Distance Insights Report

February 4, 2020

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The USGA is a nonprofit organization that celebrates, serves and advances the game of golf. Founded in 1894, we conduct many of golf's premier professional and amateur championships, including the U.S. Open and U.S. Women's Open. With The R&A, we govern the sport via a global set of playing, equipment, handicapping and amateur status rules. The USGA campus in Liberty Corner, New Jersey, is home to the Association's Research and Test Center, where science and innovation are fueling a healthy and sustainable game for the future. The campus is also home to the USGA Golf Museum, where we honor the game by curating the world's most comprehensive archive of golf artifacts. To learn more, visit usga.org.

About The R&A

References in this document to The R&A are to R&A Rules Limited. Together The R&A, based in St Andrews, Scotland, and the USGA govern the sport of golf worldwide, operating in separate jurisdictions but with a commitment to a single code for the Rules of Golf, Rules of Amateur Status and Equipment Standards. The R&A governs the sport worldwide, outside of the United States and Mexico, on behalf of over 36 million golfers in 144 countries and with the consent of 159 organisations from amateur and professional golf.

The R&A is aiming to invest £200 million in developing golf over the next decade and supports the growth of the sport internationally, including the development and management of sustainable golf facilities. For more information, visit www.randa.org.

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Distance Insights Report

1. Scope

1.1 Distance Insights project overview

The Distance Insights project is a joint initiative by the USGA and The R&A that was launched in May 2018 to study the past, present and future impacts of hitting distance[1] in golf.

The project aims to answer the following questions:

- What are the key contributors to hitting distance in golf? In particular, what are the impacts of:
    - equipment (especially golf clubs and balls)
    - the golfer (including athleticism, swing technique and course management strategy)
    - the golf course (including course layout, setup and agronomic conditions)

- What have been and might be the key impacts of increased hitting distance on the game? In particular, what are the impacts on:
    - how the game is played
    - golf courses

- What does distance mean to golf's key stakeholders?
    - comprehensive quantitative and qualitative research on the perspectives of stakeholder groups
    - assessment of key industry economic performance indicators

With these questions as guideposts, the goal was to study hitting distance and its effects for all golfer cohorts including the most highly skilled golfers (for convenience, this report refers to them as "elite" golfers) and all other non-elite golfers (for convenience, this report refers to them as "recreational" golfers). Information was gathered going back as far as possible. While there is significantly more data relating to distance since 1980 (and particularly relating to male professional golfers), important information and historical perspectives were obtained as far back as 150 years.

For additional perspective, a quantitative and qualitative research study was commissioned on current observations and insights of fourteen golf stakeholder groups.

1.2 Distance Insights project documentation

The Distance Insights project was organized and executed by staff from The R&A and the USGA using Project Management Institute best practices. Some tasks were outsourced to expert organizations or consultants and relevant past internal or external documents were also used.

The results of this project are documented in three ways: 1) This report is a summary of the research and findings; 2) the library of reports documenting the individual studies completed or pertinent to the project is available [on USGA.org and RandA.org]; and 3) our conclusions from the project are

[1] For the purpose of this report, hitting distance is defined as how far shots travel when struck by golfers on a golf course.

published in an additional paper titled “Conclusions from the Distance Insights Project: The Implications of Hitting Distance in Golf”.

2. The evolution of hitting distances

To understand hitting distances (especially driving distances) prior to systematic measurements (discussed in Section 2.2), an extensive review of historical sources has been completed. While conclusions from this historical review cannot be assessed with the same statistical rigour that can be applied to later measures, it nonetheless allows the consideration of the evolution of hitting distances over the long term.

2.1 Historical records of hitting distances prior to 1980

Many sources of information allow for an historical assessment of driving distances prior to 1980 including:

- Instructional articles and books that report typical hitting distances of contemporary elite and recreational players
- Descriptions of the game published in non-golf books and periodicals that report typical driving distances of golfers
- Media coverage of golf competitions published in contemporary golf periodicals and newspapers that report single or average hitting distances by a player or players
- Biographical profiles of elite players published in contemporary golf periodicals and books that report the subject’s typical hitting distances
- Instructional articles and books written by elite players that report the author’s typical hitting distances

More than 2000 individual reports of hitting distances were collected from more than 500 different sources published between 1790 and 1980 (R53 - The History and Evolution of Hitting Distances and Golf Course Lengths Before 1980). Recognizing their inherent limitations, these source materials collectively reveal trends of increasing hitting distances over both short and long periods of time. It is these trends and their relative magnitudes, rather than individual data points, that are important for present purposes. To facilitate an understanding of these long-term trends, the historical information on the evolution of hitting distances is divided into four eras.

2.1.1 Hitting distances prior to 1850

The relatively few contemporary historical documents concerning hitting distances prior to the middle of the 19th century suggest a very general range of driving distances of between 150-200 yards for a typical male golfer, with some reports of drives up to 220 yards. Additional sources from the second half of the nineteenth century looking retrospectively report similar distances and golf historians largely have accepted a range of 150-200 yards as a typical driving distance in the pre-1850 era. It should be noted, however, that the feather ball used in this era performed poorly in wet conditions, at which times a drive of even 100 yards could be difficult to achieve. None of the available sources differentiate between male and female hitting distances, as very few women played golf in this era; likewise, the concept of “professional golf” did not exist and contemporary sources do not distinguish between elite golfers and other golfers. Accordingly, there are no meaningful distinctions between cohorts of golfers that can be formulated for this time period.

2.1.2 Hitting distances between circa 1850 and circa 1900

Contemporary reports suggest that typical driving distances initially dropped following the introduction of the more durable gutta percha ball around 1850, but it is difficult to quantify the magnitude of this decrease based on the contemporary sources. By the late 1890s, typical drives for elite male golfers were in the range of 160-200 yards, with numerous reports of long drives in the range of 200-220 yards. There are no discernible differences between the reported hitting distances of professionals (who most often were also caddies) and elite amateurs during this time period.

Approximations of hitting distances for recreational golfers can be gleaned from contemporary instructional books and articles, which taken together suggest that a typical recreational male golfer in the late 1890s was driving the ball anywhere from 100-150 yards.

With the formation of women's golf clubs beginning in the late 1880s and subsequent reporting on women's competitions, it is possible to establish a general benchmark for women's driving distances in the 1890s. Reports from this era suggest that elite female golfers typically drove the ball between 120-140 yards, with long drives in the range of 170 yards; and that recreational female golfers typically drove the ball between 75-100 yards.

Table 1 Typical ranges of reported hitting distances circa 1900, 1930 and 1980

Date	Recreational Women	Recreational Men	Elite Women		Elite Men	
			Typical Drives	Long Drives	Typical Drives	Long Drives
Circa 1900	75-100 yards	100-150 yards	120-140 yards	150-170 yards	160-200 yards	200-220 yards
Circa 1930	100-150 yards	130-180 yards	175-225 yards	225-250 yards	220-260 yards	270-290 yards
Circa 1980	110-150 yards	160-200 yards	200-240 yards	250-270 yards	240-280 yards	280-300 yards

2.1.3 Hitting distances between circa 1900 and circa 1930

Driving distances for most segments of golfers appear to have increased by 10-25 yards in the five-year period between 1899-1904, corresponding with the introduction of the wound rubber core golf ball (also known as the Haskell ball). The significant variations in reported hitting distance during this five-year period presumably are explained, in significant part, by the transition to the new ball that occurred over several years (principally 1901-1903) when both balls were in use concurrently.

After the transition to the new ball was complete, increases in reported hitting distances continued, albeit at a slower pace, through the early 1930s.

2.1.4 Hitting distances between circa 1930 and circa 1980

The historical records indicate that hitting distances continued to increase from the early 1930s through the end of the 1970s, at an overall rate of increase that was lower than the rate of increase between circa 1900 and circa 1930. Implying that there was a trend of increasing driving distances for all cohorts of golfers for the period from the 1890s through at least 1980.

2.2 Systematic measurements of hitting distances

Measurements of driving distance began at the U.S. Open in 1940 and the U.S. Women's Open in 1964. In 1968 and 1969, the PGA TOUR measured drives for the entire field on two holes for each round at each event, and then in 1980 began doing so every year up to the present (assisted since 2004 by the ShotLink® system). Several other professional tours later started this practice and now routinely measure and report driving distances at their tournaments. Driving distance measurements for elite amateur events are more limited. The driving distances of certain recreational golfers have been measured annually by The R&A since 1996 for men and since 2013 for women.

2.2.1 Elite golf hitting distances

This section summarizes hitting distance measurements for elite golfers, both professional and amateur and focussing on shots where a player is expected to be using driver. Except where otherwise noted, driving distance measurements is typically conducted on holes where players are expected to use driver.

2.2.1.1 Professional golf hitting distances

Figure 1 presents the average driving distance on several professional golf tours, consistent with the charts in the Annual Driving Distance Reports (R08 - Annual Driving Distance Report - 2019), updated to include the 2019 seasons. It can be seen in Figure 1 that, except for the Ladies European Tour (LET) (which has been collecting data only since 2004), average driving distances have increased significantly over the time these measurements have been taken.

As noted above, the tour with data covering the most years is the PGA TOUR. Between 1980 and 2019 average driving distance on that tour increased by 39 yards, or 15%. Other tours began measuring driving distance in later years.

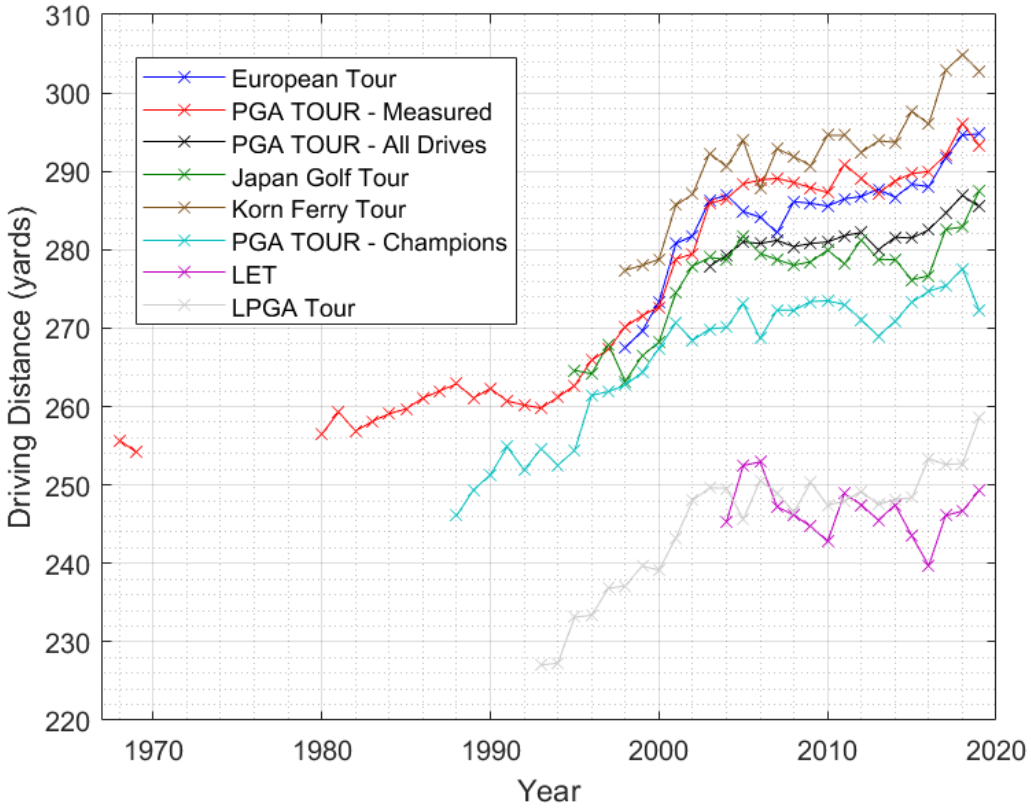


Figure 1 Average driving distance on the professional tours. It should be noted that the PGA TOUR measured driving distances for the 1968 and 1969 seasons and then again from 1980 to present.

