying circumstances.

Recording, monitoring and analysing operations enable management in resource decision making. The system should enable incorporation of a series of indicators which are interrelated. There should be a clear link between operations management and key performance indicators used in performance measurement (Slack, Brandon-Jones and Johnston, 2013). Performance objectives and measures can be aggregated into composite measures which will have greater strategic relevance as they assist in compiling an overall picture of the business and its performance.

In developing a performance management framework for golf greens one must identify the measurable criterions of quality to be used as well as determining how inputs and costs can be calculated and incorporated. The primary need is a performance management framework that can be easily adopted by course managers at the operations level to manage resource inputs with quality standards and where, required, be used as a comparator of performance in a benchmarking context.

The next chapter provides the conceptual framework developed for this research building on the principles identified in this literature review upon golf green culture, operations and performance management for golf green management. The key components required for a performance management framework for golf greens needs to include operations practices, input costs and quality assessments or standards.

Chapter 5   The Conceptual Framework

This research builds upon and goes beyond existing systems reviewed in the previous sections to propose a performance management framework for golf course managers to enable them to better manage their golf greens. The stated aim is to develop a performance management framework that enables golf course managers to target better use of resources in golf green maintenance strategies and achieve optimal surface quality. In considering existing systems in the literature it has been found that there has been limited attention paid to this research subject area for use at an operations level. Primary maintenance methods for golf greens have been identified from widely available literature which give recommendations for golf green operations. Operations practice varies. This variation is not an issue in itself as conditions on the ground vary with different golf courses as do the level or resources available, but what is relevant is that inputs do affect outputs, for example the level of quality achieved. Thus the systematic measures of performance here for golf green can be identified as maintenance practices (type and intensity), input costs and the standards for green quality. Figure 2 below illustrates the Conceptual Model devised for this research.
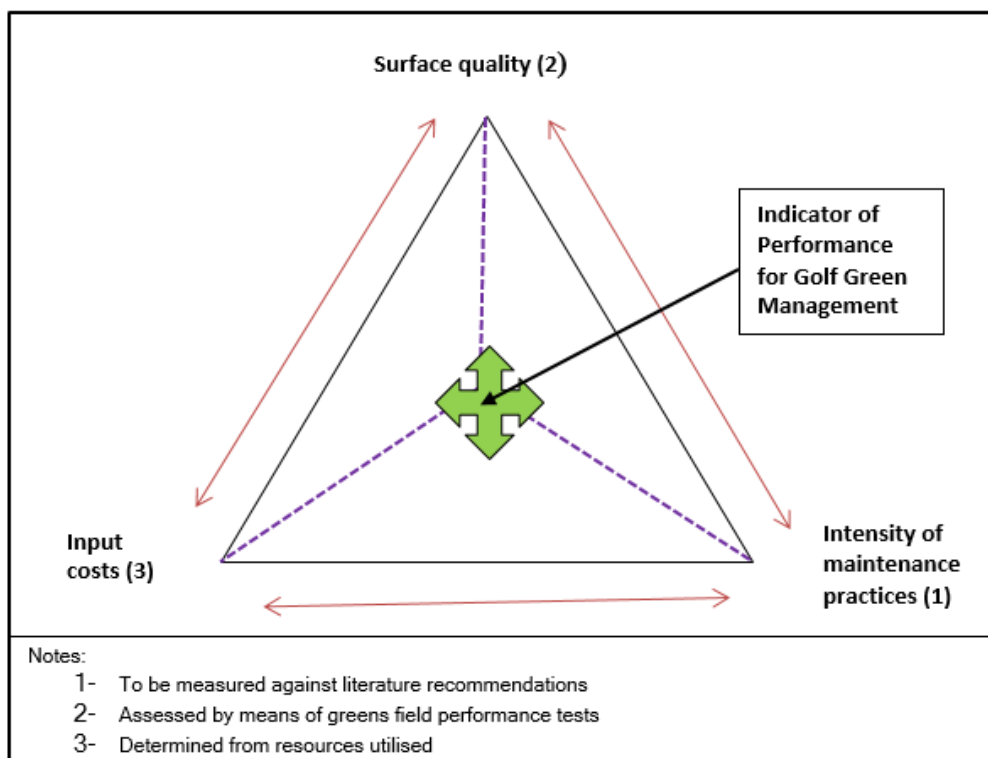
Figure 2   The Conceptual Model Developed for this Research

The indicator of performance indicates where the three parameters converge. Research data will indicate where a golf course sits on the conceptual model for greens performance and the quality they are achieving with a known level of resource input. Maintenance inputs for golf greens are compared critically with recommended inputs. Results from green performance assessments can be compared against recommended tolerances for such criteria. Costs indicate expenditure in relation to maintenance practices and quality levels achieved. Similar models for assessing outcomes of works and practices exist in other fields within the built environment domain. In project management for example, a concept known generically as "the iron triangle" (Atkinson, 1999) has been used for some time to measure the success of construction projects. For construction, the criteria used are cost, time and quality, however actual performance measures are not indicated and it is left to the researcher or manager to identify such. The Conceptual Model proposed addresses several key issues and weaknesses identified in the literature with other performance measurement systems as indicated in Table 4 below.

Table 4	Critical Review of the Conceptual Model against Existing Theory	
Criticisms of performance measurement systems	**Source**	**Comment :how the proposed Model addresses these issues**
Insufficient regard to continuous improvement and timescales for achievement.	Ghalayini et al (1996) ,Maskell (1989) ; Tangen (2004)	The field tests for greens performance have scales which can and are used as targets in industry to monitor greens and their improvement over time.
Systems lack specific practical performance measures for operations level	Ghalayini et al (1996) ; Tangen (2004)	The field tests for greens quality can easily be conducted by any course manager. Tests are well tried and tested in industry and known to most. Course managers manage their own resources for greens maintenance and decide on practices. The framework is intended for operations level.
Do not allow predictive or future performance	Ghalayini et al (1996)	Operations targets can be set for Course managers to achieve in future. Green quality assessments do give course managers an indication of impact of maintenance practices. Practices can be amended accordingly.

Need for dynamic systems	Ghalayini et al (1996) ; Maskell (1989)	The model allows for variations in input and costs to be factored and interpreted. Tests for green quality allow for variance. The Model interprets such variations into an overall performance matrix.
Need for clear links to senior management and strategy goals from the shop floor and vice versa.	Tangen (2004) ; Maskell (1989)	The model is one for operations level but considers several significant factors for senior management including resource utilization (labour, machinery, and material costs) and green quality which is important for customer care and satisfaction. The model can both inform senior management and be used in future planning and marketing for overall golf club success.
Performance measures should not be based on solely financial metrics	Tangen (2004) ; Maskell (1989)	Two areas of performance measured are concerned with golf green playing quality and of levels or intensity of maintenance practice. Cost is included but is neither the sole nor the most important factor. The goal is to achieve efficiency in operation without compromising on quality.
There should be a limited number of criteria which are easy to understand and interpret / should be simple and easy to use	Tangen (2004) ; Maskell (1989)	Metrics include five field tests for green quality, assessment of five key maintenance practices and costs as determined by labour and material inputs. All are easy to understand and use.
Need to provide Fast feedback	Maskell (1989)	Field tests give instant feedback in individual measures. Once model is in use it is easy to amend with inputs of new data for revised feedback.

The conceptual model shown in Figure 2 above covers operations and performance concerns derived from several literature sources pertinent to current golf green management today for golf course managers. These are resource inputs and efficacy of practice (Adams and Gibbs, 1994; Beard, 2002; Brown et al, 2001; McCarty, 2001; Ryan, 1999; Slack, Brandon-Jones and Johnston, 2013; Turgeon, 2002), costs for maintenance (Cobham, 1990; England Golf, 2014; Vavrek, 2010) and quality of product or surface (Dury, 1997; Windows and Bechelet, 2009; Isaac, 2012). It addresses the shortfalls in literature models and systems as well as providing a sound theoretical basis for reviewing practice.

Chapter 6   Research Design Methodology and Methods

Introduction

This chapter describes the research paradigm, methodology and data collection methods adopted for this research. Relevant theoretical aspects of research methodology and methods are discussed as appropriate to this research. Mixed methods combining both inductive and deductive approaches and utilising both qualitative and quantitative methods is also confirmed. Research methodology is that of the case study which is conducted along with a questionnaire survey to resolve the research aim and objectives.

The aim and objectives for this research have led to a comprehensive review of the literature to identify existing theory of golf green culture, operations and performance management and rationalise that a gap in knowledge exists. The conceptual framework that has been derived and presented in Chapter 5 now needs to be refined, and further detailed by incorporating site-related and practice-based information, with contextual inter-relations, to develop an innovative performance management framework. This framework is to be completed through data collection then validated through stakeholder review in subsequent sections. This Chapter describes how site-specific data and professionals' managerial experience become embedded in the conceptual framework.

Trafford and Lesham (2008, p90) relate developing a research strategy to Kipling's six "honest serving men" –What, Why, When, How, Where and Who, and proposes that these when considered as questions form the basis to research design. The stated aim identifies what this research is about. It is based in golf greenkeeping practice and seeks to review current practice in managing golf greens and the impact of maintenance practices and inputs in determining golf green quality. The golf green is the focus of much management input and from a qualitative viewpoint often the main concern of the golfer. Thus golf green management is the primary driver in determining golf course management practice and maintaining player satisfaction. Recent events such as the economic downturn, decrease in club memberships allied with more focused attention on golf green quality assessment tools and methods are impacting on the ability of and how golf course managers are maintaining golf greens.

Resources are increasingly restricted but the expectations of players remain or increase as do their choice to participate. This research is concerned with the golf course manager, promoting good agronomic practice and maintaining the best possible golf greens with the least inputs, especially where such inputs may be detrimental to playing quality, the environment, are unnecessary or unduly costly. The goal is one of improving efficacy in resource management but with optimum golf green quality. It is about allowing golf course managers to identify and manage their resources for their own situation and practice. The bulk of data for this research was collected over two years (2014-2015) and involved site visits to four golf courses in North West England to interview Golf Course Managers for management data as well as conducting tests of their golf greens for playing surface quality. A survey of Golf Course Managers was conducted using communication channels made available through the British and International Golf Greenkeepers Association.

The Research Paradigm and Approach

6.1   Research Paradigms

Particular research methods emanate from research methodologies which in turn have been developed from theory. An understanding of these theoretical perspectives can inform the researcher in selecting the most appropriate research methods for a given project. Theory informs practice. The nature and meaning of some of these philosophical perspectives is still contested and debated. Gray (2009) believes that amongst these theories Positivism and Interpretivisim (also known as anti-positivist, relativism or phenomenology) are or have been the most influential and will be considered further here.

6.2   Positivism

Here the world is real and we can learn about what is around us through our senses and gain knowledge by scientific method and empirical enquiry. Walliman (2011) believes that with this approach science builds upon what is already known and follows a reductionist approach whereby less measurable sciences can be reduced to more measurable ones and that social sciences can be value free and objective. Gray (2009) notes that this approach can be criticised as it implies that results tend to be presented as established truths and further that no theory can ever be proved simply by multiple observations as one alone that is contradictory will refute that theory. This research will therefore be conducted on multiple sites

to triangulate information from secondary resources with measurement data and survey findings in order to validate the evolving framework.

6.3   Interpretivisim (anti-positivist, relativism or phenomenology)

The central tenet here is that natural sciences and social reality are different and need different research approaches and methods. The natural sciences are looking for consistency in the data found to arrive at laws of science (termed nomothetic) whilst within the social sciences one is often looking at the actions of individuals (ideographic) (Gray 2009). Walliman (2011) states that the researcher is inextricably involved within the research they are undertaking and that as such one is not neutral as one is influenced by own preconceptions, beliefs and values. The researcher needs to consider which research paradigm is most appropriate for their own research. Table 5 below considers the strengths and weaknesses of these two paradigms.

Table 5   **Strengths and weaknesses of Positivist and Interpretivist Paradigms (adapted from Amaratunga et al 2002).**

Paradigm	Strengths	Weaknesses
Positivist	Wide coverage of a range of situations. Fast and economical Large samples can be statistically significant	Methods can be inflexible Not good for processes or understanding actions of people Not useful for theory generation Not useful for future predictions as focus is on past
Interpretivist (anti-positivist, relativism or phenomenological)	Data gathering is more natural Change monitoring over time Understand meanings of people Adjusts to emergent ideas Contribute to theory formulation	Data collection can be tedious Analysis of data can be complex Management of research more difficult Managers and others often question credibility of qualitative research

The researcher has to choose from several research methodologies and will be influenced by their own inclination towards both positivist or interpretivist paradigms and also whether they consider that theory should arise from the data (inductive reasoning) or that one should have a theoretical model to begin with (deductive reasoning). It is also influenced by one's view or perspective of research for example whether one is seeking to find a universal truth or law or whether one wishes to explore people's views and perspectives in different situations. The emphasis for this thesis is presented in the following section.

6.4   The Paradigm for this Research

This research adopts a phenomenological review of managers' attitudes towards management practice through survey that is triangulated against secondary theoretical resources and a positivistic study of green-playing quality indicators. The mixed method paradigm aims to provide a contextually prioritised system for managers to balance their resources and achievement. It is conducted from the viewpoint that the researcher is independent from that being observed, seeking to find causality (Amaratunga et al 2002).

6.5   The Research Approach

Walliman (2011) asserts that there are two basic approaches to acquiring knowledge which are Empiricism and Rationalism. Empiricism is where knowledge is derived from sensory experience using primarily inductive reasoning whereas Rationalism is that knowledge gained by deductive reasoning. These two approaches (inductive and deductive) offer the researcher two valid but distinct routes in the pursuit of new knowledge. Gray (2009, p14) asks the question *"in research should we begin with theory or should theory itself result from research?"* To determine the best approach for this study the following sections identify key parameters of alternative approaches.

6.6   Inductive Reasoning (The Empiricists Approach)

An inductive approach to research uses various forms of interpretive analysis of meaning-making to arrive at non-generalizable conclusions (Trafford and Lesham, 2008).This is considered to be the earliest and most common form of scientific research activity. Its starting point is that of observation from which general conclusions are derived. This practice is that which we experience most frequently in everyday life as we all learn from our surroundings and experiences from which we then formulate conclusions and then generalisations (Walliman, 2011). In order to formulate more valid conclusions, the researcher will often conduct multiple observations rather than basing conclusions on one case (Gray, 2009). This latter point illustrates one of the key criticisms of this approach in that how many observations are needed before conclusions can be reliable enough from which to generalise? Further how many situations and under which conditions should such observations be made to reach

conclusions? It may not always be possible to collect either the volume or type of data that was originally intended (Trafford and Lesham, 2008). Walliman (2011, p18) offers this advice – *"in order to be able to rely on the conclusions we come to by using inductive reasoning we should ensure that we make a large number of observations, we repeat them under a large range of circumstances and conditions and that no observations contradict the generalization we have made from the repeated observations."*

Clearly this appears to be sensible advice as the more observations that are made which are congruent with the conclusions and generalizations made the probability of them being true increases. It is left to the researcher, however, to determine how many observations should be made.

6.7   Deductive Reasoning (The Rationalists Approach)

Here the researcher starts with general statements (theories) which are tested thorough observations or experiments with an underlying premise is that there will be order and regularity between variables (Trafford and Lesham, 2008). A theory can be seen as a speculative answer to a perceived question or issue. The theory, usually termed a hypothesis, can therefore be either confirmed or denied (falsified) through research methods designed to test it. It is then, obvious that one observation which contradicts the purported theory is sufficient to refute it. This possibility is not seen as a negative factor as if one theory is rejected another one is proposed and again tested, culminating in the one which does match with observations being generally accepted until it can be established otherwise. Science is seen to proceed by trial and error (Walliman, 2011). It is possible that the whole theory is rejected requiring a complete new start or outlook but often partial validation of hypotheses may be attained and progress is made incrementally in small steps. Deductive reasoning can also be criticised as often theories are based on premises which may or may not be entirely true.

6.8   The Approach for this Research

Given that both inductive and deductive approaches to research both have inbuilt problems or issues with validity and reliability an approach which combines aspects of both these would seem logical. Gray (2009) states that inductive and deductive processes are not mutually exclusive. Trafford and Lesham (2008) support the concept of a using a combination of deductive and inductive approaches in social sciences, this is also an approach Gray (2009) considers useful where data collection can be developed into a concept, model or even

framework. Walliman (2011) also recognises this staged approach to research. This research takes a deductive approach towards management practice and an inductive approach to golf green playing quality and performance management.

The Research Methodology

6.9   Qualitative and Quantitative Research

Amaratunga et al (2002) consider that research can be further categorised into two distinct types from the theoretical stances considered above as either qualitative or quantitative. Trafford and Lesham (2008) report how doctoral researchers often categorise their work as deductive (quantitative) and inductive (qualitative). Qualitative research is focused on words and observations whilst quantitative is primarily concerned with numerical data. Quantitative data can be measured accurately because it contains some form of magnitude and is commonly analysed using mathematical procedures in simple terms such as counts, percentages or more sophisticated methods such as statistical analysis. Even people's opinions can be expressed quantitatively when analysing questionnaires and counting responses made to specific questions (Walliman, 2011) Qualitative data cannot be accurately measured and counted and is generally expressed in words rather than numbers (Walliman, 2011). Essentially human activities and attributes such as ideas, customs, and beliefs that are investigated in the study of human beings and their societies and cultures cannot be measured in any exact way. These kinds of data are therefore descriptive in character and therefore suitable for analysing managers' perceptions of key issues.

6.10   Mixed Methods

This research adopts a mixed methods approach to research as advocated by Amaratunga et al (2002). It is concerned with capturing both managerial phenomena and resource input data for golf green management together with golf green quality which have qualitative and quantitative characteristics. There are many authors who argue the case for using both qualitative and quantitative research methods (Kinn and Curzio, 2005). The use of these two approaches together is beneficial as both have their limitations and when used together they can in effect compensate for the weaknesses of each and afford triangulation. As Amaratunga et al (2002) state the built environment discipline draws on many other subjects including from

social and natural sciences, engineering and management and the use of appropriate methods is essential to advance the body of knowledge in this domain. They also support the mixed methods approach as a valuable concept which should be adopted.

6.11 Case Studies

The specific research methodology adopted for this research is that of the case study in order to capture timely real-world evidence of managerial performance. Case studies are frequently used in research to explore subjects and issues such as organisational performance and are an ideal method where contemporary events are being questioned where the researcher has no control (Gray, 2009). The validity of the case study methodology has been questioned as there may be bias towards verification of the researcher's preconceived ideas. Flyvberg (2006) rejects this and believes that case studies often contain a greater bias towards falsification of preconceived notions rather than their verification. A greater problem can be that it can be argued that case studies may not be representative of the population being researched and further that it is not possible to generalise on an individual case and therefore the contribution to knowledge or scientific development is limited. Meyer (2001) argues for the use of multiple case studies or sites as a means of overcoming this issue. This is supported by Flyvberg (2006) who also though, considers that generalization as a form of scientific development is overvalued and the force of example underestimated. He also states that it is often not desirable to summarise and generalise from case studies but that they can be valuable as narratives in their entirety.

Case studies can be used for a wide range of research types and questions and are particularly useful when the researcher is trying to uncover a relationship between a phenomenon and the context in which it is occurring (Gray, 2009). In this case how management practices are impacting on golf green quality. The case study approach requires the collection of multiple sources of data but, if the researcher is not to be overwhelmed, these need to become focused in some way. When selecting actual case study sites the goal is to choose cases that are likely to replicate or extend emergent theory or theoretical categories. Sampling should be concerned with information richness and selection is purposeful rather than random. The most important criteria that set the boundaries for the study are importance or criticality, relevance, and representativeness (Meyer, 2001). Gray (2009) affirms that effort should be made to ensure cases are typical of the population in question.

6.12 Case Studies - Golf Course Selection

In deciding upon case study sites (golf courses) for this research it was necessary to consider the three elements of constraints, practicality and time (Trafford and Lesham, 2008). Golf courses were selected on the basis of their locality to the researcher, their landscape and club typology and willingness of the course manager to participate. Four 18-hole private members golf courses which can be categorised as parkland located within a 30 mile radius of the researchers work in the North-West of England were used as sites for data collection. Reducing variables such as golf course type and ownership help ensure validity in data collection. Gray (2009) states that validity means that a method should measure what it is intended to measure and that to be reliable it should give consistent measurements. The goal is to minimise any biases in a study. Amaratunga et al (2002) state that the value of any research stems from the validity of its findings and subsequent contribution to knowledge.

6.13 Data Collection Methods

There is are a range of data collection methods or instruments available to the researcher in order to gain data for analysis and interpretation. These are the tools one uses in order to answer the research question or formulate theory. Data collection methods need to be chosen according to the nature of the data to be collected and the particular theoretical basis and methodology adopted by the researcher (Trafford and Lesham, 2008). Consideration should also be given as to how the data collated can be analysed.

Data that has been observed, experienced or recorded close to the event are the nearest one can get to the truth, and are called primary data (Walliman, 2011). Written sources that interpret or record primary data are called secondary sources which tend to be less reliable. Primary data is the most reliable data but can be time consuming to collect and analyse nevertheless it is critical to the aim of this research. Table 6 illustrates the primary data to be collected for this research and the method.

Table 6   Summary of Primary Data to be collected

DATA TYPE	DATA	RESEARCH METHOD	DATA SOURCE
Golf Green Performance	Surface Quality Measurements	On Site Field Testing	Case Study Sites
Golf Green Management	Maintenance Practices and Input Costs	Interviews with Golf Course Managers	
Golf Course Management	Golf Course Management Practice	Course Manager Questionnaire	National Survey

These primary data collection methods afford the best opportunities for collection of actual factual data for interpretation and analysis. Some of the merits and issues with these methods as reported by several authors are shown here in Table 7 and are discussed further below.

Table 7   Features and Issues of Data Collection Methods described in Literature

	Walliman (2011)	Sharp and Howard (1996)	Gray (2009)
Questionnaires	Can be used for qualitative and quantitative data Convenient and cheap to administer No personal influence of researcher Response rate often low for postal surveys Take time and skill to develop	Gain data from large sets Large amounts of data to analyse Data may be superficial Question interpretation Response rate	Low cost in terms of time and money Quick data collection Respondents complete in own time Anonymity can be assured No interviewer bias Response rate often low Quality of answers?
Interviews	Often inflexible for response but useful for probing questions Can be used for all subjects including sensitive ones Interviewer can judge quality of answers Recorded information available for others to analyse	High quality data How is data recorded Can be structured to ensure key data is gained Time consuming	Good for personalized data capture Certain response rate Interviewer can also read body language/non-verbal communication Interviewer can lead questions/impart bias

Direct Observation	Basic data collection method for many sciences Detached view of phenomenon being observed Quick and effective method for gaining preliminary data Can be time consuming when activity is not constant	Field work and measurement good for physical sciences Equipment used and conditions Observer may influence human behaviour Analysis for human observations can be difficult	Complex combination of all senses Can be overt or covert Data gathering can be difficult Ethical issues arise Often triangulated with other methods Need comprehensive notes

6.14 Interviews with Golf Course Managers

Interviews are the most widely used qualitative method used in built environment research as they are capable of producing rich and detailed data (Amaratunga et al 2002). Of primary concern for the researcher was the need for reliable data and a good response rate. The research is concerned with gathering factual data which can be gained using closed questions. Given that there are different types of interview it is necessary to arrive at the best method to achieve the data required.

Structured interviews are used with the Golf Course Managers at the case study sites to capture resource input data, as these afforded the best possibility for factual data collection, allowing for quick data collection led by the interviewer, easier analysis and interviewee anonymity can be assured (Gray, 2009). Golf course managers are busy people and it was important to not overly impose on their time whilst gaining much factual data. When relying on interviews as the primary data collection method it is important to establish trust between the researcher and the interviewer (Meyer, 2001). Meetings were held to explain the purpose and nature of the research and establish the parameters for both the information required and access for field testing of golf greens. The core information required was established from the review of golf green management practices. Data was recorded on a standardised schedule for later analysis (Walliman, 2011).

6.15 On Site Testing Performance Testing of Golf Greens

Golf greens on the selected golf courses have been assessed for performance quality using recognised tests. Although direct observation techniques can be time consuming (Walliman, 2011) they are accepted methods within the physical sciences (Sharp and Howard ,1996).The field tests adopted have been developed by turf management practitioners and scientists and promoted in the industry by the Sports Turf Research Institute (STRI) and The Royal and Ancient (Isaac, 2012).

When sampling one is hoping that the data you are getting will be representative or typical of the rest and that the population is homogenous (Walliman, 2011). Three golf greens on each course were selected for greens performance testing. The researcher asked each Course Manager to identify three greens of like construction profile for consistency and validity – these being what they considered to be the best, worst and medium for playing quality. Thus sampling was purposive as greens were identified against a criterion (Gray, 2009). Greens on all sites were of a soil "push up" type construction and predominantly *Poa annua* and *Agrostis capillaris* in sward composition. The tests conducted and tools/methods used at the four golf course sites are shown here in Table 8.

Table 8   Performance Tests for Golf Green Quality

DATA TYPE	Test	Tool / Method
Golf Green Performance	Green Speed	Stimpmeter
	Putting Consistency	Holing Out
	Firmness	Clegg Impact Hammer
	Soil Moisture	Theta Probe
	Soil organic Matter	Loss on ignition test

The reliability and validity of such data can is assured by multiple testing over a finite period. This will also ensure any differences in data attributable to possible differences in ground and environmental conditions can be minimised. Field tests for golf green quality were conducted in July 2013 and again in July 2014. All tests were conducted using accepted protocols and replicates appropriate for that method. Tests results being aggregated and mean values calculated for further analysis with management input data.

6.16 The Golf Course Managers' Survey

Questionnaires are one of the most popular data gathering tools and as they offer the researcher several advantages (Gray, 2009):

- They are low cost in time and money - they can be sent to hundreds of respondents at relatively cost.
- The inflow of data is quick
- Respondents can complete questionnaires when it suits them
- Data analysis of closed questions is relatively simple
- Respondents anonymity can be assured
- There is a lack of interview bias.

The major drawback; however, is frequently they have a low response rate. Respondents may also give flippant or inaccurate answers which the researcher cannot detect. In contrast with face-to face interviews the interviewer can often judge the quality of answers given, check understanding of questions and encourage full answers (Walliman, 2011). The opportunity to collect much factual data (Sharp and Howard, 1996) from as many respondents as possible in a constrained time frame (Gray, 2009) led to the decision to use a questionnaire survey. Such a survey approach also ensured that there is no interviewer bias, that respondents could complete in their own time and that anonymity could be maintained (Gray, 2009).

A survey of Golf Course managers was conducted in July of 2015. This was completed using the online programme - Survey Monkey. The survey was distributed to 1100 Golf Course Managers by the British and International Golf Greenkeepers Association – the national organisation for golf greenkeepers in the UK. The questionnaire survey was conducted to inform the research aim and objectives alongside that data derived the case study sites in order to gain a greater viewpoint about golf greenkeeping, golf green quality and performance measurement nationally. The survey included a series of open and closed questions covering: Golf Course Management, Operations, Golf Green Quality and Performance Measurement. **(See Appendix 1)**

6.17   Validity and Reliability

In order that defendable inferences can be made from data collected in any research project it is crucial that research methods or tools must be both valid and reliable. To ensure reliability the research method or instrument must provide similar results at different times (Gray, 2009). Gray further states that, in research, validity is concerned with the degree to which data is accurate and credible. This infers that research, to be relevant and useful should use methods which are repeatable, report true results and be of value to practice. Amaratunga et al (2002) state that the value of any research stems from the credibility of its findings and subsequent contribution to knowledge, they also suggest that there is no single best way to approach research and that research methods selected should be the most suitable to achieve the desired objectives. This research required management data from golf course manager's and the collection of field data for golf green performance measurement. The use of the selected data collection methods, multiple case study sites and a national survey of golf course managers help to ensure data is reliable as it is derived directly from the primary source being investigated (also concurrent with Walliman, 2011). The questionnaire survey is used to ascertain the usefulness of a performance management framework in industry and the response to Question 15 unequivocally validates the model in the eyes of the key stakeholders – the golf course managers.

6.18   Data Analysis

The maintenance inputs for golf greens and their surface performance characteristics from quality assessments can be compared critically with recommended inputs and tolerances from literature and practice. Results will be aggregated using ranking scales so that numeric values can be determined for particular golf course greens which can be plotted onto a radar chart congruent to the conceptual model developed for this research. Slack, Brandon-Jones and Johnston (2013) refer to a useful method for monitoring performance objectives in operations management which is illustrated here in Figure 3. One can clearly see the comparison between desired objectives and that actually achieved. It serves as a visual representation which allows the manager so see the overall performance of an operation. Such a method suits the multi-faceted conceptual framework of this research and allows for the multiple data sets to be simplified for management interpretation and action.

POLAR REPRESENTATION - TARGETS AND ACTUAL PERFORMANCE

Required performance   Actual performance

Objective 1

Objective 5   Objective2

Objective 4   Objective 3
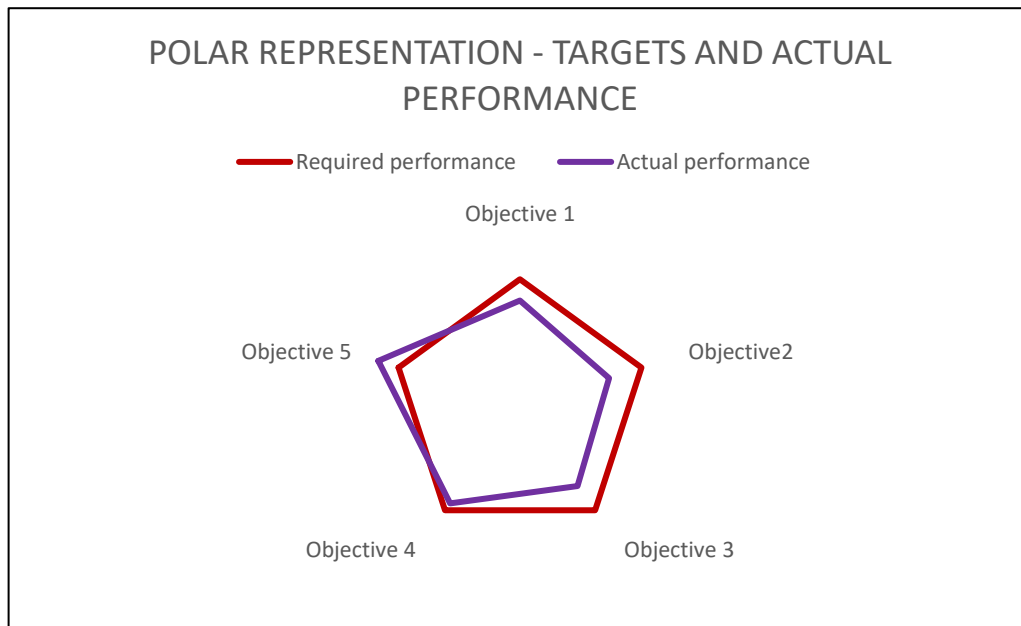
Figure 3   **The Polar Representation of Performance Objectives to be used in this thesis**

Management data from case study sites and the course manager's questionnaire will also be presented with descriptive statistics including the use of pie charts, bar charts and histograms (Gray 2009).