Before 1968, driving distances for an entire field were also measured at several U.S. Opens (a field that included both professionals and amateurs) and the events in the UK 1964-1966 (R13 - Comparison of historic (1964-1966) tournament performance data with its modern equivalent). In Figure 2, the progression of average distance is shown with significant innovations overlaid and in Figure 3 the same data is presented with significant equipment rule change milestones shown.

Figure 4 shows these measures along with the season long averages shown in Figure 1 for the PGA TOUR (R06 - Analysis of Playing Lengths of Golf Courses on the PGA TOUR) It can be seen in Figure 4 that driving distances have increased from 1940 onwards. Figure 4 also notes the average rate of driving distance increases for different eras on the PGA TOUR. Annual average increases ranged from 0.18 yards per year during periods of more incremental change to 2 yards per year during periods of more significant change.

Similar trends can be observed for the longest hitters. In 1995, the longest 20 hitters on the PGA TOUR (the only tour then measuring hitting distance) had an average driving distance of 278 yards, compared with the average tour driving distance of 263 yards.

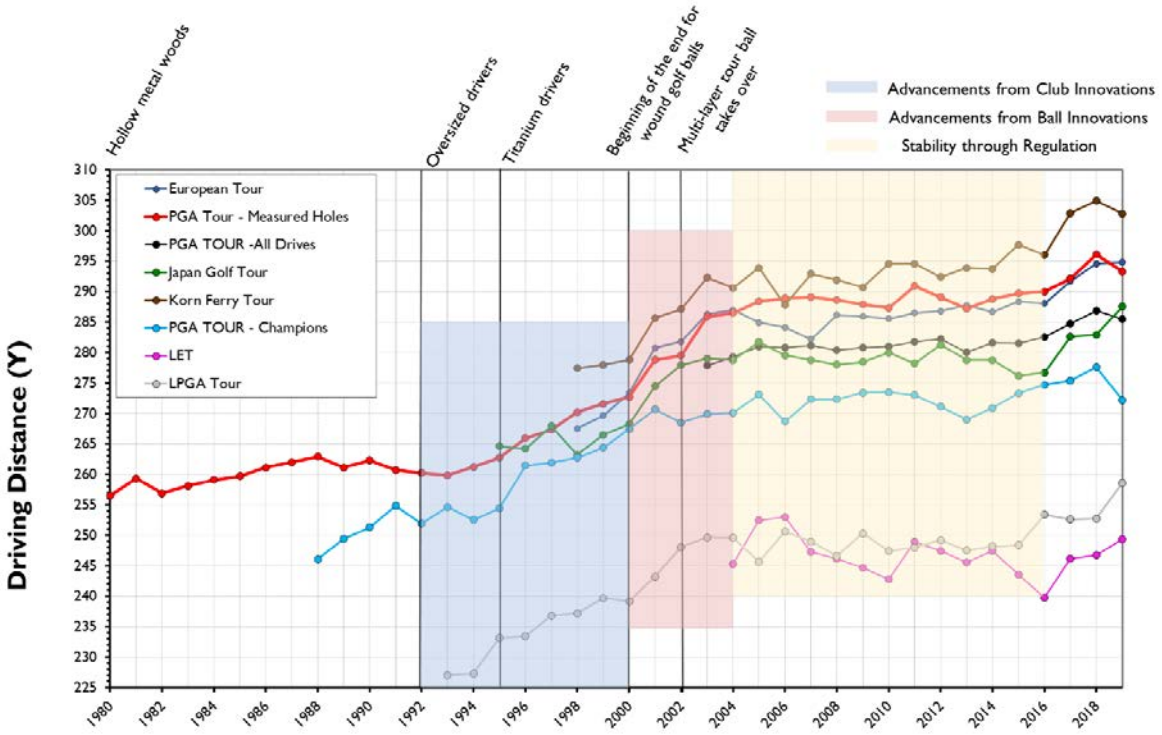


Figure 2 Average driving distance on the major tours with significant innovation milestones overlaid

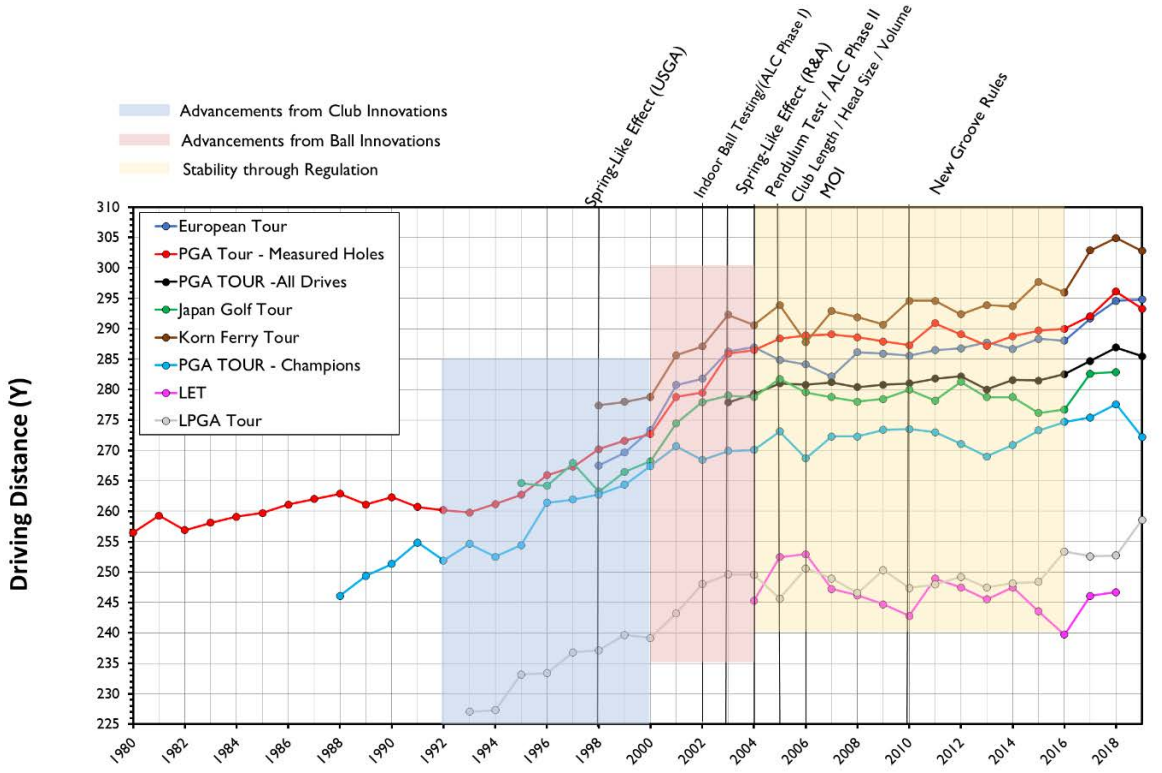


Figure 3 Average driving distance on the major tours with significant Rule change milestones overlaid

By 2003, after a period of significant equipment advances the driving distance of the 20 longest hitters from both the European Tour and the PGA TOUR averaged 303 yards, with an average driving

distance for both tours combined of 286 yards. After virtually no increase for the next 10 years, these distances have increased since 2013 at a rate of about one yard per year, with the average drive of the Top 20 increasing by eight yards and the average distance on both tours combined increasing by seven yards. By 2019 the combined average drive of the 20 longest hitters from both the European Tour and PGA TOUR had increased to 310 yards, and the average driving distance for both tours combined had increased to 294 yards.

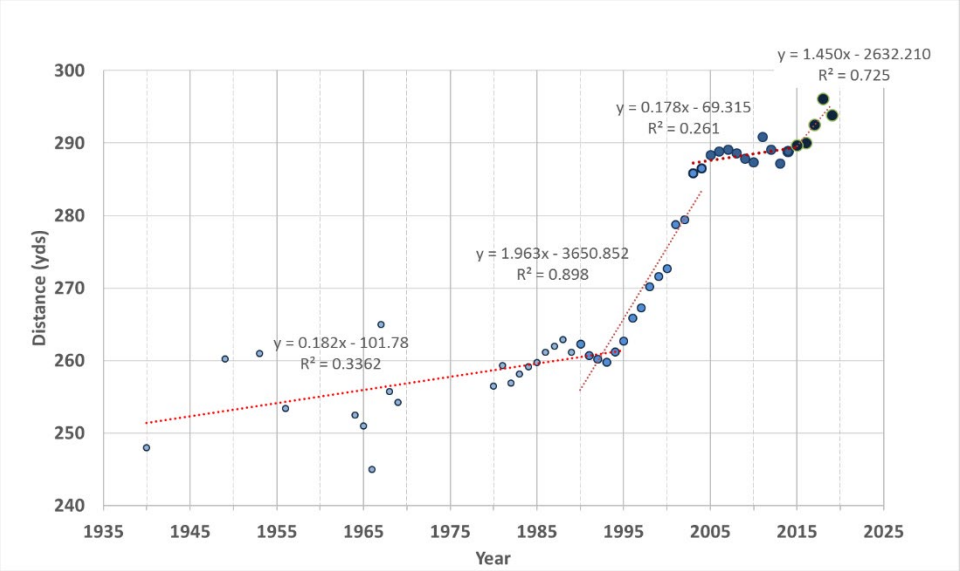


Figure 4 PGA TOUR average driving distance data (1968-present) supplemented with additional data points from other men's professional tournaments (prior to 1968) with multiple linear regressions over different eras

The LPGA Tour has measured season-long driving distances since 1993. Driving distances were also measured at the U.S. Women's Open (a field that includes both professionals and amateurs) as early as 1964. Figure 5 shows these two sources of average driving distance for these sets of elite women golfers.