6.19 Ethical considerations

Walliman (2011) identifies two key aspects regarding ethics and research namely that:

- The individual values of the researcher relating to honesty and frankness and personal integrity.
- The researchers treatment of other people involved in the research, relating to informed consent, confidentiality, anonymity and courtesy.

A major part of ethical consideration within this research was the need to achieve informed consent from golf course managers for access to their courses and management information. Gray (2009) states that the information needed to be provided to achieve such consent will often include:

- The aims of the research
- Who will be undertaking it?
- Who is being asked to participate?
- What kind of information is needed?
- How much of the participants time is needed?
- That participation is voluntary
- Who will have access to the data after it is collected?
- How will anonymity of respondents/participants be preserved?

Table 9 below summarises the ethical and health and safety issues pertinent to this research project and how these were addressed.

Table 9	Ethical Protocol for this Research
ETHICAL ISSUE	STRATEGY ADOPTED
Confidentiality/Anonymity – of data collected, budgets, test results, surveys	All data sources and participants will remain anonymous and not identified in thesis.
Security of data storage	Data to be retained electronically on password protected computer and locked filing cabinet by researcher.
Access to sites / golf courses	Researcher will approach golf courses and negotiate access with managers there.
Consent of participants (Course managers)	Written consent to be sought prior to research work.
Disturbance to play/golfers (greens testing)	On-site tests to be negotiated with Course Manager in times of little play. Golfers to be advised when on site. Play will take priority.
Ownership of data	Data will be the property of researcher, Anglia Ruskin University and RansomesJacobsen.
Health and Safety (when on course – golf balls/lone working etc.)	Researcher will wear high visibility vest and hardhat when on site and comply with golf course H & S requirements. Course manager will be informed when on site and exact whereabouts.
Costs/implications to material suppliers (fertiliser companies etc.)	Research aims to raise awareness of sound greenkeeping practices and promote sustainability. No products will be identified by trade names in thesis.
Judgement of Greenkeeper practice	Research aims to raise awareness of sound greenkeeping practices and promote sustainability. No individuals will be identified in thesis.

An application to the University's Faculty Research Ethics Panel for this research was approved on the 13th June 2013 **(Appendix 2)**. Informed consent was achieved prior to any site visit for investigative research purposes.

Chapter 7 Research Findings and Analysis

Introduction

This chapter presents and analyses the data captured from the golf course manager's questionnaire and the four case study golf courses. The conceptual framework developed for this research is derived from literature and identifies golf green management practices, input costs and golf green performance data as the key parameters for a performance management framework. A national survey of golf course managers was completed during July 2015 to review industry practice and provide benchmark data for the performance management framework. Golf green management data including cultural (operations) practices and resource inputs was obtained from golf course manager interviews during site visits to the golf course case study sites in July of 2013 and again in 2014. Data was recorded using pre-planned forms compiled from information derived from the literature review of golf green culture and management. Field testing of golf greens (quality) was completed during the same visits for course manager interviews at each golf course. Visits were agreed in advance with each golf course manager.

7.1 Section 1 – Golf Course Managers' Survey Results

This section presents the results from a national survey of Golf Course Managers conducted from 7 -23 July 2015. 1100 Golf Course Managers, who were members of the British and International Golf Greenkeepers Association, were invited to complete the electronic questionnaire with the software Survey Monkey. The survey had a positive response rate of 324 respondents (29%). The purpose of the questionnaire was to review industry practice in operations and performance measurement and to inform the performance management framework. The questionnaire (Appendix 1) focused on six areas: respondent information, drivers for course management, decision making, golf green management, golf green quality and finally performance measurement.

7.2   Part 1 Respondent Details

Questions in this section were concerned with respondent's position, experience in greenkeeping and management and their level of academic qualification. The aim was to determine the credibility and reliability of the course management data. It was necessary to ensure data was reliable and reflective of industry practice. Of the 324 respondents 170 (52%) identified themselves as Course Managers and 127 (39%) as Head Greenkeepers. The remaining had other titles such as Estates Director or Superintendent. Questions 2 and 3 asked respondents about their years in greenkeeping and golf course management. The results can be seen here in Figures 4 and 5.

Years in Greenkeeping

	0-10	11-20	21-30	31-40	41-50
No.	11	93	124	83	12

No. of Respondents in each year group division
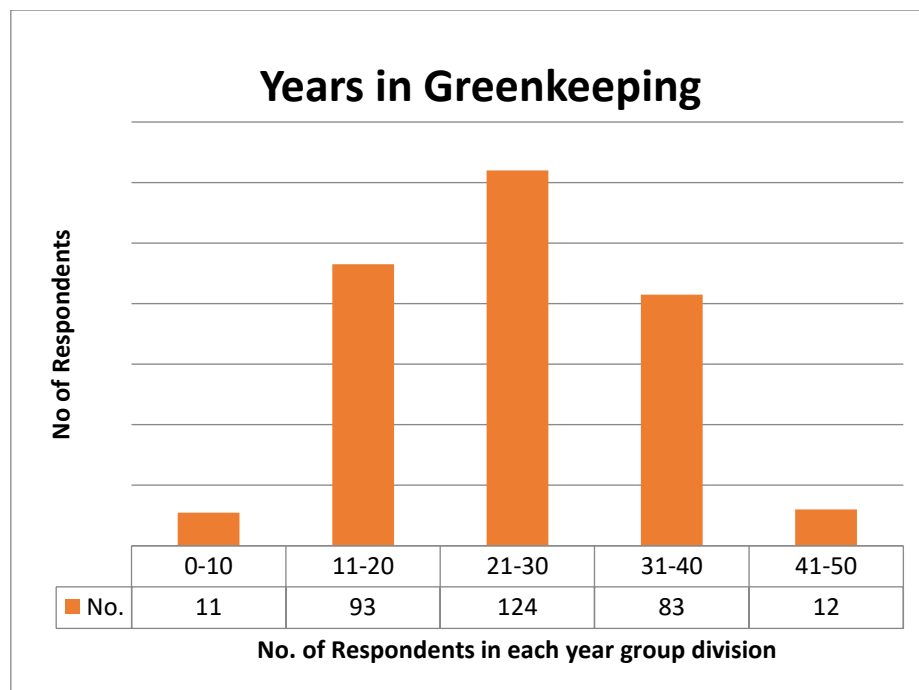
Figure 4   Respondents Years in Greenkeeping

93% of respondents here had between 11 and 40 years in greenkeeping and thus have experience of greenkeeping operations pertinent to this research. This supports later responses about greenkeeping operations in that respondents have the necessary experience and knowledge.

Years in Management

No.	0-10	11-20	21-30	31-40	41-50
No.	138	88	70	17	2

No. of Respondents in each year group division
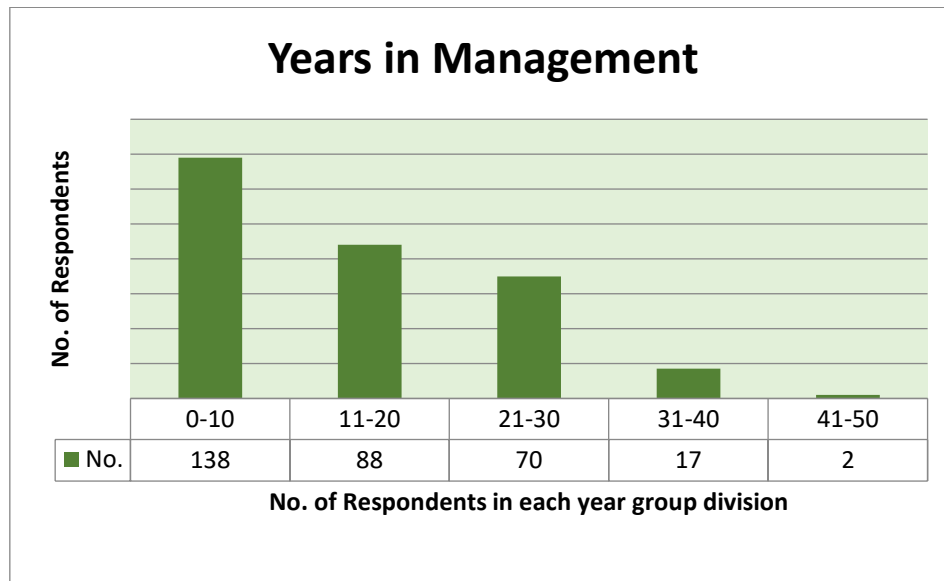
Figure 5   Respondents Years in Management

The experience of course managers is important in ascertaining operations and management practices including decision making, planning and organising work. This supports later responses about management as respondents have the necessary experience and knowledge. 50% of respondents had between 11 and 30 years' experience in golf course management.

The final question in this section was concerned with academic qualifications in greenkeeping and golf course management. Only 48% of respondents had undergraduate degrees. 49% had technical further education qualifications at level three or below. This was surprising as in most professions it is common for managers to have had a university education and have first degrees. This is the case in the USA for golf course managers. It is conceivable that without such qualifications respondent knowledge and understanding about theoretical aspects of operations management would be compromised. The questions about such matters in the survey did have a lower response rate.

7.3 Part 2 Drivers

Questions in this section were to ascertain what course managers considered to be the main influences affecting their ability to manage the golf course but also their philosophical position. In golf greenkeeping it is common to find greenkeepers who take a "traditional" approach (Arthur and Isaac, 2015) largely based on experiential learning and those that adopt a more technical scientific approach (Beard, 2002) based on management data collection and analysis. Finally, this section asked respondents to identify the main issues affecting greenkeeping today. Results are shown below in Figure 6 and Table 10.
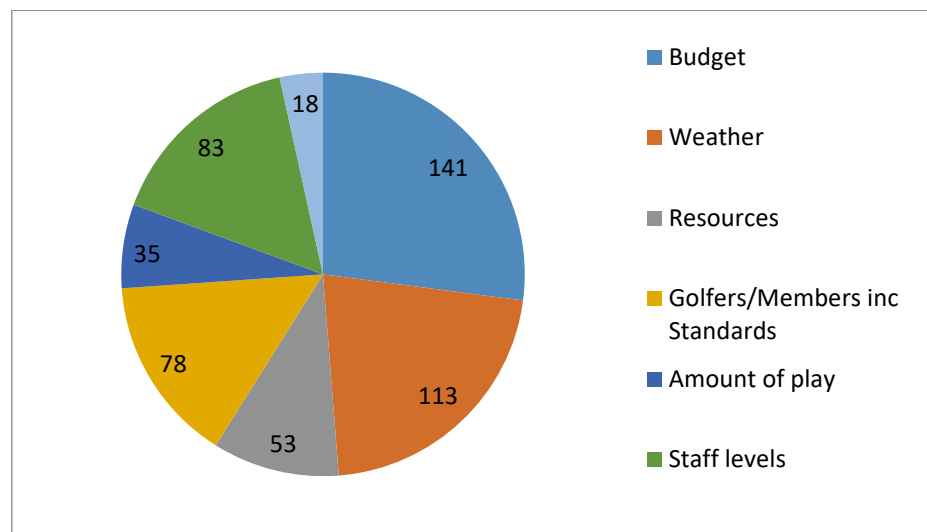
Figure 6 **Factors Directly Impacting on Golf Course Management (No. in each category)**

Figure 6 shows respondents considered that budgets (27%), the weather (22%), and staff levels (16%) were the major contributory factors affecting golf course management but notably the demands of golfers (15%) and expectations for quality surfaces are also evident. These responses support the earlier introductory findings from literature by demonstrating that multiple factors impact upon management decisions.

Table 10   Philosophy for Golf Course Management

Response (words used by respondents to describe their own management style philosophy)	Number of Respondents	Arbitrary Category	Number of Respondents	%
Customer focused	12	Contemporary	82	36
Modern	40			
Performance focused	14			
Presentation	3			
Responsive	13			
Simplistic	33	Historical	147	64
Sustainable	52			
Traditional	62			

Table 10 shows the responses (actual words used by respondents) words **and** the number in each case, that managers used to describe their philosophical stance / approach to golf course management which influences their decision making. These have been categorised here arbitrarily as either contemporary or historical. 64% of respondents identified themselves as taking this latter approach in their practice. These identify most closely with that approach maintained by Arthur and Isaac (2015) where greenkeeping is a practice rather than science and is also seen as more low input and based on experiential learning.

7.4   Main Issues Affecting Golf Courses

Table 11 and Figure 7 show the issues that golf course managers believe are affecting golf course management today. Respondents were asked to rank their top three according to their impact on the golf greenkeeping industry. The highest yielding responses have been aggregated here and can be seen in Figure 7.