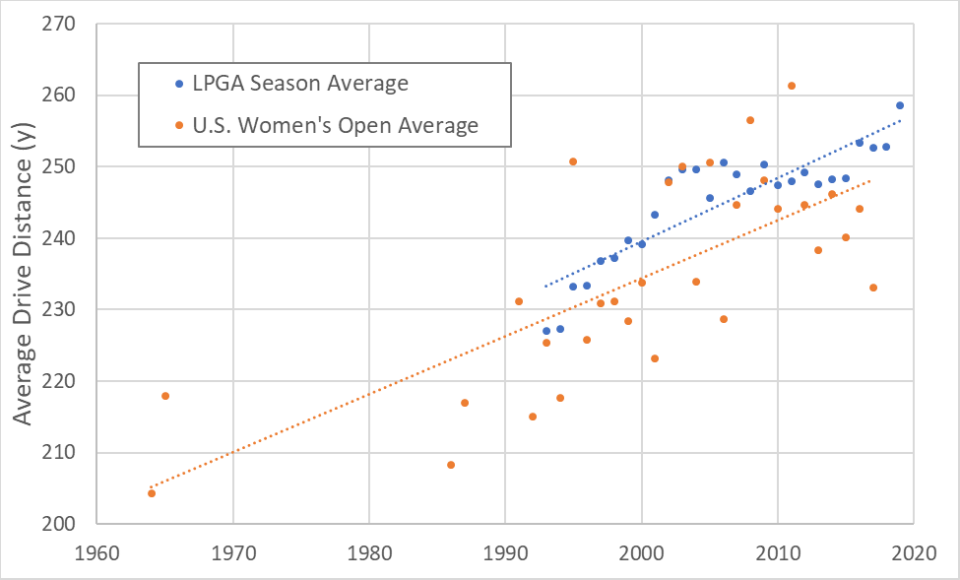


Figure 5 Average driving distance measurements and linear regressions on the LPGA Tour (since 1993) and the U.S. Women's Open (since 1964)

Driving distance for these elite women players has increased significantly over the past 55 years. The average rate of increase of driving distance for the LPGA Tour has been 0.9 yards per year since

1993, with a similar rate at the U.S. Women's Open of 0.8 yards per year. There have been comparable increases for the longest women players. Around 1930, elite female golfers reportedly had typical driving distances of 175-225 yards (see Table 1) and long drives were typically in the range of 225 – 250 yards, while today the average hitting distance on the LPGA Tour is more than 250 yards (Figure 1) and the tour's top 20 players average more than 270 yards.

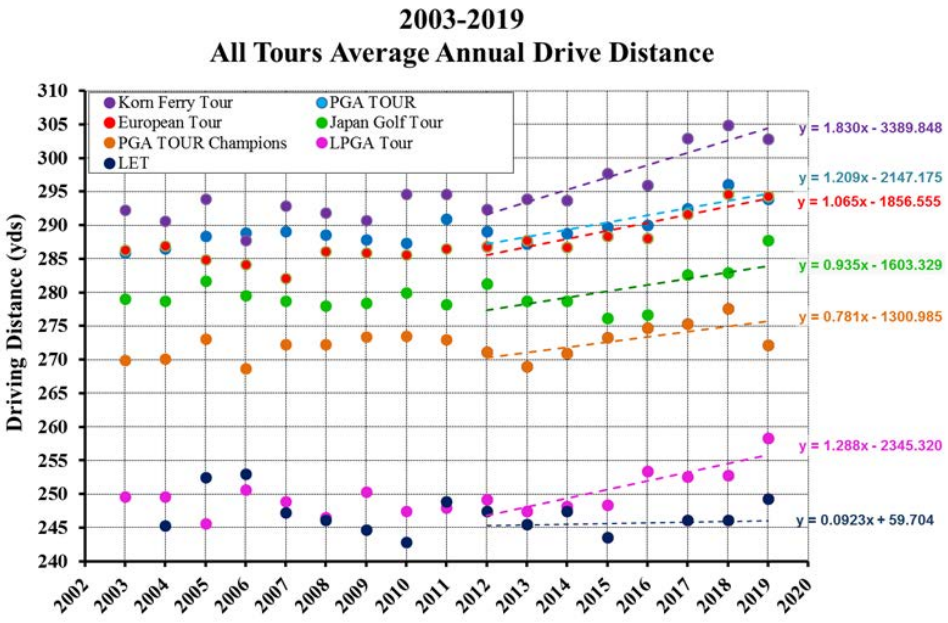


Figure 6 Tour average driving distance since 2003 (with linear regressions since 2012)

It can be seen in Figure 6 that since 2012, the average driving distance on all tours except the LET has increased at a rate between 0.9 and 1.3 yards per year.

As can be seen in Figure 7, the proportion of drives exceeding 300 and 320 yards on both the European Tour and PGA TOUR has also been increasing, while the proportion of drives less than 280 yards has been decreasing (R08 - Annual Driving Distance Report - 2019).

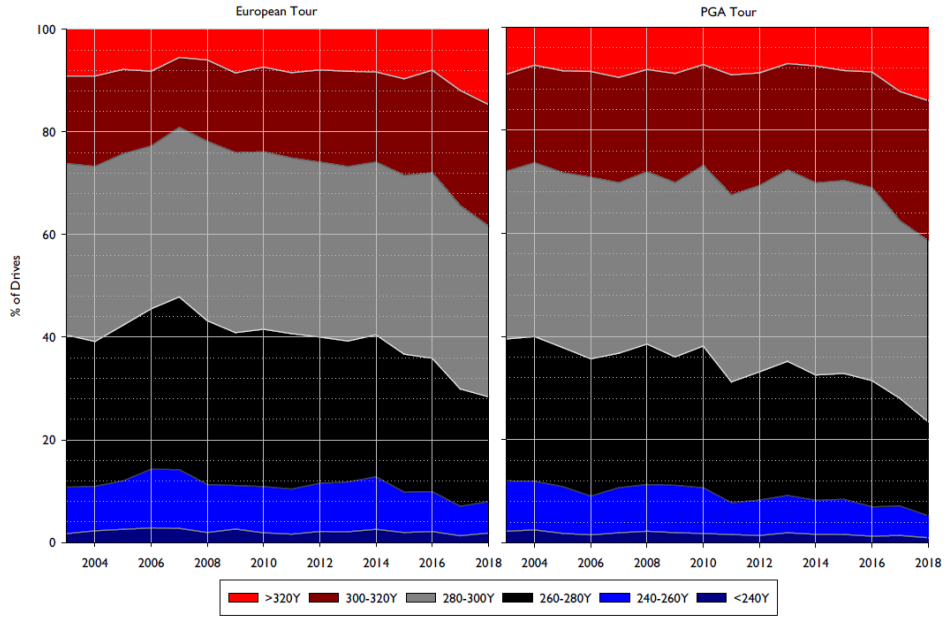


Figure 7 Proportion of driving distance on European Tour and PGA TOUR

There are very few sources indicating golfers' specific hitting distances for clubs other than those used on the driving holes that were measured. However, during the 2014 U.S. Open and U.S. Women's Open held in back-to-back weeks at Pinehurst #2, the USGA collected approach shot distances and club selection for both the men and women competitors (R09 - Approach Shot Distances and Hole Lengths on the PGA TOUR). In an effort to create the same golf experience and challenge for both the men and women, holes were set up such that both men and women were expected to hit the same irons into the greens. To measure the efficacy of this approach, data were collected on approach distances for both the men and women competitors.

To gather the data, players' caddies were paid to record their distance to the hole for each approach shot as well as which club their player used for that shot. These data, comprising thousands of shots, were collected during each of the practice rounds as well as the 4 championship rounds (data were only collected during the first two championship rounds of the U.S. Women's Open). In addition, greenside observers noted the balls' interaction with the green (e.g., how much it rolled and whether the shot hit the green, stayed on the green, or missed the green). Of note is that generally most approach shots exhibited little or no forward movement after the ball hit the green and most stayed on the green.

Figure 8 shows the average and standard deviation for their approach shot distances for the range of irons.

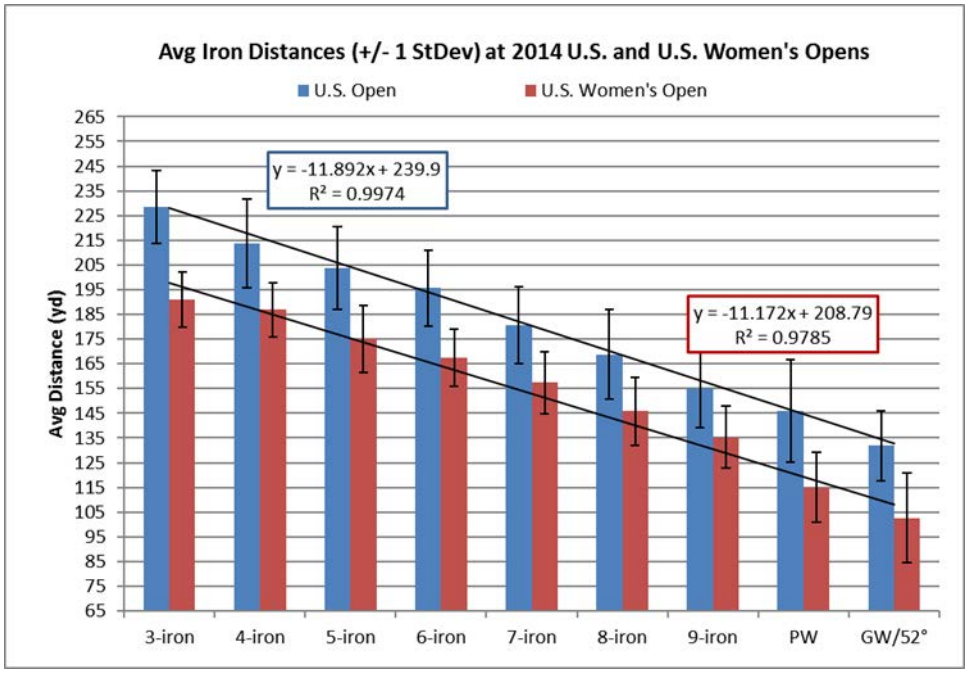


Figure 8 Average and standard deviation of approach shot distances by iron selection at 2014 U.S. Open and U.S. Women's Open

2.2.1.2 Elite amateur golf hitting distances

Hitting distances of elite amateur golfers have not been measured nearly as extensively as the hitting distances of professional golfers. However, the USGA and The R&A have periodically measured driving distance at their respective Amateur Championships since 1998. These results are summarized in Figure 9.