Table 11   Main Issues Affecting Golf Courses

Reponses Ranked 1	No. of Respondents	Reponses Ranked 2	No. of Respondents	Reponses Ranked 3	No. of Respondents
Budgets (Revenue issues)	56	Budgets (Revenue issues)	32	Budgets (Revenue issues)	28
Climate change/weather	28	Climate change/weather	21	Climate change/weather	27
Demand for golf	46	Demand for golf	35	Demand for golf	25
Education (of Players and Staff)	1	Education (of Players and Staff)	3	Education (of Players and Staff)	16
Environmental issues	4	Environmental issues	11	Environmental issues	13
Greenkeeper Professional Image	6	Greenkeeper Professional Image	5	Greenkeeper Professional Image	2
Legislation/Restrictions (e.g. Pesticides and H&S)	9	Legislation/Restrictions (e.g. Pesticides and H&S)	26	Legislation/Restrictions (e.g. Pesticides and H&S)	24
Players expectation (Standards and Members Management)	57	Players expectation (Standards and Members Management)	55	Players expectation (Standards and Members Management)	52
Resource Issues	8	Resource Issues	9	Resource Issues	21
Salaries (for Greenkeepers)	6	Salaries (for Greenkeepers)	9	Salaries (for Greenkeepers)	3
Staff	7	Staff	22	Staff	17

These responses support the earlier introductory findings from literature in making the case for this research. The most significant here, budgets, demand for golf and member expectations, (see Figure 7 below) support that found in literature (England Golf, 2014; KPMG, 2015; and Vavrek, 2010).
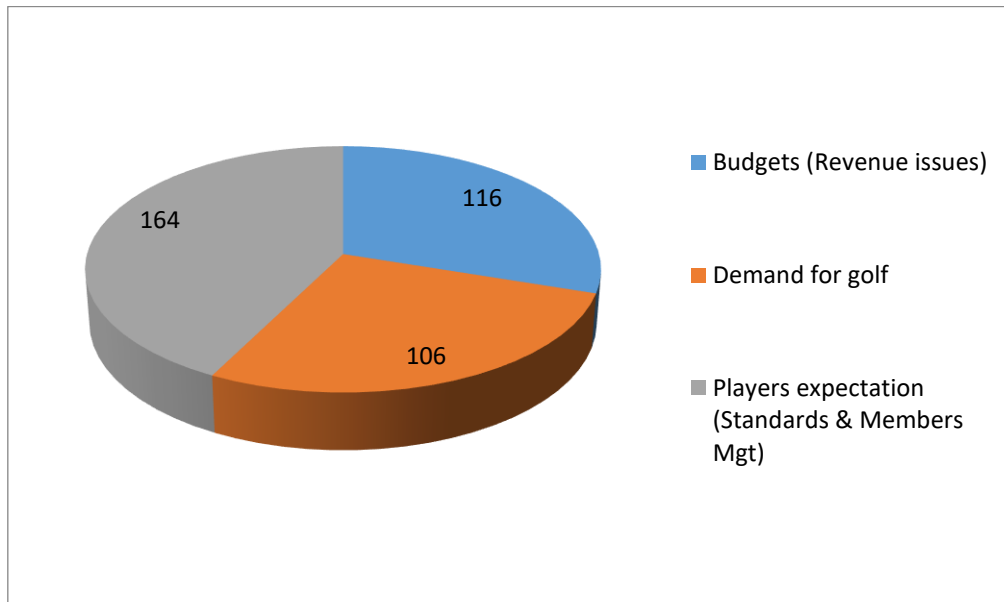
Figure 7   **Main Issues Affecting Golf Courses**

(No. in each category)

The demand for golf and player expectations account for 58% of the total here and of course both have direct impact on the third factor here of budgets available for golf course management. This reaffirms the need for golf course managers to manage resources for both efficiency and quality outcomes.

7.5   Part 3 Decision Making

Questions in this section were to establish what operations decisions course managers made and how these are implemented into practice with staff. The aim is to report the basis for golf course operations management in practice. Results are shown below in Figures 8 and 9.
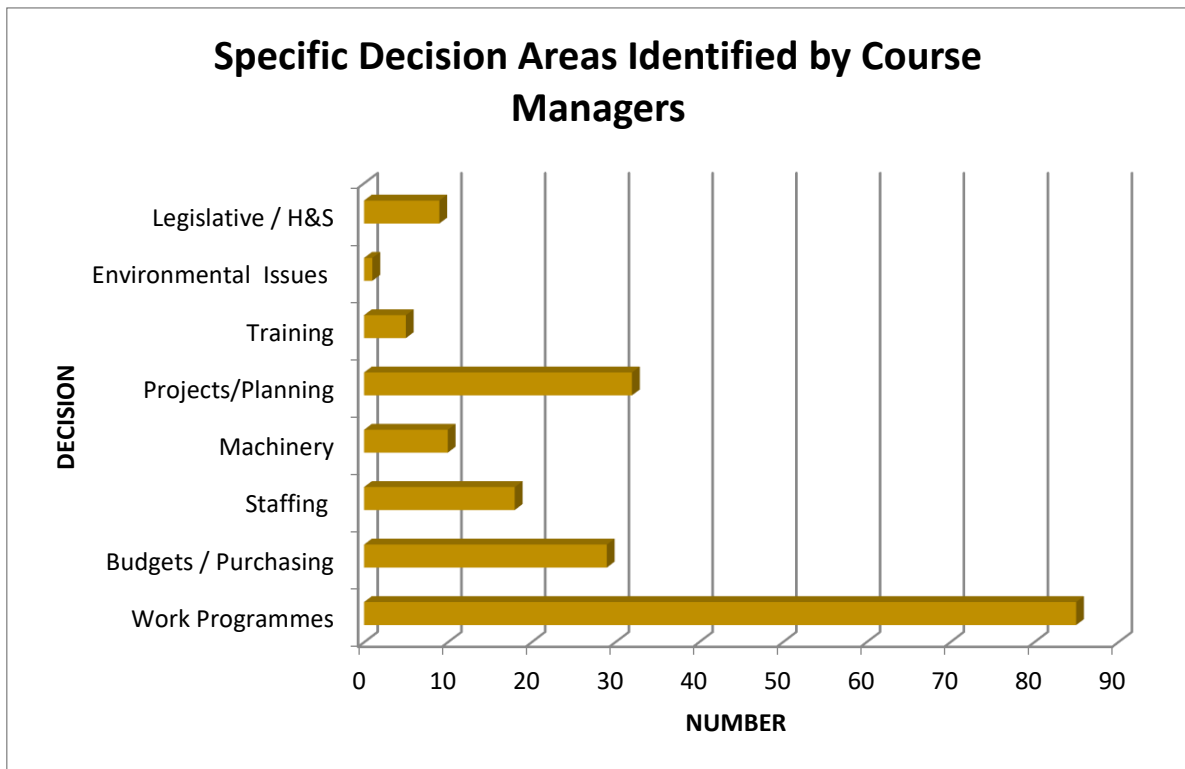
Figure 8   **Operations Decisions**

Figure 8 shows the decision areas identified by respondents as golf course managers. 75% are concerned with direct scheduling and resourcing operations for course maintenance. In implementing decisions 63% did so directly and verbally via both informal and planned meetings with staff members. A further 25% used written programmes and reports to disseminate information and decisions. Other means used included email and staff noticeboards. This confirms that golf course managers spend most of their time in managing routine maintenance operations, being primarily concerned with agronomic matters on the golf course.

The final question in this section asked respondents how they planned and organised greenkeeping operations. Figure 9 shows the results for this question.
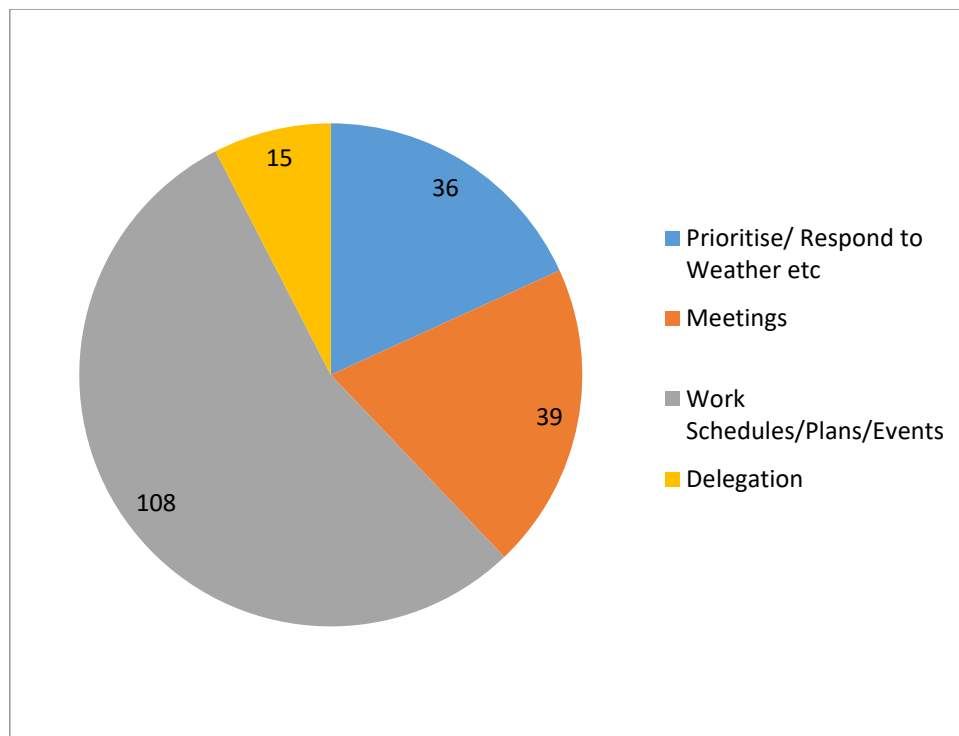
Figure 9　　　　Planning and Organizing Operations

(No. in each category)

In planning and organising work 108 respondents (55%) did so using a pre-planned schedule, some of which were organised around key dates for the club such as important tournaments and competitions. 39 (20%) did so via staff meetings. 36 (18%) respondents indicated that they reacted to prevailing weather conditions and a smaller number, 15 (7%) delegated the task to another such as their deputy.

7.6　Part 4 Managing Golf Greens

This section was essential in validating the chosen operations reviewed for management intensity in golf green culture. Although these were established from literature, the results here confirm practice in accordance with theory for golf green management. Respondents were asked to identify the most significant operations practices (Table 12), rank them in order of importance and then to identify work times for five practices which have been adopted in reviewing golf green culture. The table shows how many times a practice was ranked as

number 1,2,3,4 and 5 by respondents (for example, Aeration was ranked as 1-(44 times), 2-(52 times) , 3-(23 times) , 4-(16 times) and 5-(10 times) from 145 respondents). The total column indicates the fractional importance of each practice amongst the spectrum of practices. These are used to inform adopted ranking methods for management intensity and operation costs in the performance management framework.

Table 12   **Top 5 Most Significant Maintenance Practices for Golf Greens**

Golf Green Practices Combined							
Practice	Ranked 1	Ranked 2	Ranked 3	Ranked 4	Ranked 5	TOTAL Responses	Total %
Aeration	44	52	23	16	10	**145**	**19**
Irrigation	2	7	14	18	13	54	7
Mowing	79	15	17	12	14	**137**	**18**
Nutrition	13	22	31	25	23	**114**	**15**
OM Management	8	10	11	17	12	58	8
Over-seeding	1	3	1	4	2	11	1
Plant Protection	1	5	4	11	17	38	5
Rolling	1	9	5	6	29	50	6
Topdressing	5	26	39	30	15	**115**	**15**
Verti-cutting	1	6	6	10	12	35	5
Brushing	0	0	4	6	6	16	2

The data therefore reveal that the most significant practices identified by golf course managers for golf green maintenance were aeration, mowing, nutrition (fertilizer application) and topdressing. Irrigation, contrary to literature, is not seen as significant as these four practices. The results reaffirm the practices identified in literature for golf green management and confirms the key practices used in the performance management framework. Times for operations, confirmed here by course managers, have been used in Table 15 to allow costing of operations in the performance management framework.

7.7   Part 5 Golf Green Quality

This section was essential in confirming the chosen performance tests for golf green quality for management intensity in golf green culture. Although these were established from literature, the results here confirm the practice of methods and tests adopted in industry. Respondents were asked if routine testing for golf green quality was conducted and if so which assessments were used.
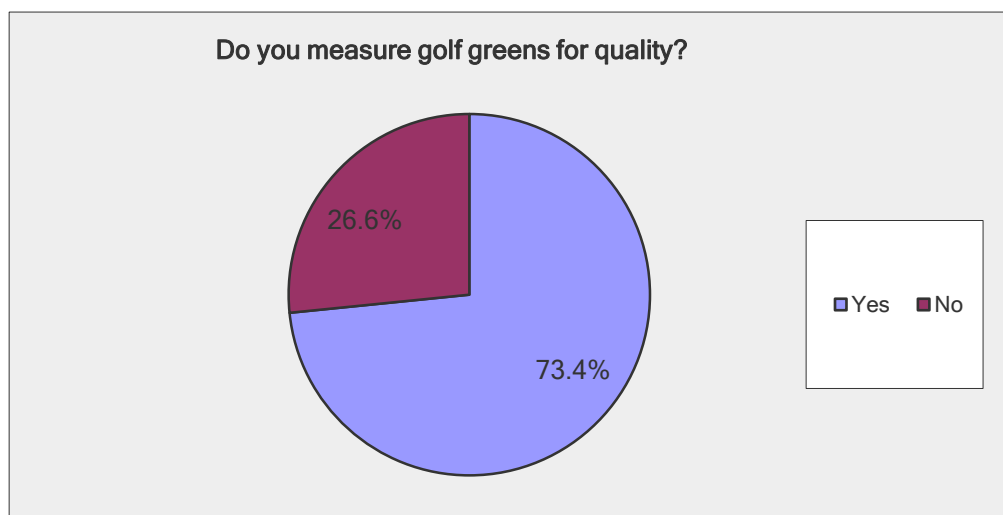
Figure 10   Measuring Golf Green Quality

Just over 73% of respondents (Figure 10) confirmed that they routinely assessed golf greens for performance quality using a range of measures. Figure 11 shows the measures of golf green quality reported by respondents. Thus. Course managers are already collecting data that could be used within the performance management framework.
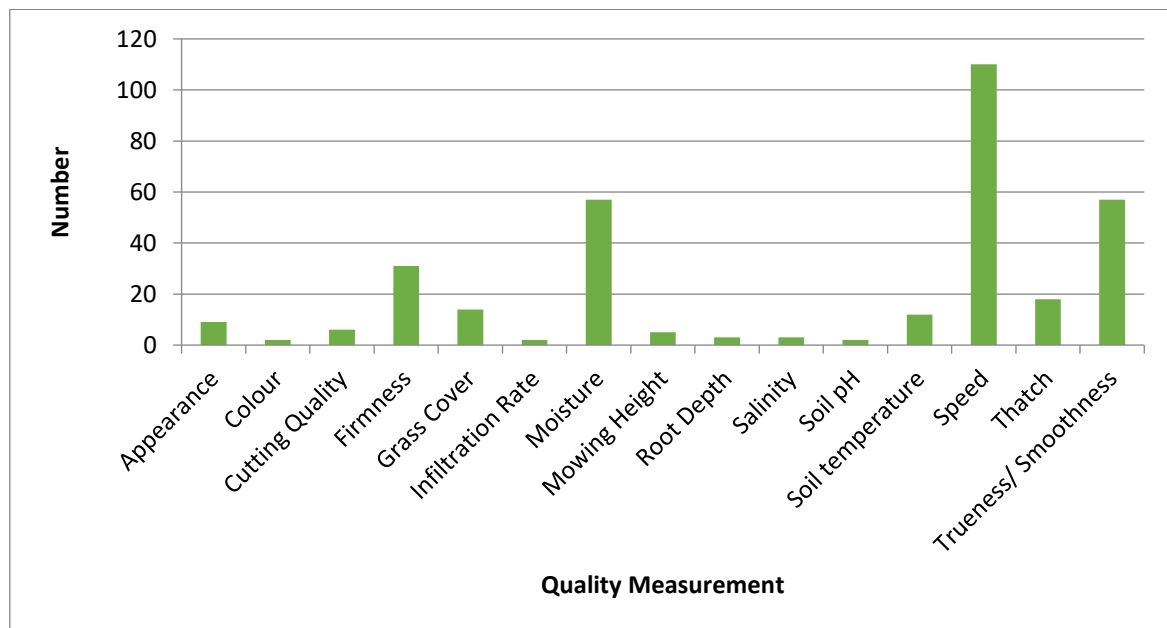
Figure 11   Golf Green Quality Measures

The most frequent reported quality assessment measures used were firmness (9%), moisture content (17%), speed (33%) and surface smoothness or trueness (17%). These concur with the methods most often described in literature (Windows and Bechelet, 2009).

7.8   Section 6 Performance Measurement

The primary focus of this research has been to develop a performance management framework for golf course managers to manage their golf greens and attain a level of efficacy in resources whilst achieving golf green quality in accordance with golfer expectations. There is currently no such comprehensive framework in industry. The final section of the golf course managers' survey asked them if they considered such as framework would be of value to their practice.
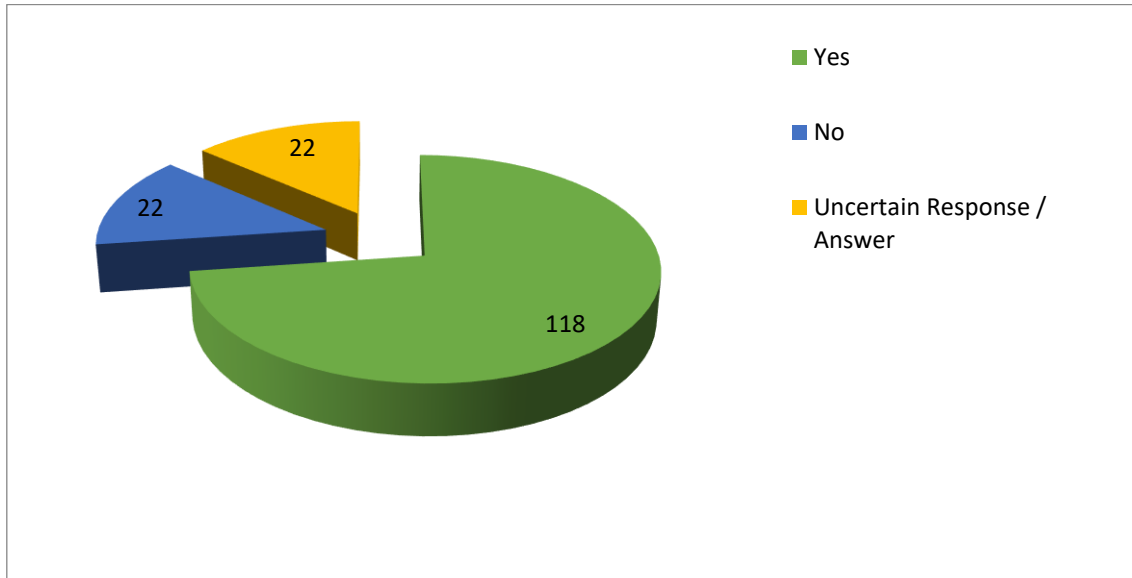
Figure 12   Golf Green Performance Measurement

(No. in each category)

Figure 12 shows the number of responses for each of three category answers. 73% (118 of 162) of respondents answered Question 15 by indicating that they supported the development of a performance management framework and expressed interest in seeing such a framework for their own practice. This supports the focus of this research. 14% were not sure if such a framework was needed and 14% stated that they had no interest.

7.9 Section 2 – The Golf Course Case Study Sites

This section presents the findings from the case study sites involving course manager interviews and onsite golf green quality assessments. The four golf courses are integral to informing the performance management framework which is presented at the end of this section. The data for each framework criterion, (inputs, costs and quality) are presented for 2013 and 2014 on radar graphs as the figurative analytical illustration of where each golf course fits onto the performance management framework.

7.10 Data Interpretation for Golf Green Resource Inputs

In order to effectively assimilate and interpret golf green management data it was first necessary to develop data sets from literature and practice against which that gained from the case study sites could be measured. Tables 13 and 14 below have been formulated specifically for this research and form the benchmark data for this purpose.

7.11 Golf Green Maintenance Practices (Intensity)

Table 14 illustrates the benchmark data for the ranking of golf green maintenance practices according to intensity of practice derived from literature. Cultural practices here are mechanical practices of mowing, aeration, rolling, fertilizer application and topdressing and these are standardised on a scale ordered 1, 5 and 10. Parameters are height of cut (HOC) for mowing; occasions per annum for aeration and rolling; material quantities of nitrogen (N) fertilizer and topdressing per annum. These parameters represent the extremes found in literature. Cultural intensity is seen as high where practices are at the upper limit for each practice. For example, mowing at a cutting height at or below 2mm is the most intensive as is application of N fertilizer at $25g/m^2$ per annum. These are given a ranking of 1 (high cultural intensity). Low cultural intensity (ranking 10) is seen here as the more beneficial objective for management.

Table 13   **Ranking of Golf Green Maintenance Practices (Intensity)**
Defined for this Study

Mowing	Aeration	Rolling	Annual N Fertilizer Application	Annual Topdressing	Cultural Intensity	Score / Ranking
HOC mm	Occ. Per annum	Occ. Per annum	N g/m^2	kg/m^2 per year		
<2mm	>26	>52	>25	>25	HIGH	1
5mm	15	26	16.5	12	MEDIUM	5
>8mm	<4	<1	<8	<6	LOW	10

7.12   Golf Green Maintenance Practices - Operations Times

Table 14 illustrates the benchmark data for operations times for the range of golf green cultural practices considered here. In conducting this research, it has been found that no definitive operations times exist specifically for golf green culture which actually correspond to that found in industry practice. There is a dearth of such material in literature for golf course management. Work times have been assembled from a landscape industry construction guide, "SPON's External Works and Landscape Price Book" (2016 Edition) and one professional body for grounds management, the Institute of Groundsmanship (IOG). Information in "SPON's is biased towards landscape construction and amenity landscape situations. The IOG, whilst a professional organisation representing turf managers, is biased towards sports surfaces other than golf such as football and cricket. This is reflected in its publications and membership, but within its technical pages, on its website (www.iog.org), it does offer some operations times for golf green maintenance. However, it was found that such times were not wholly appropriate to the specific nature of golf green operations being considered here or were not as industry practice and indeed some, such as rolling with IOG data, were absent entirely. The professional association for golf course managers, (the British and International Golf Greenkeepers Association-BIGGA) have no publically available data on operations times for golf green maintenance. To help alleviate this situation primary data on operations times was

acquired in the survey of Golf Course Managers. Figures from all three sources are shown here in Table 14. Given the shortfalls in the data derived from SPON'S and the IOG together with possible reliability issues with course manager data a mean value has been calculated here to provide a more reliable and consistent operations time for determining actual the operations times needed for this research. The data from golf course managers, is based on their experience, as opposed to actual recorded times in accordance with work study method and practice.

Table 14   **Golf Green Maintenance – Operations Times (Extracted from Published References)**

	Hours per 500m^2 Golf Green				Hours for 18 Golf Greens			
SOURCE 1=Course Managers' Survey (2015) 2= Spon's (2016) 3= IOG (2016) **4= MEAN Values**	1	2	3	**4**	1	2	3	**4**
Mowing (Ride-0n)	0.13	0.08	0.22	**0.14**	2.34	1.44	4	**2.60**
Fertilizer Application	0.15	0.83	0.33	**0.43**	2.7	14.94	6	**7.88**
Aeration-Spike/Slit	0.18	0.33	0.44	**0.31**	3.24	5.94	8	**5.72**
Aeration-Hollow core	0.76	0.41	3	**1.39**	13.6	7.38	54	**25**
Topdressing	0.33	0.33	1.33	**0.66**	5.94	5.94	24	**12**
Rolling	0.15	0.33	■	**0.24**	2.7	5.94	■	**4.32**

7.13 Golf Green Maintenance Practices – Intensity - RESULTS

Tables 15 - 18 show the results obtained through interview at the four case study golf courses. The five maintenance practices, for management intensity, are weighted equally to allow an aggregated value **Mean Management Intensity Score** for each golf course will be decided. This is used as the final indicator (numeric score) of management efficacy for plotting on a radar graph with the other performance management framework components. This will allow comparative analysis for this criterion against input costs and green quality.

All tables here present the data from the interviews concurrent at 2013 and 2014. Golf Course Managers confirmed that there had been no changes in their golf green maintenance practices over this period. In order to arrive at one value for maintenance intensity ranking scores for the five practices reviewed have been averaged. This single value can then be used with values for quality and resources costs on the proposed performance framework

Table 15   Golf Course A - Management Intensity

Mowing HOC	Ranking Score		Mean Management Intensity Score (based on criteria defined in Table 13)
4.66 mm	5		
Aeration frequency	Ranking Score		
22	1		
N Application	Ranking Score		
2.4 g/m^2	10		5.2
Topdressing	Ranking Score		
11.11kg / m^2	5		
Rolling (occ)	Ranking Score		
22	5		

Table 16   Golf Course B - Management Intensity

Mowing HOC	Ranking Score		Mean Management Intensity Score (based on criteria defined in Table 13)
3.95mm	5		
Aeration frequency	Ranking Score		
15 + 2	1		
N Application	Ranking Score		
20 g/m^2	1		2.6
Topdressing	Ranking Score		
22.22kg / m^2	1		
Rolling (occ)	Ranking Score		
25	5		

Table 17   Golf Course C - Management Intensity

Mowing HOC	Ranking Score		Mean Management Intensity Score (based on criteria defined in Table 13)
5.11mm	10		
Aeration frequency	Ranking Score		
15	5		
N Application	Ranking Score		
$3.58g/m^2$	10		5.4
Topdressing	Ranking Score		
$13.33kg/m^2$	1		
Rolling (occ)	Ranking Score		
52	1		

Table 18   Golf Course D - Management Intensity

Mowing HOC	Ranking Score		Mean Management Intensity Score (based on criteria defined in Table 13)
4.62mm	1		
Aeration frequency	Ranking Score		
12	5		
N Application	Ranking Score		
$9.3g/m^2$	1		3.4
Topdressing	Ranking Score		
$14.44kg/m^2$	1		
Rolling (occ)	Ranking Score		
29	1		

Tables 15-18 Show different scores for management intensity across the four golf courses. Golf Courses B and D have lower scores mainly because they are using more fertilizer as an input that either A or C. This is a resource which has pronounced effects on grass growth and the potential for environment damage as well as impacting on the management budget. Topdressing, a labour and material cost, are both higher in golf courses B and D.

7.14 Golf Green Maintenance Practices COSTS - RESULTS

Tables 19-22 show the results for the four golf courses costs for labour and materials for the five operations practices under review. Operations frequency (occasions per annum) was obtained from course managers. This is multiplied by the time per occasion, derived from table 15 above, to give the total hours for that operation per year. Labour costs have been calculated from golf course labour budgets and staff working hours to arrive at the hourly rate. Material costs also collated from course managers. All tables here present the data from the interviews concurrent at 2013 and 2014. These costs represent the second input criterion for the performance management framework.

Table 19   Golf Course A – Annual Golf Green Input Costs

	Occ. per annum (A)	Hours per Occ. (B)	Hours per annum (C)	2013			2014		
				Cost per Hr. (Labour) (D)	Material Costs £ (E)	Labour (C x D)	Cost per Hr. (Labour) (D)	Material Costs £ (E)	Labour (C x D)
Mowing	229	2.6	595.4	£12.18		£7252	£12.39		£7377
Fertiliser Application	16	7.88	126.08	£12.18	£1080	£1536	£12.39	£804	£1562
Aeration	22	5.72	125.84	£12.18		£1533	£12.39		£1559
Topdressing	5	12	60	£12.18	£4700	£731	£12.39	£4700	£7434
Rolling	22	4.32	95.04	£12.18		£1158	£12.39		£1178
					£5780	£12210		£5504	£19110
TOTALS				**£17990**			**£24614**		

Table 20   Golf Course B - Annual Golf Green Input Costs

	Occ. per annum (A)	Hours per Occ. (B)	Hours per annum (C)	2013			2014		
				Cost per Hr. (Labour) (D)	Material Costs £ (E)	Labour (C x D)	Cost per Hr. (Labour) (D)	Material Costs £ (E)	Labour (C x D)
Mowing	220	2.6	572	£9.07		£5188	£9.40		£5377
Fertiliser Application	10	7.88	78.8	£9.07	£5000	£715	£9.40	£4000	£741
Aeration	15 2	5.72	85.8 50	£9.07		£778 £454	£9.40		£807 £470
Topdressing	11	12	132	£9.07	£5500	£1197	£9.40	£6500	£1241
Rolling	25	4.32	108	£9.07		£980	£9.40		£1015
					£10500	£9312		£10500	£9651
TOTALS				**£19812**			**£20151**		

Table 21   Golf Course C - Annual Golf Green Input Costs

	Occ. per annum (A)	Hours per Occ. (B)	Hours per annum (C)	2013			2014		
				Cost per Hr. (Labour) (D)	Material Costs £ (E)	Labour (C x D)	Cost per Hr. (Labour) (D)	Material Costs £ (E)	Labour (C x D)
Mowing	190	2.6	494	£13.90		£6867	£13.90		£6867
Fertiliser Application	13	7.88	102.44	£13.90	£2460	£1424	£13.90	£2565	£1424
Aeration	15	5.72	85.8	£13.90		£1193	£13.90		£1193
Topdressing	6	12	72	£13.90	£6000	£1001	£13.90	£7420	£1001
Rolling	52	4.32	224.64	£13.90		£3122	£13.90		£3122
					£8460	£13607		£9985	£13607
TOTALS				**£22067**			**£23592**		

Table 22   Golf Course D - Annual Golf Green Input Costs

	Occ. per annum (A)	Hours per Occ. (B)	Hours per annum (C)	2013			2014		
				Cost per Hr. (Labour) (D)	Material Costs £ (E)	Labour (C x D)	Cost per Hr. (Labour) (D)	Material Costs £ (E)	Labour (C x D)
Mowing	208	2.6	540.8	£10.51		£5684	£10.37		£5608
Fertiliser Application	11	7.88	86.68	£10.51	£3045	£911	£10.37	£3000	£899
Aeration	12	5.72	68.64	£10.51		£721	£10.37		£712
Topdressing	6	12	72	£10.51	£6000	£757	£10.37	£6500	£747
Rolling	29	4.32	125.28	£10.51		£1317	£10.37		£1299
					£9045	£9390		£9500	£9265
TOTALS				£18435			£18765		

In Tables 19-22 there is some variance in total cost between the four golf courses and some between years at the same course. This is most apparent at golf course A where the increase in the hourly rate, due to changes in staffing levels, has had the most significant impact on overall resource inputs. Golf Course A is however, spending much less on fertilizer than courses B, C and D and has actually reduced material expenditure here in 2014. Labour is the most significant resource input cost in all cases, as would be expected, given its role in all operations.

7.15 Data Interpretation for Golf Green Quality

In order to effectively assimilate and interpret golf green quality data it was first necessary to develop a series of ranking scales derived from literature and practice against which measurements from the four golf courses could be aggregated and ascribed a numeric value to be mapped with management intensity and cost indexes.

Table 23 illustrates the ranking scales specifically developed for this purpose and comprises an ordered scale from 1- 10, where 1 is seen as low quality and 10 is high quality. The values here for the five tests of golf green surface and structural quality represent those used in practice and based in literature. Here surface tests of holing out (consistency), speed and firmness are considered high quality where there is a higher value. Golf green structural properties (soil / rootzone properties) are considered high quality when moisture and organic matter levels are low.