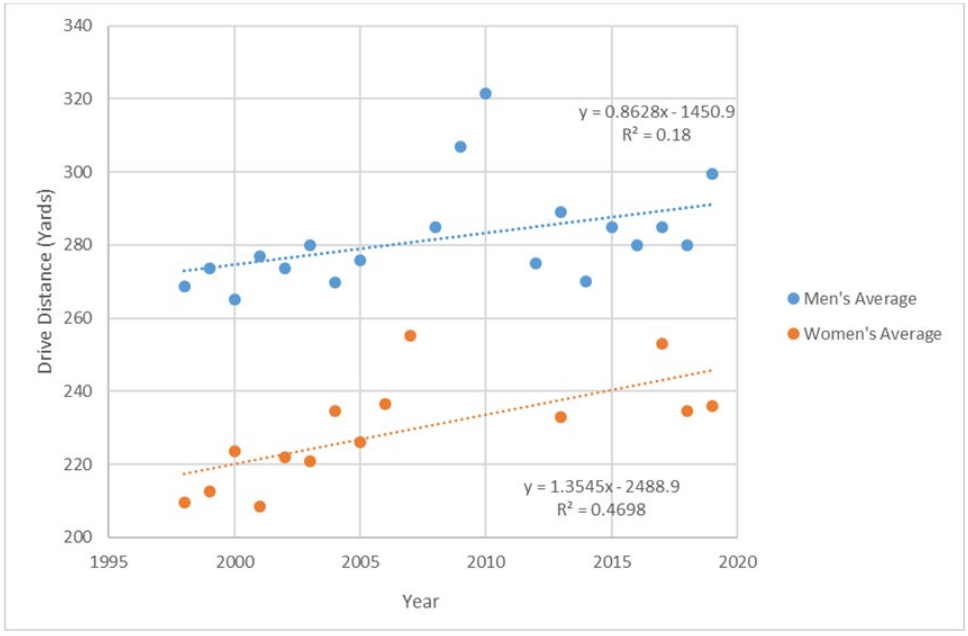


Figure 9 Average driving distance for the U.S. Amateur, The Amateur Championship, U.S. Women's Amateur and The Women's Amateur championships

It can be seen in Figure 9 that the average driving distances for both groups has climbed significantly since 1998 at rates between 0.8 and 1.4 yards per year. Comparing Figure 9 and Figure 1, the average driving distance for the male amateurs corresponds well with that of male professionals. The driving distance of female amateurs also compare well with the driving distances of female professionals in recent years, after averaging significantly shorter drives in earlier years (the amateurs averaging around 220 yards in 2000 compared with the LPGA Tour average of nearly 240 yards).

2.2.1.3 Long drive contestants

As an indicator of human potential this section provides data from long drive competitors. Launch condition data for men and women competing in two World Long Drive competitions during 2019 were analysed (R07 - Analysis of Trackman data gathered at World Long Drive events). It can be seen in Figure 10 that the carry distances for both men (average of 352 yards) and women (average of 282 yards) in these competitions were significantly longer than the total average driving distances of their professional tour counterparts.

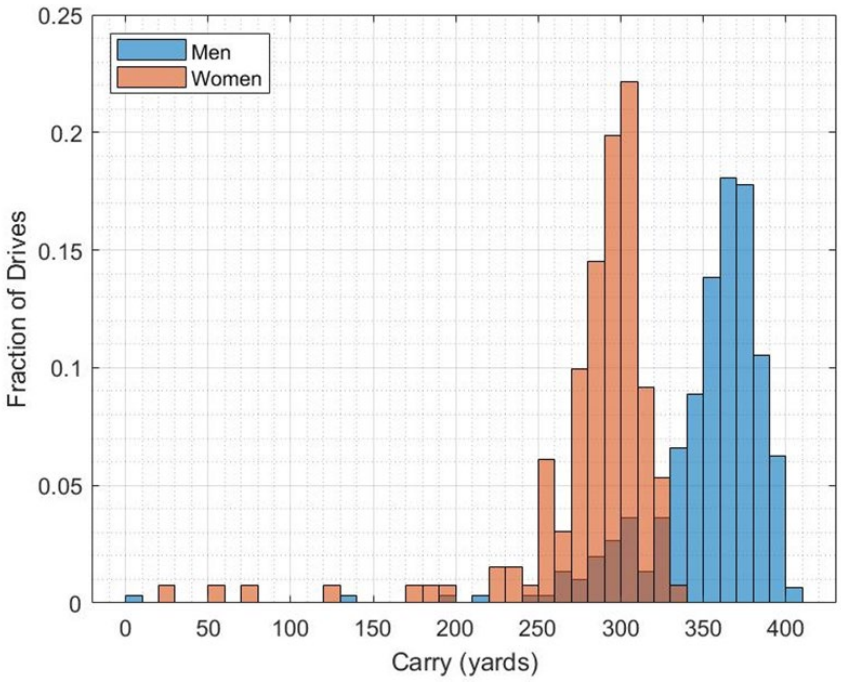


Figure 10 Carry distances of male and female World Long Driver competitors in 2019

2.2.2 Recreational golf hitting distances

The hitting distances of recreational golfers have not been the subject of many systematic measurements. The most longstanding effort has been the driving distance measurements conducted by The R&A annually at six venues between 1996 and 2019 (R05 - Analysis of Amateur Driving Data 1996-2018). Where possible, the same venues and competitions were studied every year, with distances measured on the same holes.

Figure 11 shows the average driving distances of male players in each handicap category[2] each year between 1996 and 2019.

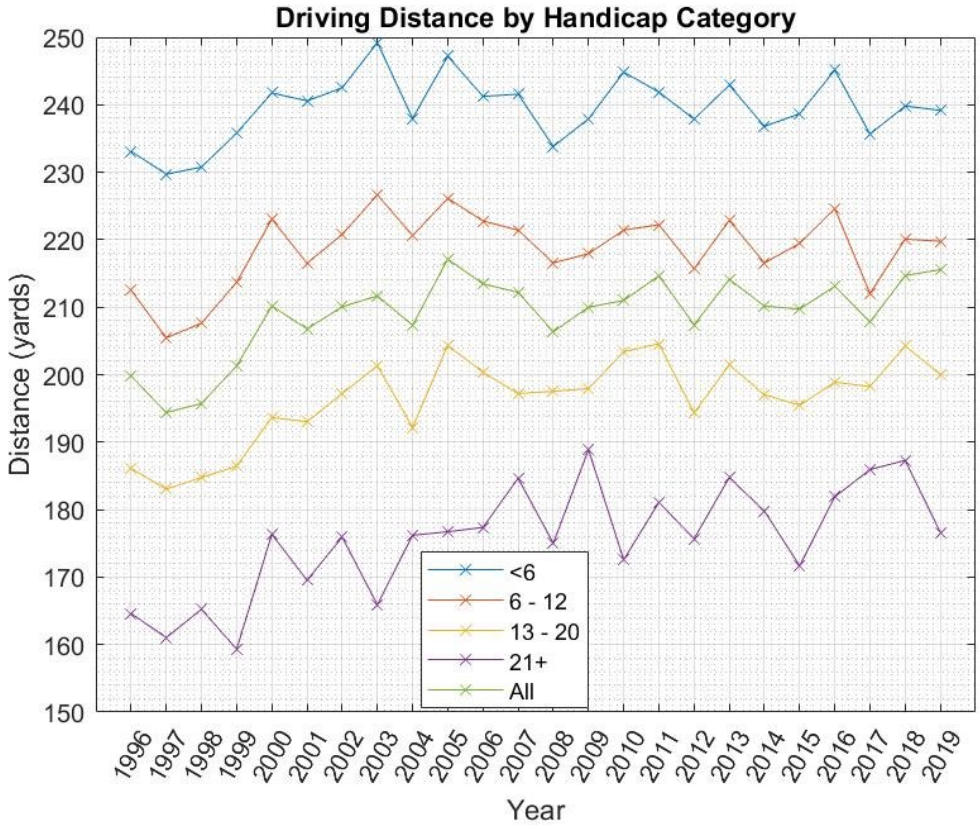


Figure 11 Average male driving distances measured in The R&A's amateur driving distance studies

Over the period of the study, driving distances increased for these UK-based male players from all handicap categories, with the overall combined average increasing from 200 yards in 1996 to 216 yards in 2019. The largest increase in 2018 was for category 4 male golfers (handicaps of 21 and above), whose average increased from 165 yards in 1996 to 187 yards (but it fell back down to 176 yards in 2019, demonstrating the volatility in some of this data). These results compare well with the values collected during a different study conducted at the World Amateur Handicap Championship (R05 - Analysis of Amateur Driving Data 1996-2018). These results are also consistent with a study published by the golf performance tracking system Arccos which reports that average driving distance for male amateurs in 2018 was 217 yards (R51 - The divide between professional and amateur golfers is growing). Finally, these distances are also consistent with a study by Trackman which reported that the average distance of amateur male golfers is 214 yards (https://blog.trackmangolf.com/performance-of-the-average-male-amateur/).

As shown in Figure 12, these studies also recorded the golfers' club selection, which is known to influence driving distances.

[2] The term category pertains to a range of handicaps given within the legend in Figure 11, namely <6, 6-12, 13-20 and 21+.

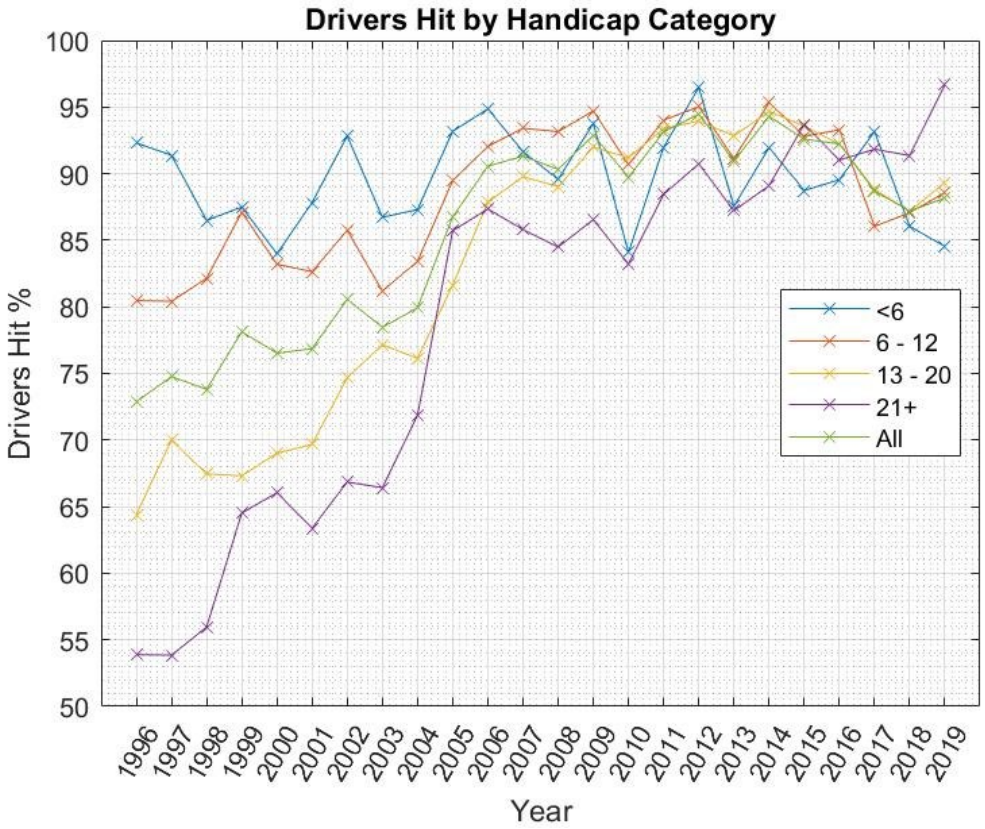


Figure 12 Driver usage percentages for male golfers within each handicap category from The R&A's amateur driving distance studies

As with driving distance, while the data in Figure 12 represents a robust sample of golfers enabling long-term trends to be evaluated, significant year-to-year variations may occur for various reasons.