Table 23   Ranking of Golf Green Surface Quality

Holing Out (occ.)	Speed (ft.)	Firmness (Gravities)	Moisture (%)	Organic Matter (%)	Ranking Score	Quality Standard
30	12.0	130	0	0	10	HIGH
26	11.0	120	6.25	3.125	9	HIGH
22	10.0	110	12.5	6.25	8	HIGH
18	9.0	100	18.75	9.375	7	MEDIUM
15	8.0	90	25	12.5	6	MEDIUM
11	7.0	80	31.25	15.625	5	MEDIUM
7	6.0	70	37.5	18.75	4	LOW
3	5.0	60	43.75	21.875	3	LOW
0	4.0	50	50	25	2	LOW
	< 4.0	< 50	> 50	> 25	1	LOW

The **Ranking Score** for each golf course is used as the final indicator (numeric score) of golf green quality for plotting on the adopted radar graph with the other performance management framework components. This will allow comparative analysis for this criterion and against input coasts and green quality. Three greens were selected for field testing with the course manager at each of the four courses. The tests were then conducted on each green for speed, putting consistency, firmness, moisture content. Each green had a number of replicate tests to allow means to be calculated for each test and green in accordance with testing protocols for methods used. Soil cores were taken to test for organic matter content. Organic matter was determined by loss on ignition tests in laboratories at Myerscough College. The 2014 visits were conducted to repeat the field testing again on the same greens, to allow for comparison with earlier data and note any significant differences, which were not found. This 2nd testing of greens though allowed confirmation of the methods used and strengthens the field data as two data sets are now available for analysis.

7.16 Golf Green Quality (Field Testing) RESULTS

Tables 24-27 show the results for the four golf courses. Figures indicate the mean for each quality assessment test against its ranking score in accordance with Table 23 above. This single indicator value can then be used with values for management intensity and input costs on the proposed performance framework. All tables here present the data for both 2013 and 2014.

Table 24   **Golf Course A - Golf Green Quality Results**

2013			2014		
Quality Test	Ranking Score	Mean Surface Quality Score	Quality Test	Ranking Score	Mean Surface Quality Score
Mean speed 8.33	6		Mean speed 9.03	7	
Mean Holing Out 7.88	4		Mean Holing Out 8.11	4	
Mean Firmness 110.33	8	6.6	Mean Firmness 87.67	5	5.6
Mean Moisture 16.9	7		Mean Moisture 37	4	
Mean OM 4.53	8		Mean OM 4.53	8	

Table 25   **Golf Course B - Golf Green Quality Results**

2013			2014		
Quality Test	Ranking Score	Mean Surface Quality Score	Quality Test	Ranking Score	Mean Surface Quality Score
Mean speed 10.66	8		Mean speed 11.02	9	
Mean Holing Out 8.55	4		Mean Holing Out 7.89	4	
Mean Firmness 83.55	5	6.4	Mean Firmness 60.94	3	5.4
Mean Moisture 14.84	7		Mean Moisture 42.70	3	
Mean OM 3.17	8		Mean OM 3.17	8	

Table 26   **Golf Course C - Golf Green Quality Results**

2013			2014		
Quality Test	Ranking Score	Mean Surface Quality Score	Quality Test	Ranking Score	Mean Surface Quality Score
Mean speed 8.27	6		Mean speed 8.37	6	
Mean Holing Out 7.33	3		Mean Holing Out 7.33	3	
Mean Firmness 71.16	4	5.6	Mean Firmness 98.33	6	5.4
Mean Moisture 14.17	7		Mean Moisture 33.65	4	
Mean OM 5.01	8		Mean OM 4.46	8	

Table 27   Golf Course D - Golf Green Quality Results

2013			2014		
Quality Test	Ranking Score	Mean Surface Quality Score	Quality Test	Ranking Score	Mean Surface Quality Score
Mean speed 9.26	7	6	Mean speed 9.83	7	5.8
Mean Holing Out 8.33	4		Mean Holing Out 8.33	4	
Mean Firmness 96.66	6		Mean Firmness 103	7	
Mean Moisture 31	5		Mean Moisture 38.07	3	
Mean OM 4.47	8		Mean OM 4.42	8	

Tables' 24-27 show little significant difference in golf green quality between courses and all have deteriorated in green quality in the second year of measurement. On the scale devised for this (Table 23) all courses can be considered of **medium** quality overall. None are especially poor nor outstanding for golf green quality when assessed with multiple methods (Table 8).

7.17 Comparative Course Management (Golf Green Data) and the Performance Management Framework

The data from the above tables for maintenance intensity, cost and quality have been plotted onto analysis framework graphs in Figures 13 and 14 for both years of primary data collection (Tables 28 and 29).The units in these tables are unit free arbitrary indices used here to enable the 3 performance measurement factors to be plotted onto radar graphs. In these graphs UGC represents a utopian golf course where costs are low, quality is highest and inputs are low. The graphs clearly illustrate how the case study golf courses compare with each other and the hypothetical case in each year.

Table 28   Overview of Data Collected for 2013

	Quality	Management Efficacy	Annual Cost £	Cost Index (£ x 10-4)
Golf Course A	6.6	5.2	17990	1.79
Golf Course B	6.4	2.6	19812	1.98
Golf Course C	5.6	5.4	22067	2.20
Golf Course D	6	3.4	18435	1.84

Figure 13   Radar plot comparing data sets for four observed courses (GC1-4) measured in 2013 against a hypothetical Utopian Golf Course (UGC).

Table 29   Overview of Data Collected for 2014

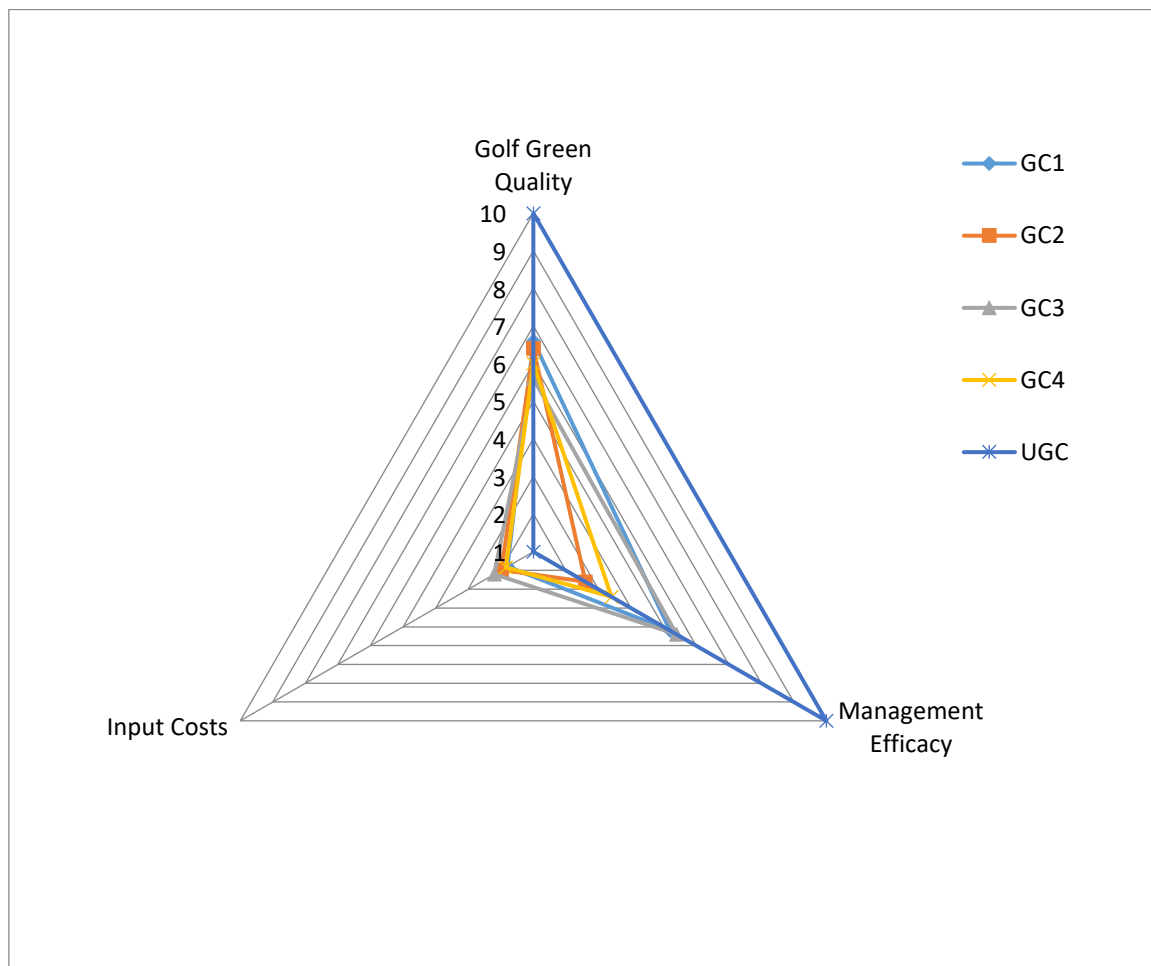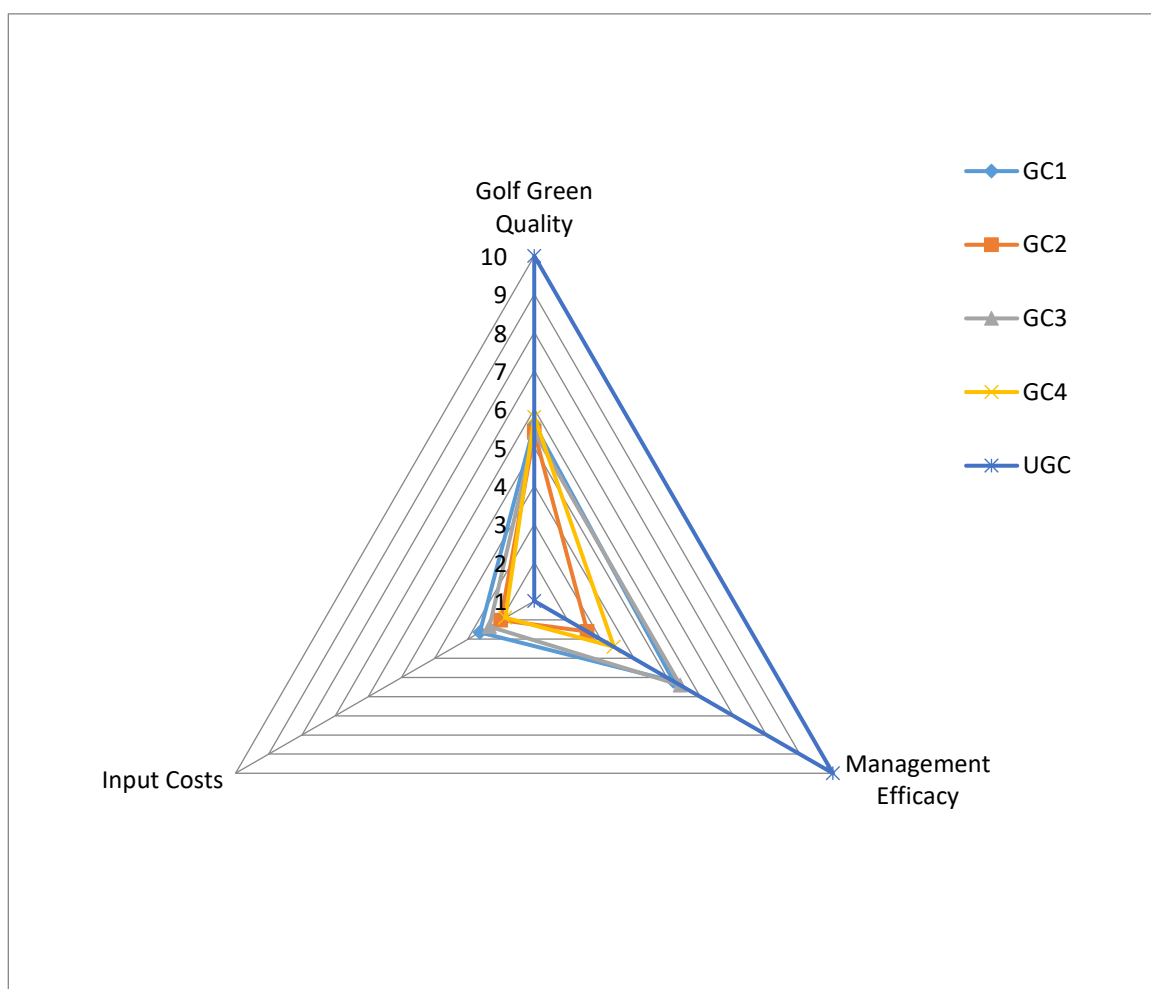|	Quality	Management Efficacy	Annual Cost £	Cost Index (£ x 10-4)
Golf Course A	5.6	5.2	24614	2.64
Golf Course B	5.4	2.6	20151	2.01
Golf Course C	5.4	5.4	23592	2.35
Golf Course D	5.8	3.4	18765	1.87

Figure 14   Radar plot comparing data sets for four observed courses (GC1-4) measured in 2014 against a hypothetical Utopian Golf Course (UGC).

The performance management framework as shown in figures 13 and 14 is not proposed as a means of comparing golf courses although the framework does allow for this. In practice it would be difficult to access another's courses' input and quality data for mapping. What is important is what managers do with this information in their own practice and for their greens. Comparison is made here to illustrate how the performance management framework works. It is done to show how results can be mapped on a matrix radar graph. It is interesting to note though that in 2014 Golf Course C achieved the same index ranking for quality as Golf Course B but with greater management efficacy. This supports the proposition of Isaac (2012) and others that golf greens can be maintained with less inputs with no loss in surface quality. This is the ideal scenario for management. Less inputs is more cost effective but quality must still be maintained or even enhanced. Over the two years Golf Courses B and D were the worst performing in terms of management efficacy and golf green quality. Both these courses apply more fertilizer and topdressing that the other courses and it is this practice which may offer greatest opportunity for operations improvement and efficiency savings.

7.18 Summary Findings

The survey of golf course managers supported many findings in literature, especially concerning the current state of the industry. It confirmed the key operations data for case study investigation. It was also critical in developing interpretative scales for analysing case study data and informing the performance management framework. Respondents were experienced in greenkeeping operations (93% had between 11 and 40 year experience) as well as golf course management (50% had between 11 and 30 years' experience). The majority of respondents, when answering the question about their own philosophical approach to greenkeeping, stated that they adopted an historical approach to greenkeeping. This in literature implies a low input approach to greenkeeping. Respondents in identifying the most significant issues to their practice reported decreases in operations budgets, decreasing staff levels and the weather. Falling golf club budgets, decreased demand for golf and increasing player expectations, identified as the main issues for golf clubs further corroborate the difficulties for both operations managers and their organisations identified earlier in literature. There is a clear link here from decreasing play, the ensuing reduced income from players and the budget available to the course manager. The challenge of meeting increased player expectations for quality with a reduced budget is clearly evident.

In planning and organising work course managers are most occupied with organising greenkeeping operations for course maintenance and development. Survey respondents

identified mowing, fertilizer application, topdressing and aeration as the most important cultural practices for golf green maintenance. A confirmation of that found earlier in literature. Planning work is quite simplistic and frequently based on lists of operations to be completed that week or month. These may or may not be in a written format and are communicated to staff via notice boards or in meetings. Some managers do plan around club events such as tournaments or competitions when scheduling work however. For others, adopting a reactive approach, the weather is the key determinant in scheduling operations. There is no evidence in practice, from this research, of managers adopting more formal scheduling and monitoring tools such as GANTT charts in planning and communication operations. Managers provided times for operations, based on their own experience, but there is no evidence from either practice or literature that this aspect of work study is used in managing operations for resource efficacy.

The majority of respondents in the survey (73%) confirmed that they are collecting data for measuring golf green performance. Measures of quality used most frequently included green speed, surface trueness/smoothness, moisture and firmness. This is done to monitor performance of greens over time and largely based on methods promoted by the STRI and others but there is no evidence in practice or literature as to how such measures are critically assessed with resource inputs. Course managers are monitoring golf green performance but not resource inputs and it is these which are becoming increasingly strained by declining budgets.

The collection of resource input data and golf green quality measures was essential in developing and reporting the performance management framework seen here in Figures 13 and 14. In constructing base operations times to use with golf green cultural practices the times given by course managers in the survey were based on their own experience and are not based on actual site measurement with work study methods. They are not the same as either literary source but neither of those are equivalent either. The use of a mean value from three independent sources was the most viable option here in the absence of onsite measurement. It is obvious from both literary and survey sources there is variability in such data for golf green maintenance which is not helpful for the operations (course) manager in resource planning. Labour is the most significant cost at the case study sites for golf green maintenance but managers at these sites were unaware of individual operation costs , only overall staff costs, and did not plan or organise work in this way. In operations fertilizer and topdressing were the main material costs for golf greens.

Table 30 shows the results from the four case study sites for quality scores and annual costs and differences in these for the years 2013 and 2014. All golf courses have reduced scores for golf green quality for 2014 which may be due to onsite prevailing weather conditions at the time as there was no change in cultural operations in greens maintenance. Golf Course A was the best overall golf course in 2013 for golf green quality and costs as well as having the second best score for management efficacy. The increase in costs, 37%, at Golf Course A in 2014 was due to an increase in hourly staff rates together with increased expenditure on fertilizer. These cost increases should be considered further by the clubs management, any decrease in golf green quality aligned with increase in costs is a cause for concern. This is not the desired outcome in operations management for resource efficacy.

Table 30   Golf Green Costs and Quality

	Quality Score			Annual Cost £		
	2013	2014	Difference	2013	2014	Difference
Golf Course A	6.6	5.6	1.0 (-15%)	17990	24614	6624 (+37%)
Golf Course B	6.4	5.4	1.0 (-16%)	19812	20151	339 (+1.7%)
Golf Course C	5.6	5.4	0.2 (-4%)	22067	23592	1525 (+7%)
Golf Course D	6	5.8	0.2 (-3%)	18435	18765	330 (+1.8%)

7.19 Industry Validation of the Performance Management Framework

The results from the golf course manager's survey indicate that there is industry support for a performance management framework for golf green management. As shown in Figure 12 73% of respondents stated that such a framework would be a valuable component in their management practice and would be interested in adopting such. The following responses were submitted in Question 15 of the survey:

- *"any innovation to assist in maximising resources and planning would be an advantage with the challenges in reduced resources"*
- *"it should produce a more scientific and quantifiable based approach and understanding to managing greens, green performance and help plan scheduled inputs"*
- *"It would give a good indication as to what needs to be altered to improve quality, a good tool to demonstrate the importance of operations to golf club committees and players"*

Chapter 8   Conclusion and Recommendations

8.1   Golf Green Maintenance

In reviewing literature for golf green management there is general consensus about the operations needed for maintenance. There are few specific parameters for these operations as variation in golf course type, physical and geographical factors and obvious variations in local climate and environmental conditions mean that golf course managers must decide specific maintenance regimes for their own golf greens and courses. There is variation in recommendations but most notably between UK and US sources (Table 3). Research conducted confirmed generic practices for greens maintenance in industry was in accordance with principles in literature. The golf course managers' survey reaffirmed those used for assessment of golf green maintenance at the four case study sites. The different intensity of golf green maintenance practices allowed the development of ordered scales against which intensity of maintenance could be measured in practice. Allowing for variation in sites it is proposed that high inputs, e.g. levels of fertilizer input, should be (and have been scored) highly (negatively) in the sense that such inputs are costly to both management and environment. This is in accordance with recent literature (Isaac 2007; Ormondroyd, 2007) concerning sustainability and golf course management. An input not measured within this research was that of irrigation. Irrigation is a highly variable practice as it is determined largely by prevailing weather conditions. In practice for the four case study sites, it was not possible to accurately determine water usage application rates or total usage. Course managers at these sites utilised automatic irrigation frameworks and did not accurately record how much had been applied. Some used mains supply which was included within a total amount of water used at the club. Irrigation was not identified as one of the most important golf green operations in the course managers' survey.

8.2   Operations Management

Golf Course managers are operations managers and responsible for directing and controlling maintenance inputs for golf green and course maintenance in a way which optimises such resources and achieves customer satisfaction. As Cobham (1990) describes for landscape managers, they are expected to achieve cost-effectiveness and thereafter improve on this. In planning operations most course managers did so with , albeit rather simplistic, pre-planned schedules with club tournaments and competitions often forming the key dates around which

such are organised. This is not unexpected. A surprise from the survey was the number of course managers who had no pre-determined plan and reacted to weather conditions as a driver for operations. Whilst weather affects the timing of specific operations it is still necessary to conduct key practices and have a plan. There is a danger that some may be missed or have to be postponed with possible adverse effects to the surface. Golf course managers are not utilising scheduling and monitoring systems such as those described by Brown et al (2001) or Slack, Brandon-Jones and Johnston (2013) in planning and monitoring operations. Such systematic approaches afford the best opportunity for managers to identify areas where trade-off decisions may be needed to achieve overall organisational objectives (Cockerham and Van Dam, 1992; Slack, Brandon-Jones and Johnston, 2013) eliminate waste and reduce costs. Further, structured operation plans allow for more effective monitoring and control of planned activities in a timescale which allows managers to make an informed response. Cockerham and Van Dam (1992) and others have previously identified the lack of research in operations management for turfgrass management. There is little evidence of any such research in the literature since their writing. This research also highlights several areas of operations management that would be useful for industry practice. As already mentioned, work study and operations times need further study but so do aspects of resourcing and planning to optimise resources.

8.3   Resource Input Costs

This research has been conducted in a time when golf is a declining sport with falling memberships and rounds of golf at many clubs. Members have become more demanding in their expectations from the course and quality of surfaces as seen in surveys conducted by Syngenta (2013) and England Golf (2014). This is confirmed in the golf course managers' survey as did the issue of budgets – a fall in which is a direct effect of the latter. It is this situation that course managers are having to operate with increasingly tight budgets (Vavrek, 2010) but still meet or exceed player expectations. The performance management framework proposed here can assist managers in identifying how resources are translating into quality surfaces and in identifying where operations can be adapted to suit resource and finance availability. In determining resource costs one must know both times for maintenance operations and labour costs (Slack, Brandon-Jones and Johnston, 2013). Information for both is lacking in literature, especially in this context. Existing literature is focused mainly on amenity landscape management such as that by Cobham (1990) and Parker (1989). Research here has proposed operations times for those reviewed and are appropriate in the development of the performance management framework proposed but this is an area where

little published research exits. This would be a valuable future research project in itself. The course managers' survey provided valuable data but is based on their own experience, which, whilst reflective of industry practice, could be questioned for accuracy and reliability. Future studies in this capacity should adopt a more rigorous work study approach to establish firm operations times. Course managers at the four sites did not know their own hourly rates for labour but only overall costs. Hourly rates were calculated for this thesis from annual labour costs and working hours including overtime for weekend working. It was found that course managers generally know total costs but have little, if any, knowledge of individual costs for individual practices for golf greens. Such costs are subsumed in overall course management figures. A cost not considered in this research also is that for machinery. Again, machinery costs were only available for overall budgets and too complex to breakdown for solely greens maintenance without a further more detailed study. One problem would be apportioning the cost of a particular machine solely to golf green maintenance. A greens mower might be straightforward but what of a tractor utilised for a range of maintenance practices? Only a more detailed study recording all operations and times with all costs known would allow such analysis.

8.4   Golf Green Quality

Golf green quality assessment has become more commonplace in recent years with developments in technology and interest from both greenkeepers and players in surface quality. The golf course managers' survey confirmed that the majority were measuring golf greens for quality using a range of quality measures. Again, the survey ratified the use of those methods adopted for greens assessment at the four case study golf courses of surface firmness, moisture and organic matter content, speed and surface smoothness. There are, of course, other indicators of surface quality (IOG,2003 :Dury,1997), but these represent those promoted by the UK's industry's leading research organisation, the Sports Turf Research Institute and are supported by Golf's Governing Body , The R&A , as being the most significant in golf green management (Windows and Bechelet, 2009; Isaac,2012). In undertaking such assessments more frequent measurement that that undertaken for this research should be completed for greater reliability and year round performance. The research was restricted by time and course access but this would not be the case for most course managers. Nevertheless, as with resource inputs and practices reviewed it was sufficient to inform and test the performance management framework developed in this research. The data collected for maintenance costs (labour and materials), together with maintenance intensity and golf green quality can, and have been reported and presented within the performance management framework.

8.5 A Performance Management Framework for Golf Greens

All operations need some kind of performance management system as a prerequisite for improvement (Slack, Brandon-Jones and Johnston, 2013).This research proposes a unique and innovative performance management framework for golf course managers to enable them to better manage their golf greens as shown in figures 11 and 12. The aim is to arrive at an optimum level of quality with the minimal level of input and thereby reduce costs. Such an approach can positively benefit golf course sustainability and reduce negative environmental impact from maintenance practices. In considering existing performance management frameworks, it has been found that none provide a specific tool that could be used to model, control, and monitor and improve the activities at the operations level (Ghalayini, et al.1996). Further in the review of literature it has been found that no such framework exists either generally or specifically within this research subject area for use at an operations level. The adopted research methodology and methods have produced a viable framework for Golf Course managers to effectively measure their resource inputs and assess the impact of these on golf green quality. Therefore this research fills the gap in knowledge identified from professional experience, verified in the literature and satisfied through site measurement and survey. The framework has ramifications for professional practice to the extent that it allows golf course managers to critically assess their own operations management practises and identify where possible efficiency savings in resource inputs can be made. Although the framework proposed can be used to compare golf courses directly , irrespective of landscape typology, green construction, maintenance regime or desired quality for that course., in practice it will be most useful for monitoring one's own management practice. Golf Course managers can decide their own practices, inputs and quality standards.

Mapping the key parameters of quality, costs and inputs in a benchmarking radar chart has been shown to reflect the efficacy of golf green management in a way that allows stakeholders to identify and adjust operation variables. A performance management framework for golf greens has industry has industry support as evidenced in this research. This performance management framework satisfies the gap in knowledge that has been identified in literature and in practice. The survey of UK Golf Course Managers was conducted with the support of the British and International Golf Greenkeepers Association (BIGGA). Such organisations and industry forums may afford the opportunity to promote this framework to Golf Course Managers.

8.6 Achievement of Research Aim and Objectives

Table 31 summarises the key conclusions from this research.

Table 31 **Summary of Achievement of Research Objectives, Key Research Question and therefore the Aim of this Research**

Objective 1 Critically review existing golf green management theory and practice to verify a gap in knowledge perceived through professional experience.	There is variance in practice with golf green culture as this is dependent upon both site constraints and factors but also the course manager's approach or philosophical stance to greenkeeping. The majority of survey respondents favoured a "traditional" approach based more on their experience than a scientific analytical approach. Golf Course managers are collecting performance data for their golf greens but there is no objective analysis of this with inputs and their management.
Objective 2 Critically review existing operations and performance management theory and practice to establish new ways to challenge and enrich existing golf green management strategies.	Golf Course managers are operations managers and can learn from operations management theory Most work is needed in the field of work study where this can contribute significantly to effective resource management. Controlling costs needs accurate data and labour is the dominant cost in golf green management. There is little or no published research in the golf course management literature focusing on operations management.
Objective 3 Identify the primary factors and inputs that affect golf green quality and playing performance to enable new golf green management strategies.	The primary management practices of mowing, fertilizer application, aeration and topdressing are the key practices in maintaining golf greens and impacting upon their quality. Irrigation is undoubtedly important but one which is more complex to quantify and manage in input terms. Managing operations effectively provides the most scope for improving golf green quality.
Objective 4 Determine the parameters that influence resource optimization and therefore enable golf course managers to identify strategies that positively affect the efficacy of lean-input golf green management.	It is theoretically and practically possible to achieve good quality greens with lower inputs. It is the course manager's decision making, allocation and prioritization of resources in operation management that most significantly affects this. Golf Course managers need to measure all inputs at the operations level in order to fully determine their effects on playing surface quality. Resource availability, utilization are significant.
Research Question How can golf greens be better managed for playing quality performance and optimum resource efficiency?	All resource inputs need to be recorded together with quality assessments of green performance. Critical comparative analysis of these together can inform decision making identifying areas where efficiencies in inputs and costs can be made. Golf course managers should review their own operations management processes and identify where these can be improved. This needs to be done with the setting or their own performance targets for golf green performance which are congruent to the player expectations at that site.
Aim To develop a performance management framework that enables golf course managers to target better use of resources in golf green maintenance strategies and achieve optimal surface performance quality.	This research proposes a unique and innovative performance management framework for golf course managers to enable them to better manage their golf greens. It identifies indices of maintenance Inputs, costs and golf green quality as key parameters and 73% of respondents validate this model by confirming its need in practice.

8.7   Recommendations for Stakeholders

Recommendations for golf course stakeholders including golf course managers, club managers and future research emanating from this research are:

Golf Course Managers:

- Adopt this performance management framework for own golf course and implement over 2 or more years with more measurements of golf green quality.
- Review own operations management practices to identify areas for efficiency savings.
- Identify all golf green resource inputs and costs including machinery and irrigation.
- Assess own planning and organisational methods utilised in managing resources.

Golf Clubs (Senior Managers):

- Agree quality standards to be achieved for golf greens with Course Managers and ensure these are communicated to members.
- Review budgets for club management prioritising the golf course.
- Identify own operations management efficacy.
- Ensure strategic aims and objectives are congruent with operation ones.

Recommendations for Future Research

- A detailed case study utilising the performance management framework and incorporating detailed assessment of all resource inputs including machinery and irrigation costs.
- A detailed study of golf course managers' practice to determine if they are actually implementing a reduced inputs approach in line with a traditional / sustainable philosophy to greenkeeping.
- Work and method study research to establish operations times for golf green maintenance (and other areas of the golf course) practices.
- Development of objective quality standards for other areas of the golf course.

Chapter 9

Reflection of the Professional Doctorate (DProf) Experience

My journey began when I read the leaflet promoting the doctorate programme at ARU. The course flyer promoting the programme at that time asked:

- Do you want to conduct relevant professional research whilst in full time employment and obtain a doctorate?
- Do you want to make an impact in your professional practice?
- Do you want to engage in personal development at the highest level?