It can be seen in Figure 12 that, except for the lowest handicap golfers, recreational golfers in this study are using driver more often now than in the late 1990s (see Section 3.2.1.1 for comments on driver forgiveness). In the early years of the study, driver usage by handicap category went down with increasing handicap. Since the mid 2000s, however, the likelihood for all handicap categories to use driver has become more similar. The overall increase in driver usage accounts for approximately 4 yards of the 15-yard increase in driving distance.

Since 2013, drives have also been measured at recreational women's events. The yearly averages by handicap category are shown in Figure 13.

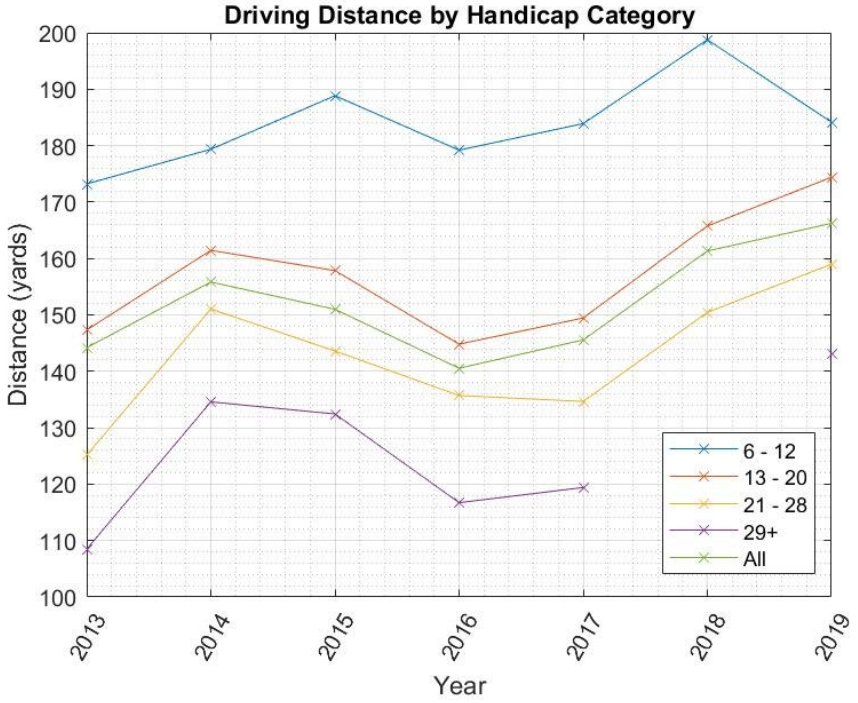


Figure 13 Average female driving distances measured in The R&A's amateur driving distance studies

Due to the short period of these studies, it is not possible to comment on longer-term distance trends for recreational women golfers. However, the studies' reported average driving distance for recreational UK-based women in the range of 145 to 166 yards is consistent with the results in other studies (R55 - The relationships between driver clubhead presentation characteristics, ball launch conditions and golf shot outcomes, Journal of Sports Engineering and Technology 2014 228:242).

3. The factors which impact hitting distances

This section examines the contributors to increases in hitting distance, which can be grouped broadly into three categories:

- Equipment
- The player
- The course

It is divided into two main parts, the first part covering periods before relevant technical analysis and measurements were carried out on a systematic basis and the second part covering the more recent decades when this became common; taken to be pre-1990 (Section 3.1).

The analysis concerning from 1990 to the present (Section 3.2) focuses more on elite male driver shots because this is the group for which most data exists, but the same factors can also contribute to distance increases for other golfer cohorts, though the extent of the contributions may differ.

3.1 Contributors to hitting distances prior to 1990

An extensive literature review was completed to identify potential contributors to hitting distances before 1990. This review was supplemented with examination and measurement of surviving examples of clubs, balls and other equipment in museum and private collections. Given the nature of

the information available, it is not realistic to associate discrete changes in hitting distances with any individual factor, as it is likely that multiple factors worked in concert to generate distance gains. Similarly, it is not viable to provide definitive values for distance changes associated with the contributors. The focus is on identifying the developments over the long term that may have affected hitting distance.

3.1.1 Contributors to hitting distances prior to 1850

3.1.1.1 Equipment

Prior to 1850, golf was played with a feather ball. Comprising a hand-sewn leather sack with a largely smooth surface (but with stitched seams) and stuffed with feathers, the feather ball was firm and elastic when finished, but nonetheless comparatively fragile. Most strokes were made with a wooden-headed club – a so-called "long-nose wood" – that featured a narrow, long and shallow clubhead, a comparatively flat lie, and long, thin shafts. The earliest surviving examples (attributed to the early 1600s or perhaps late 1500s) were large, blocky and heavy with thick necks and deep faces; by the 1850s, clubheads had become lighter and more delicate, making them easier to swing and better shaped to sweep the fragile feathery from the turf. Play with iron clubs was limited, as iron clubheads easily damaged the hand-sewn ball. The earliest known irons from the 1600s and 1700s feature large and heavy clubheads with thick hosels and stout shafts. Smaller and lighter clubheads became more common in the early decades of the 19th century.

3.1.1.2 Players

The flat lie of a long-nose wood promoted a swing plane that was much flatter than the modern golf swing. The flat, sweeping swing in combination with the feather ball that featured a comparatively smooth surface produced a low-trajectory ball flight likely to lead to significant bounce and roll.

3.1.1.3 Course conditions

Prior to the Industrial Revolution, people in the agrarian communities in Scotland and England had little time for recreational activities from the time of spring planting through the early fall harvest. Moreover, the land on which the game was played in many towns was often planted with crops or used for grazing livestock during the summer months. Dormant turf, thin turf coverage and sometimes frozen ground contributed to firm and fast conditions during the late autumn and winter months when the game was more frequently played.

3.1.2. Contributors to hitting distances from circa 1850 to circa 1900

3.1.2.1 Equipment

The gutta percha ball appeared in the late 1840s and by the early 1860s it had replaced the less durable feather ball entirely. The first gutta percha balls were finished with smooth, painted surfaces that produced poor flight characteristics. Within a few years, ball makers started to hammer patterns on the ball's surface, eventually incorporating finer incised lines or bramble patterns into the surface to improve the ball's flight. In contrast to the feather ball, the gutta percha ball was hard and less elastic and produced less bounce and roll.

The latter half of the 19th century saw the evolution from long-nose woods to far more durable, heavier clubheads that were wider from front to back and featured deeper faces. By the 1880s,

clubheads also became shorter in length from heel to toe. The changes in shape were a response to the hard gutta percha ball, which caused the heads of long-nose woods to split. A radical design for wooden clubs was introduced in the late 1880s – the so-called "bulger" driver with a face that was convex rather than concave and a shorter and broader pear shape which placed more mass directly behind the ball.

Iron clubs also evolved significantly and became more popular between 1850 and 1880 in response to the durability of the gutta percha ball and evolution in swing techniques. Irons were no longer used solely to extract the ball from a difficult lie, but also were used for approach shots to the green. As such, iron clubs continued to become smaller and lighter and lofts became variable. Irons outnumbered woods in a standard playing set by the 1890s.

3.1.2.2 Players

Thicker club shafts, stouter clubheads and the more durable gutta percha ball encouraged a more forceful swing, while the shorter overall length of woods and irons promoted a more upright swing. Golfers were able to swing harder at the ball to encourage longer carry (which was important, given that the solid gutta percha ball produced less roll) despite the restrictive clothing that was common for both men and women. The first book of golf instruction appeared in 1857 and the first instructional by a golf professional was published in 1896; from the outset, such instructional materials included advice on how to swing to maximize distance.

3.1.2.3 Course conditions

Turf conditions improved considerably in the latter half of the 19th century as golf evolved into a summer activity. While summer conditions were likely drier (promoting increased bounce and roll), linksland and inland grasses grown on sandy soils would have been longer and thicker, diminishing roll; inland sites that featured heavy or clay-rich soils were soft and mushy in winter, but often became rock hard in the summer. The invention and later adoption of lawn mowers for use on golf courses in the second half of the 19th century allowed for the maintenance of mown fairways that stretched from tee to green and lowered the height of turfgrass on golf courses from about 1.5 inches to 1 inch (R52 - The Evolution of Fairway Agronomy).

3.1.3 Contributors to hitting distances from circa 1900 to circa 1930

3.1.3.1 Equipment

In 1898, Americans Coburn Haskell and Bertram Work developed a golf ball with a core composed of wound rubber tape and thread that led immediately to dramatic increases of 10-25 yards in hitting distances for most players. In the three decades that followed, the components and manufacturing processes used to make the new rubber-core ball were improved. This included innovations in: cover materials, thickness and application; cover patterns, including most importantly the invention of the dimple pattern in 1905; core material tensile strength and winding processes; the evolution of core materials from rubber tape and thread to solid and liquid compounds; and multiple variations in size and weight (prior to the implementation of standards in 1921).

While improvements to the design and manufacture of golf balls likely contributed most to hitting distance increases during this time (R31 - Historical Equipment Research and Testing), other developments in equipment also influenced player swing technique and hitting distance. This included the continued evolution and refinement of the driver, including experimentation with

clubhead and club face-insert materials, as well as clubhead shape and mass; evolution and refinement of irons, including differential weighting of clubheads; and thicker, stronger shafts that allowed players to swing more aggressively without fear of breaking the club.

3.1.3.2 Players

After 1900, swing techniques evolved to favour a draw or hook shot (for right-handed players) that was more compatible with the rubber ball, as it imparted less backspin and produced more roll. Concurrently, typical attire for men and women became far less restrictive with lighter materials and fewer layers; the new fashion, in combination with stronger club materials, encouraged a longer backswing, a full turn and a more forceful swing. In the late 1910s and 1920s, the use and widespread availability of slow-motion photography and film improved the understanding of swing mechanics and considerably advanced the art and science of golf instruction.

3.1.3.3 Course conditions

The early decades of the 20th century witnessed considerable improvements in golf course agronomics, supported by new scientific research on turfgrass, improvements in irrigation methods, and advances in mowing equipment that gradually reduced mowing heights to less than 1" and perhaps as low as .75" (R52 - The Evolution of Fairway Agronomy). Where improved turf replaced hard surfaces, bounce and roll would have been diminished; lower mowing heights, on the other hand, would have promoted roll (R03 -Agronomic Impacts on Bounce and Roll Distance). The relative impact on hitting distances would have varied from course to course based on prior agronomic conditions.

3.1.4 Contributors to hitting distances from circa 1930 to circa 1990

3.1.4.1 Equipment

Following more than three decades of rapid advances in the materials, design and manufacture of golf equipment, especially for clubs and balls, the onset of the Great Depression and the outbreak of World War II slowed investment in further research and development for nearly two decades. Moreover, efforts to contain distance increases were pursued by the governing bodies during these same years, including the adoption in 1942 of an initial velocity restriction on golf balls which augmented the existing equipment rules. For several decades, through the 1950s and 1960s, golf ball manufacturers focused on incremental innovations in dimple design and cover painting and polishing to improve aerodynamics, as well as improvements in ball compression (and especially on improving manufacturing processes and equipment to create consistency in ball compression).

During this time there were also numerous studies conducted on the performance of the golf ball, primarily its resilience and aerodynamics, with a goal toward developing a test or tests to limit that performance. While some of the test and measurement methods were crude and imprecise by today's standard, this seminal research can provide qualitative, and some limited quantitative, insight into the historical performance of golf equipment (R31 -Historical Equipment Research and Testing).

In 1928, Professor H. A. Thomas of the Carnegie Institute of Technology developed an apparatus for measuring the coefficient of restitution (COR or *e*, a standard measure of the energy retained during a collision). Thomas tested nine brands of golf balls and measured coefficients of restitution between 0.57 and 0.64. These values are much lower than values measured in subsequent tests in the 1940s, late 1950s and even today.

Subsequent to Thomas' testing, Lyman Briggs of the National Bureau of Standards used Thomas' machine to extend his research over a broader range of impact velocities. As the USGA was researching different diameter and weight combination in golf balls, Briggs also tested a variety of these combinations. In tests on a 1.68-in diameter ball with a weight of 1.62 oz in 1931, the same size and weight limits in effect today, he measured a value for *e* of 0.726. Figure 14 shows the results of testing conducted by Thomas and Briggs.

In 1940, the Armour Research Foundation built a new device to establish a USGA standard for ball resilience. The ball was struck by the striker at a speed of 144 ft/sec. The velocity of the ball was measured by photo electric cells that were 10.62 feet apart. The resilience was stated in terms of this velocity. The results of testing conducted by Thomas and Briggs along with the USGA Standard are shown in Figure 14.

Also shown in Figure 14 are results from tests conducted by the Arthur D. Little Company. In 1958, while endeavouring to develop of new device for the USGA that could test across a range of impact velocities and with different striker weights, the Arthur D. Little Company tested two brands of golf balls, the Titleist DT-100 (Acushnet's highest compression brand at that time) and the Club Special (their lowest compression brand). The 1958 results were compared with earlier historical results and it was noted; "The *e*-value of 0.726 obtained by Briggs for the official ball in 1931 compares closely with the present value for the Club Special." The figure also illustrates clear improvements in the golf ball.

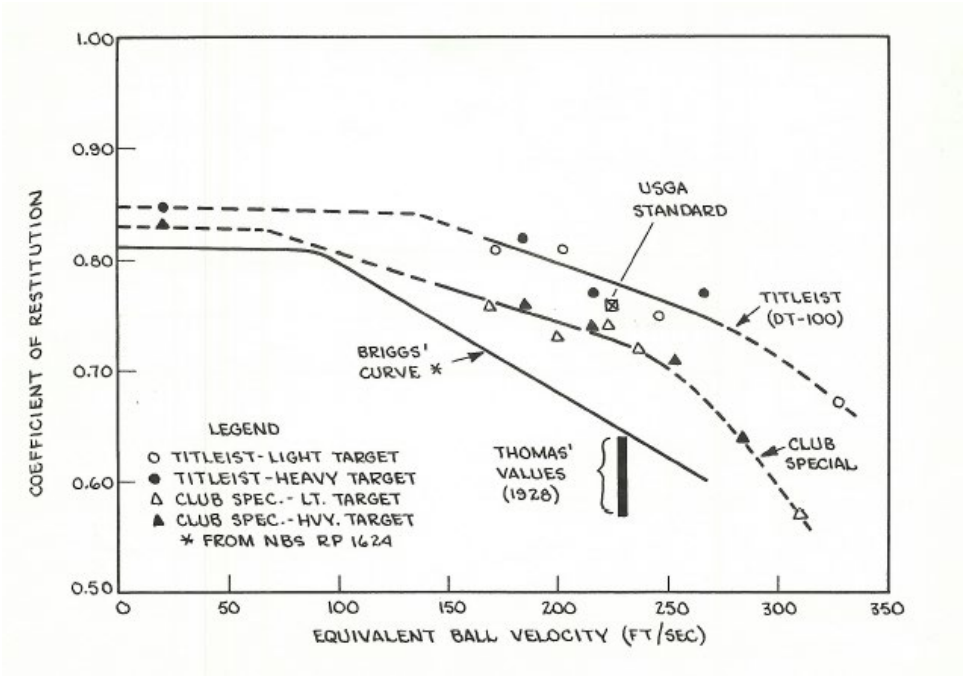


Figure 14 Comparison of then current 1958 Tests to results from 1928, 1931 and the 1942 USGA Standard

In addition to performance gains from golf ball resilience, aerodynamics has greatly improved through the decades. In 1994, Aoyama conducted a study comparing the aerodynamics of a golf ball popular on the professional tours at that time, the Titleist "K2" along with the Titleist Tour Balata, which was popular with tour players in the early 1990s. In 1970 golf balls were all very similar in construction and nearly all of them used a 336-octahedron dimple pattern known as the Atti pattern. Aoyama conducted drop tunnel, mechanical golfer testing and trajectory simulations over a wide range of launch conditions. He concluded that while the results were very launch condition dependent, there was a distance advantage for the 1990s era ball for most of the tested launch conditions (which matched concurrent PGA TOUR launch conditions). He noted that, "[O]ver the

range of launch conditions typically generated by today's professional tour players , no player is likely to gain more than 10 yd and no player is likely to lose more than 5 yards by playing the Tour Balata versus the K2."

The K2 ball aerodynamics were studied by the USGA and compared to those of the Tour Balata. The results are shown in Figure 15.

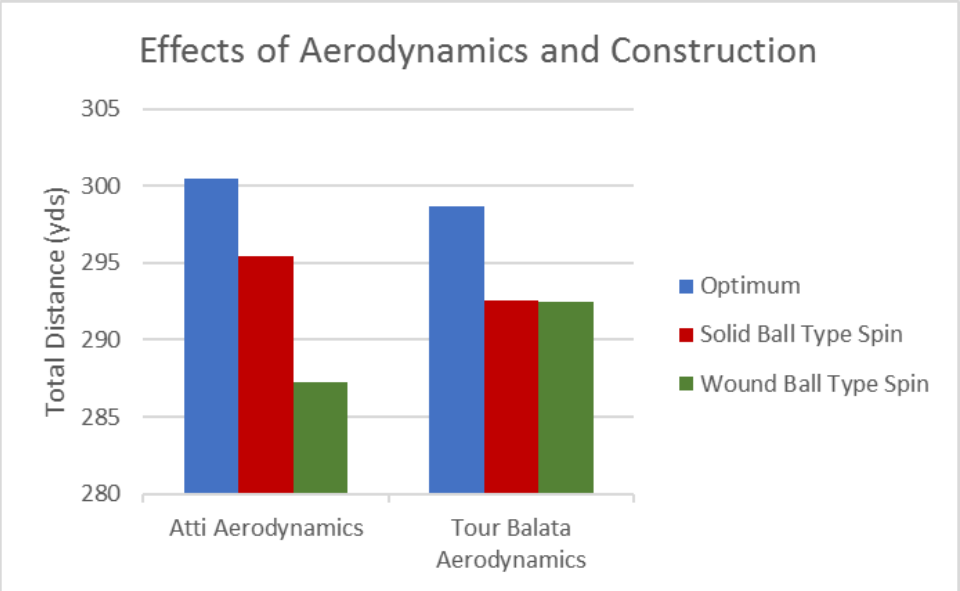


Figure 15 Effects of Different Dimple Patterns with Varying Constructions

Simulations were conducted at a launch speed of 256 ft/s for all golf balls. It is important to note that it is challenging to examine the effects of aerodynamics changes in golf balls without recognizing that the aerodynamic performance of those balls was tailored to the way the ball was being driven at the time. For instance, using spins appropriate to a solid ball, the Atti pattern would appear to have a distance advantage over the dimple pattern over the Tour Balata (red columns). However, in the context of a more appropriate spin for the Tour Balata, the Tour Balata aerodynamics had a clear distance advantage over the Atti pattern (green columns). The magnitude of this advantage compares favourably to Aoyama research. Modern aerodynamics have a distinct advantage over both the Atti pattern and Tour Balata ball aerodynamics. These effects are shown at various ball speeds in Figure 16.

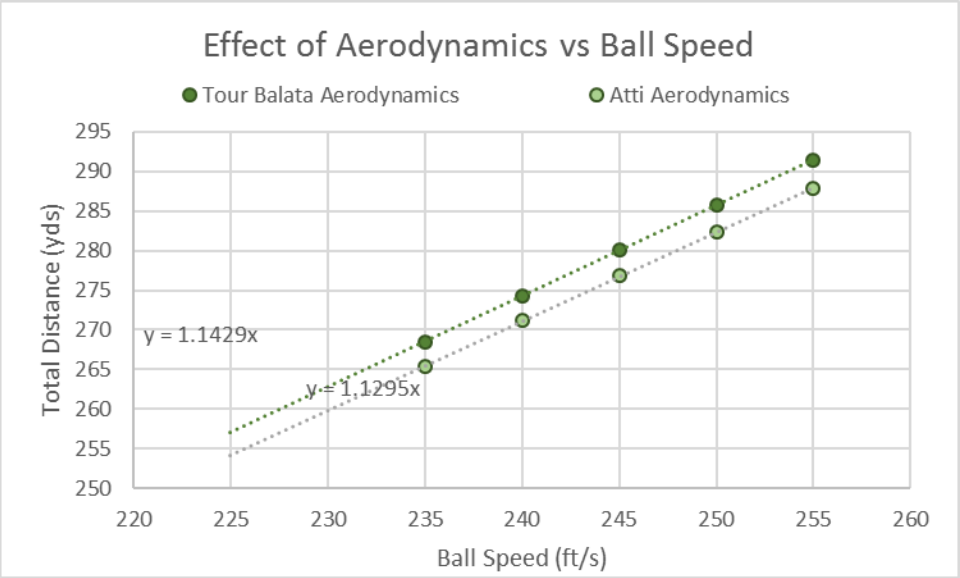


Figure 16 Effects of Different Dimple Patterns at Varying Ball Speeds

Importantly, the 1930s also witnessed the widespread adoption of improved steel shafts that resisted twisting and breaking and so promoted aggressive swings. Improvements in club design in the 1950s and 1960s led to drivers with deeper faces and more mass; as well as irons with perimeter weighting and cavity backs that increased moment of inertia (increased moment of inertia directly contributes to the forgiveness of a club for off-centre strikes; a club with a high moment of inertia will rotate less during impact and transfer more energy to the ball).

New technologies, materials and production methods that emerged throughout the industry during the so-called “Space Race” of the 1960s migrated to golf in the 1970s. Most notable was the experimentation with golf ball dimple patterns which led to improved aerodynamic performance after nearly 40 years of minimal innovation; ball producers found that they were able to control and tailor the trajectory, spin rate, and angle of descent of golf balls – properties that could impact overall distance for various players. Concurrently, advances in chemistry and materials science led to the development of new synthetic compounds and polymers that were used both in wound balls and in the first-generation of solid-core balls that were introduced at this time.