My response to all of these was unreservedly yes, all of these questions were exactly what I was thinking at that time in my career. At that time I was managing a small team of staff, at Myerscough College, all engaged in teaching sports turf at various academic levels. I was highly conscious that for our undergraduate provision we should be conducting research to inform teaching and also raise our academic profile. My motivation for commencing with the doctorate therefore was twofold, firstly to achieve my own professional aspirations and, secondly to develop research in my discipline at my employment. The flexibility and work based nature of the Professional Doctorate fitted exactly with my employment and interests

The journey has not been easy, there have been many personal and professional issues to cope with along the way. I have even changed jobs to complete this doctorate. With hindsight this was a good move and one I should have made much earlier. I am still engaged in teaching but have relinquished management responsibilities to focus on research at my workplace. Accepting criticism was not easy, working in academia I thought I had completed my educational development and was a competent writer. Such criticism is needed though, and I now recognise its importance in writing and conducting research at this level. This probably was the single, most difficult challenge for me personally as I found it difficult to not take this personally. I now believe it is the most valuable lesson I have learned from the professional doctorate.

Undertaking the Professional Doctorate has benefitted me personally as well as having a profound effect on my career. Attending and speaking at ARU and industry conferences has greatly improved my confidence and ability as a speaker. The culmination of this was my attendance at the 5th European Turfgrass Society Research Conference in Portugal, 2016

where I was able to present my research to industry peers and researchers. As a result I was able to publish a paper on my research "Managing golf greens: aligning golf green quality with resource inputs" in October, 2016 in the peer reviewed journal, Urban Forestry and Urban Greening. Both these were personal firsts and highly satisfying achievements for me. An even more momentous moment for me personally, was being elected as ETS President at the end of the 2016 Conference to serve for the next four years. In this capacity I am managing the affairs of the society with my team and will be organising the 2018 ETS Conference to be held in the UK for the first time in its history.

The research undertaken for the Professional Doctorate has contributed directly to a new Master's Degree at Myerscough College – MA Sustainable Golf Course Management. This fully Online Course has now recruited its first students and has been supported by The R&A which is very satisfying for me personally. The contacts and expertise I have developed have also raised my own profile in the industry and I am an now in negotiation with two international turf supply companies to sponsor two Masters by Research (MRes) students at Myerscough college – both or which I will be actively managing.

To conclude this doctorate has been the hardest thing I have ever done professionally but as it turns out, the most rewarding and the one which has opened up most doors for my future.

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11   Appendices

Appendix 1 - Golf Course Managers Questionnaire

<u>ABOUT YOU</u>

1   What is your current position? Please state your job title.

2   How many years have you worked in golf Greenkeeping?

3   How many years have you been employed as a Course Manager/ Head Greenkeeper?

4   Please state your highest academic qualification in Sportsturf or Greenkeeping (e.g. BSc, FdSc, HND, etc.)

<u>DRIVERS</u>

5   What factors impact upon your management of the golf course and how you maintain it?

6   How would you describe your philosophy or approach to golf greenkeeping?

7   What do you think are the main issues affecting golf Greenkeeping today? Please identify in order your top 3:-

       1_____

       2_____

       3_____

<u>DECISION MAKING</u>

8   What operational decisions do you make as a golf course manager?

9   How do you action these decisions?

10 How do you plan and organise golf greenkeeping operations?

<u>MANAGING GOLF GREENS</u>

11 Please identify and rank in order of their significance your top 5 most significant practices for maintaining golf greens?

1_____

2_____

3_____

4_____

5_____

12 For the operations listed below please state how long in Minutes you believe each one takes for one green (assume 500m2):

- Mow (ride-on mower)   _____
- Apply fertiliser (pedestrian applicator)   _____
- Top dress   _____
- Core aerate (with core removal)   _____
- Spike or slit or sarrel roll   _____
- Roll (turf iron)   _____

Golf Green Quality

13 Do you (or your staff) measure greens for quality?   Yes / No

14 If you answered yes to Q13 please identify what measurements, how they are taken and how often?

Performance Measurement

15 We are developing a system to align resource inputs with green quality. Would you value such a system? If so please state why. If not, please describe what you use instead.

Appendix 2 Ethics Approval Letter

Project Number: FST/FREP/12/321

Project Title: *Managing golf greens: aligning golf green quality with resource inputs.*

Principal Investigator: Stewart Brown

Thank you for supplying revisions to your application for ethical approval, as requested by the Faculty Research Ethics Panel (FREP) following its meeting on 13th June 2013.

I am pleased to inform you that your application has been approved by the Chair of the Faculty Research Ethics Panel under the terms of Anglia Ruskin University's *Policy and Code of Practice for the Conduct of Research with Human Participants.* Approval is for a period of three years from 16th August 2013.

It is your responsibility to ensure that you comply with *Anglia Ruskin University's Policy and Code of Practice for Research with Human Participants,* and specifically:

- The Participant Information Sheet and Participant Consent Form should be on Anglia Ruskin University headed paper.
- For online surveys it is recommended that the researcher turns off the IP logging software to ensure secure communication between the survey taker and server.
- The procedure for submitting substantial amendments to the committee, should there be any changes to your research. You cannot implement these changes until you have received approval from FREP for them.
- The procedure for reporting adverse events and incidents.
- The Data Protection Act (1998) and any other legislation relevant to your research. You must also ensure that you are aware of any emerging legislation relating to your research and make any changes to your study (which you will need to obtain ethical approval for) to comply with this.
- Obtaining any further ethical approval required from the organisation or country (if not carrying out research in the UK) where you will be carrying the research out. Please ensure that you send the FREP Secretary copies of this documentation.
- Any laws of the country where you are carrying the research out (if these conflict with any aspects of the ethical approval given, please notify FREP prior to starting the research).

- Any professional codes of conduct relating to research or research or requirements from your funding body (please note that for externally funded research, a project risk assessment must have been carried out prior to starting the research).
- Notifying the FREP Secretary when your study has ended.

Information about the above can be obtained on our website at:

http://web.anglia.ac.uk/anet/rdcs/ethics/index.phtml/ and or
http://www.anglia.ac.uk/ruskin/en/home/faculties/fst/research0/ethics.html

Please also note that your research may be subject to random monitoring by the Committee.

Please be advised that, if your research has not been completed within three years, you will need to apply to our Faculty Research Ethics Panel for an extension of ethics approval prior to the date your approval expires. The procedure for this can also be found on the above website.

Should you have any queries, please do not hesitate to contact me. I would like to wish you the best of luck with your research.

Yours sincerely,

Sue Short

Secretary to the Faculty Research Ethics Panel (FREP)
Faculty of Science and Technology
MAR325
Tel: 0845 196 3927
Email: FST-Ethics@anglia.ac.uk

cc.   Dr Alan Coday

Appendix 3 ARU Ethics Forms

Anglia Ruskin University

Cambridge & Chelmsford

Date

To Potential respondent

By e-mail

Chelmsford   Campus
Bishop   Hall   Lane
Chelmsford   CM1   1SQ
www.anglia.ac.uk

Supervisor's Direct Dial 0845
196 3944
E-mail
alan.coday@anglia.ac.uk

DProf Research Project

Participant Information Sheet

Section A: The Research Project

Title of project: Managing Golf Greens: aligning golf green quality with resource inputs.

1.   Purpose and value of study:

The study seeks to investigate how levels of resource input utilised for golf green maintenance impact on golf green performance and whether optimum benchmarks can be established for managing such resources to achieve best possible quality surfaces with reduced or minimalist inputs.

2.   Invitation to participate

The researcher invites interested golf course managers to participate in this study. The researcher would like access to your own golf greens for onsite testing of surface quality components as well as access to management data regarding own practices and methods for golf green management.

5

3.   Who is organising the research

The research is organised by **Stewart Brown - A research student of Anglia Ruskin University and staff member at Myerscough College.**

4.   What will happen to the results of the study

The results from the study will be used in the production of a thesis for the researchers Professional Doctorate qualification. It is envisaged also that papers will be produced for relevant industry and academic publication. The researcher sees no conflict of interest within this research project and is only seeking to ascertain actual practice within industry.

5.   Source of funding for the research.

The research is sponsored by RansomesJacobsen and supported by Myerscough College

6.   Contact for further information:

This is provided above in this Participant Information sheet

Section B: Your Participation in the Research Project

1.   Why you have been invited to take part

Access is needed to golf courses for greens testing and golf green management data. Your golf course is in the area for this study and fits the typology of course decided by the researcher.

2.   Whether you can refuse to take part

You are under no obligation to take part in this research project whatsoever.

3.   Whether you can withdraw at any time, and how
Should you wish to withdraw at any time you can do so by contacting and informing Stewart Brown.

4.   What will happen if you agree to take part (brief description of procedures/tests)

Site visits to conduct greens testing on your golf course will be arranged with you in advance. Tests for greens will include green speed, smoothness, firmness and moisture levels. The researcher will also need to conduct interviews with you to collect management data about green maintenance. This will include such details as fertiliser inputs, mowing heights, frequencies, aeration and top dressing practices etc.

5.   Whether there are any risks involved (e.g. side effects from taking part) and if so what will be done to ensure your wellbeing/safety

There are no anticipated risks to you in taking part in this research.

6.   Agreement to participate in this research should not compromise your legal rights should something go wrong

7.   There are no special precautions you must take before, during or after taking part in the study

8.   What will happen to any information/data/samples that are collected from you:

The results and data sets collated from you site will be made known to you and interpreted for you to use as you wish. This management data and evaluation should allow you the opportunity to critically reflect on you own management practices.

9.   Whether there are any benefits from taking part

It is envisaged that results will enable you to reflect and review your own management practices allowing greater efficiency in resource allocation for golf green management and enhanced golf green quality.

10.   How your participation in the project will be kept confidential

Your name and golf course will be kept anonymous and not revealed in any publically available documentation. Results are for researchers own use and will not be shared with others using any identifying name or other feature. Results will be kept securely.

Supervised by: Alan Coday PhD BSc FIWSc
Senior Lecturer
MSc Conservation of Buildings Course Leader.

ETHICS REVIEW CHECKLIST FOR RESEARCH WITH HUMAN PARTICIPANTS

Date 08.12.10. V1.0

Name:	Stewart Brown	**SID:**	0314568

Title of Research Project:	Managing Golf Greens: aligning golf green quality with resource inputs.

Faculty:	Built Environment	**Supervisor(s):**	Dr Alan Coday

Type of research: *Tick all that apply*	☐ Undergraduate ☐ Taught postgraduate ☑Research degree ☐ Member of staff ☐ Other

If you require this checklist or any of the documentation in an alternative format (e.g. Braille, large print, audio or electronically) please contact Julie.Scott@anglia.ac.uk

You need to consider ethics for all research studies. Research is defined in the UREC (Research Ethics Sub Committee) Policy and Code of Practice for the Conduct of Research with Human Participants on Page 5. Please refer to:

http://www.anglia.ac.uk/ruskin/en/home/central/rds/services/research_office/research_degrees/ethics.html

Please complete this mandatory Ethics Review Checklist for all research applications. This is to ensure that you are complying with Anglia Ruskin University Policy and Code of Practice for the Conduct of Research with Human Participants.

All research applications are dealt with in the same way. **There is no distinction between undergraduate, taught Masters, research degree students and staff research.**

For research involving animals, please complete the Animal Ethics Review Checklist to determine your course of action.

This checklist should be completed by the Principal Investigator or the student in consultation with his/her supervisor.

If your study requires a Risk Assessment, this must be submitted with your application. Please contact Paul.Varley@anglia.ac.uk **for further information.**

<u>**CHECKLIST**</u>

	YES	NO
1. Does your research involve human participants? (including observation only)	☑	☐
2. Does your research involve accessing personal, sensitive or confidential data?	☑	☐
3. Does your research involve 'relevant material' as defined by the Human Tissue Act (2004)?	☐	☑
4. Does your research involve participants who are 16 years and over who lack capacity to consent and therefore fall under the Mental Capacity Act (2005)?	☐	☑
5. Will the study involve NHS patients, staff or premises *or* Social Services users, staff or premises?	☐	☑

If you have answered **NO** to *all* the above questions, you do not need formal ethics approval. You do, however, need to submit this checklist signed and dated to the relevant Faculty Research Ethics Panel (FREP) Administrator prior to starting your research.

If you have answered **YES** to *either* or *both* Questions 1 and 2, you need to submit an application, including this checklist, to your FREP.

If you have answered **YES** to Question 3, you need either to submit your application to your FREP or an NHS Research Ethics Committee (REC), even if the study does not involve the NHS. Please seek further advice if you are unsure about which committee it needs to be submitted to.

If you have answered **YES** to Question 4, you need to seek approval from an NHS REC, even if your study does not involve the NHS.

If you have answered **YES** to Question 5, you need to obtain approval from:
a. Both an NHS REC and the NHS Trust(s) where you are carrying the research
out (RandD Management Approval) *or*
b. The Local Research Governance Group (Social Services).
Please note that you must send a copy of the final approval letter(s) to:
Beverley Pascoe, RESC Secretary, Research, Development and Commercial Services.

Additional information:

Applicant's signature:		**Date:**	28/04/13

Supervisor's signature:		**Date:**	17 May 2013

All materials submitted to RESC/FREP will be treated confidentially.

Subject of assessment (May be an activity, hazard or relate to an individual)		RA conducted by.	Date.	RA ref. no.
Title of Research Project - Managing Golf Greens: aligning golf green quality with resource inputs.Venue XXXX Date of Visit XXX		NAME Stewart Brown	RA Date 28 April 2013	

List the risk/s involved or describe the hazard	
Site Entry	**Risk of unauthorised entry.**
Lone working on site	**Risks from wet/rough ground and trip hazards**
Use of field testing equipment on golf greens	**Risk of personal injury**
Working on golf greens	**Risk of personal injury/ golf balls in play**
Interruption to golf play	**Antagonism of golfers on course**

List the current control measures in place. Please check the RM website for help and advice available at; http://rmd.anglia.ac.uk

Risk	Control measure
Risk of unauthorised entry.	**Researcher will only be on site with Course Managers approval. Location will be known to Course manager. Researcher will report to course manager on arrival and departure from site.**
Risks from wet/rough ground and trip hazards	**Researcher is experienced in golf course work and will wear appropriate PPE when on site**
Risk of personal injury	**Equipment is low risk and is well known to researcher who has many years' experience using such equipment.**
Risk of personal injury/ golf balls in play	**Researcher will wear visible PPE.**
Antagonism of golfers on course	**Researcher will maintain look out for golfers and give way to play as required**

Current risk level. High / Medium / Low	
(See risk matrix) (Delete as appropriate)	

List the actions required to reduce the risk. Please check the RM website for help and advice available at; http://rmd.anglia.ac.uk

Risk	*Additional Action Required*	*Date actioned*	*Actioned by*
Site entry and lone working	**Researcher will have access to own mobile phone on site and have contact details for Golf Course Manager**		
Golf balls	**Researcher will wear hard hat and hi-vis vest when on site**		

Revised risk level.	**High / Medium / Low**		
(**See risk matrix**)	(**Delete as appropriate**)		
RA verified Dr Alan Coday – Research Supervisor			**Date.** **XXX**

Risk assessment issued to the following; **Host XXX,** **Research Supervisor - Dr Alan Coday**						**Date.** **XXX**
Risk assessment review date. **(Usually annually)**						
Risk assessment reviewed by.						