In the late 1960s, golf club shaft manufacturers began to pursue the use of graphite shafts, which were stronger than steel and could be made lighter than steel shafts. This allowed additional weight to remain in, or be transferred to, the clubhead; in addition, graphite shafts could be made longer while retaining swing weight, potentially allowing for increased clubhead speed. Finally, beginning in 1979, the metal-headed wood was re-introduced to the game (following earlier experimentations between the 1890s and 1920s). These new metal woods had a rigid face (which alone did not increase hitting distance) and a higher moment of inertia that reduced distance loss from off-centre hits.

3.1.4.2 Players

Key advancements in equipment – notably steel shafts, refined dimple patterns, and deeper faces on drivers – accelerated the adoption of a more upright swing that produced significantly higher ball flight trajectories which for some players may have generated more distance. A significant step forward in golf instruction came in the late 1960s, with the first rigorous scientific analysis of the golf swing and the various factors that contribute to performance, including hitting distance. (Cochran and Stobbs, The Search for the Perfect Swing, 1968).

3.1.4.3 Course conditions

As with equipment, research and development of new varieties of turfgrass and course maintenance practices and equipment initially were curtailed due to the Depression and World War II. In the post-war decades, however, the development of new strains of fescue and bent grasses, the continued improvement to fairway irrigation systems, and new types of mechanical equipment for golf course maintenance practices led to improved agronomic conditions that on some golf courses could have resulted in increased hitting distances.

Gang mowers, typically with five to seven blades per reel, were commonly used on fairways from the 1930s to the 1970s. The ground-driven reels used from the 1930s through the 1950s enabled mowing heights between 0.75" and 1.5"; in the late 1960s, triplex mowers were introduced with reels that were driven hydraulically, enabling mowing heights between 0.5" and 0.75".

3.2 Contributors to hitting distances from the 1990s to the present

3.2.1 Equipment

Since about 1990, equipment performance has been studied extensively. As it has become possible to quantify equipment performance with greater accuracy and to obtain measurements in controlled studies, golf clubs as well as balls, have been researched extensively. The resulting improvements to golf equipment and the timeline of the introduction of new products and regulations (R32 - History of Equipment Rules) can provide context to changes in hitting distances over time (R08 - Annual Driving Distance Report - 2019).

3.2.1.1 Contributions of the driver to hitting distances

Driver characteristics have changed since the early 1990s (R48 - Review of Driver Clubhead Characteristics 1992-2018), in particular since the introduction of The Big Bertha driver in 1991. While Mizuno offered the first titanium driver, Ti-110 in 1990, titanium driver use became widespread with the introduction of the Great Big Bertha in 1995. These improvements were facilitated by developments in materials and manufacturing techniques enabling the emergence of large hollow metal clubs with significantly improved performance over the solid persimmon clubs they replaced.

One of the most visually apparent changes has been the increase in the average driver volume from an average of around 200 cm^3 in 1997 to over 400 cm^3 in recent years (Figure 17), with commensurate increases in the length, height and depth of clubheads (R48).

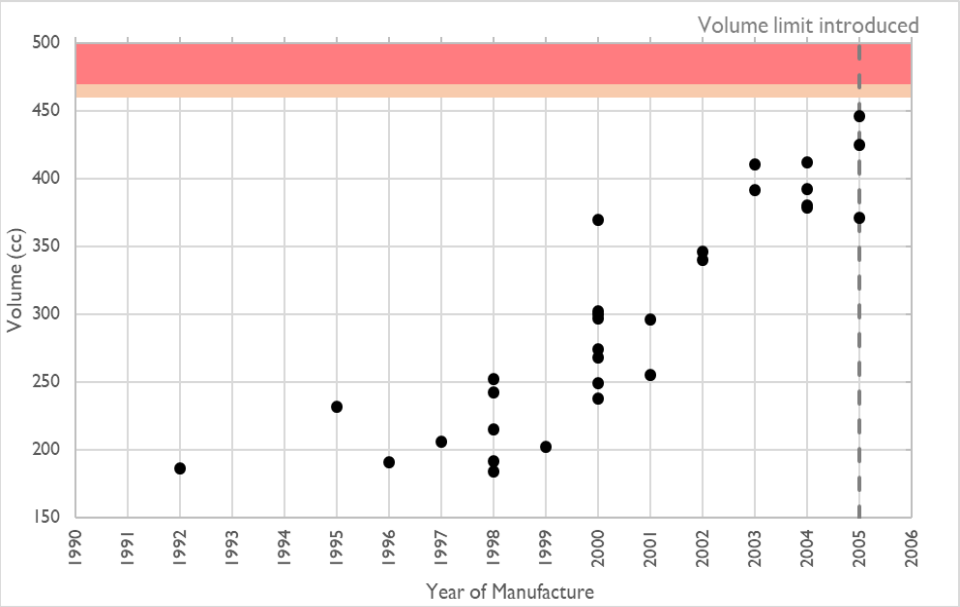


Figure 17 Changes in driver clubhead volume over time for a selection of clubheads

The aerodynamic disadvantage of this increase in size generally does not make a significant difference to clubhead speed, since overcoming drag represents only a small percentage of the energy required to swing a golf club. Analytical models suggest that by eliminating clubhead drag completely, a physical impossibility, clubhead speed would increase for a high-swing-speed player by only 2 miles per hour (R19 - Effect of Equipment on Distance - Driver). Despite this increase in clubhead size, clubhead mass has remained relatively consistent (Figure 18).

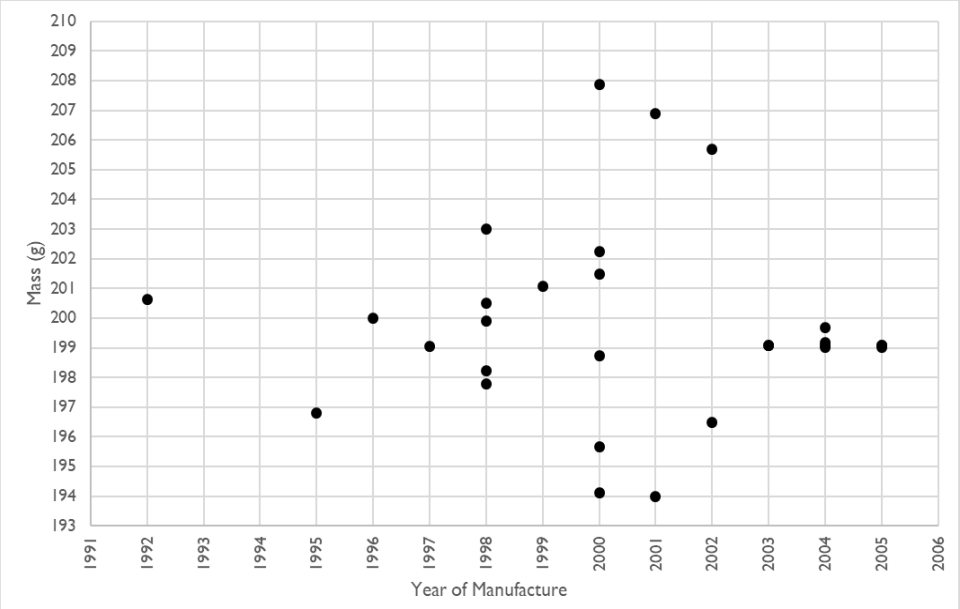


Figure 18 Changes in driver clubhead mass over time for a selection of clubheads

Enabled by improvements in clubhead materials (first high-strength steels, then most impactfully the adoption of titanium alloys and composite materials) and advanced manufacturing techniques, the evolving driver clubheads have contributed to distance in two key ways: increased moment of inertia and enhanced spring-like effect (or coefficient of restitution).

Increased moment of inertia directly contributes to the forgiveness of a club for off-centre strikes; a club with a high moment of inertia will rotate less during impact and transfers more energy to the ball (R47 - Results of Robot Face Mapping). The moment of inertia about a vertical axis of driving clubs increased significantly between 1990 and 2007, from an average of 2500 g·cm^2 to over 4000 g·cm^2 (Figure 19).

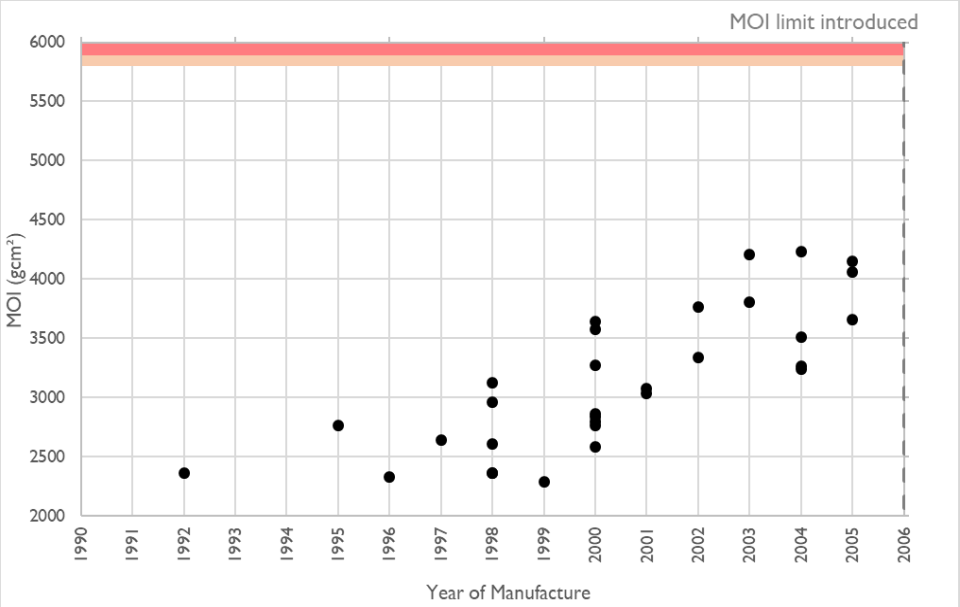


Figure 19 Changes in driver clubhead moment of inertia over time for a selection of clubheads

Research has shown that clubs with a higher moment of inertia about a vertical axis have lower distance loss for off centre hits (for all clubs, including irons); distance loss compared to a centre strike (Figure 20) and offline dispersion are lower for clubs with a higher moment of inertia (R19 - Effect of Equipment on Distance - Driver, R47 - Results of Robot Face Mapping). An increase in the moment of inertia, and subsequently the forgiveness, of drivers might also encourage a player to try to hit the ball harder to gain distance, since the distance loss for missing the optimal location on the club face is smaller.

Distance Insights Report

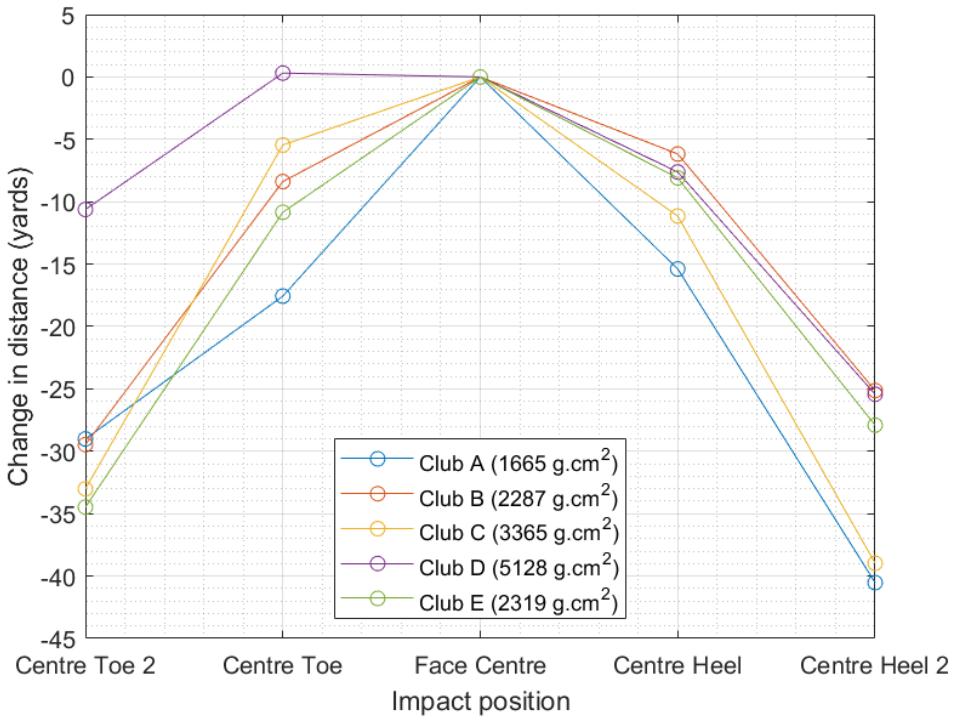


Figure 20 Distance loss against horizontal impact distance for five clubs with increasing moment of inertia (A-E). The testing locations were spaced at 12.7mm (0.5-in) intervals.

In addition to distance loss, the moment of inertia of the driver also influences the dispersion of shots as is shown in Figure 21 (R47 - Results of Robot Face Mapping).

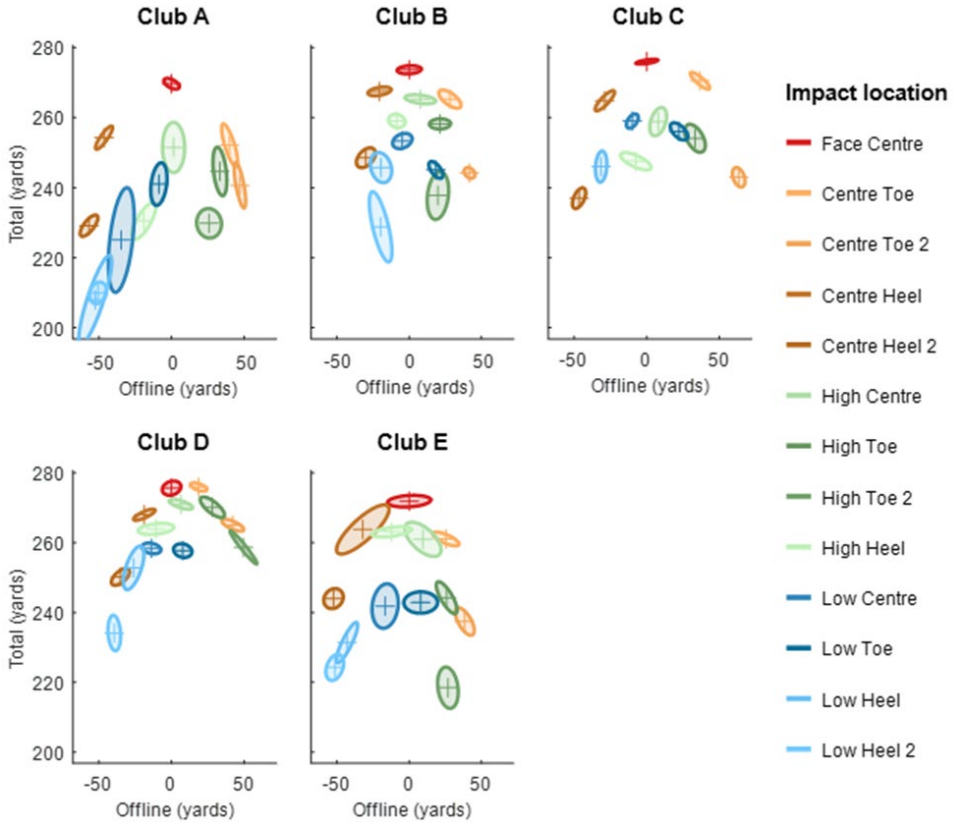


Figure 21 Simulated total position for the 13 impact locations for the five clubs studied. Ellipses enclose 95% of the points measured. Impact locations are detailed in Figure 1. Club A: Wood, Club B: Steel, Club C: 3 Wood, Club D: Modern, Club E: Small modern. Further information on the data can be found in R47.

As well as being more forgiving, modern driver designs have increased the coefficient of restitution of the impact between a club and a golf ball. This is often referred to as the spring-like effect and is associated with the thin, flexible components of modern golf clubs.

In 1996, while researching spring-like effect, Johnson and Hubbell conducted a number of experiments on impacts of golf balls with plates of various thicknesses to determine the effect that the flexibility had on ball rebound velocity. They concluded that velocity ratio (the ball rebound speed divided by the inbound speed) increased as the plate thickness decreased. These tests formed the basis for the adoption of a limit and test for spring-like effect by the USGA in 1998 and subsequently by The R&A in 2003 (R32 - History of Equipment Rules).

Studies were conducted by Hocknell (Hocknell, 2002) over a broad range of impact speeds. He concluded that modern drivers improved efficiency by a combination of driver features including face area, face thickness and moment of inertia and "[O]f these, face thickness is the design parameter which has been modified by the greatest extent to increase the COR [e]." The results of Hocknell's research as well as the test by Johnson and Hubbell and the earlier work by Arthur D. Little are shown in Figure 22.

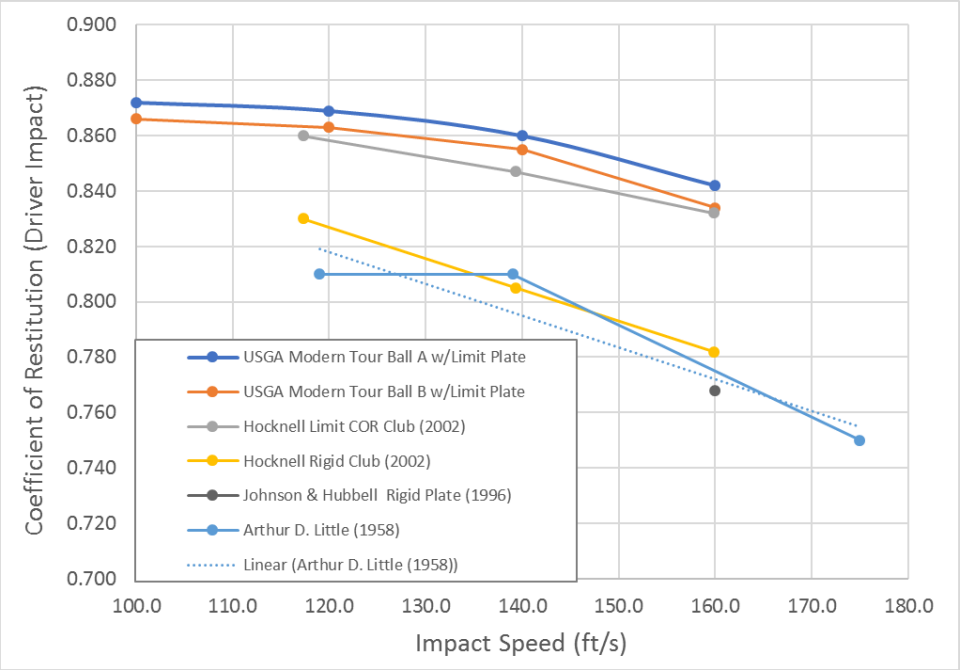


Figure 22 Coefficient of restitution for some modern balls with rigid and flexible targets. It should be noted that the values exceed the limit due to the testing methods (see also Figure 28)

The coefficient of restitution is a measure of the energy lost in the collision between the club and the ball and a higher coefficient of restitution is associated with a higher ball speed for the same clubhead speed (R19 - Effect of Equipment on Distance - Driver, Figure 23).

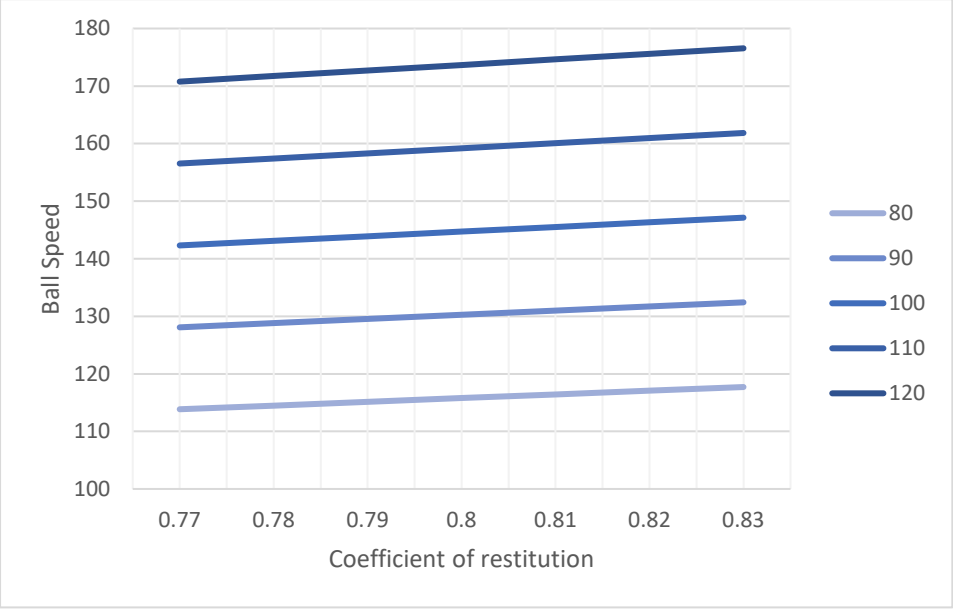


Figure 23 Effect of changes to the coefficient of restitution to ball speed for clubhead speeds of 80-120 mph – assuming a club mass of 205 g, a ball mass of 45.7 g and an angle of incidence of 10.5°

An increase in coefficient of restitution will yield a greater increase in distance for golfers with a higher clubhead speed than for those with a lower clubhead speed (R31 - Historical Equipment Research and Testing).

Characteristic time is a measure of a clubhead's spring-like effect as measured by the USGA and The R&A's pendulum test. The characteristic time of clubs has increased from between 140 and 180 µs

between 1990 and 1998, to a characteristic time of between 220 and 257 µs from 2003 onwards, as shown in Figure 24 (R48 - Review of Driver Clubhead Characteristics 1992-2018).

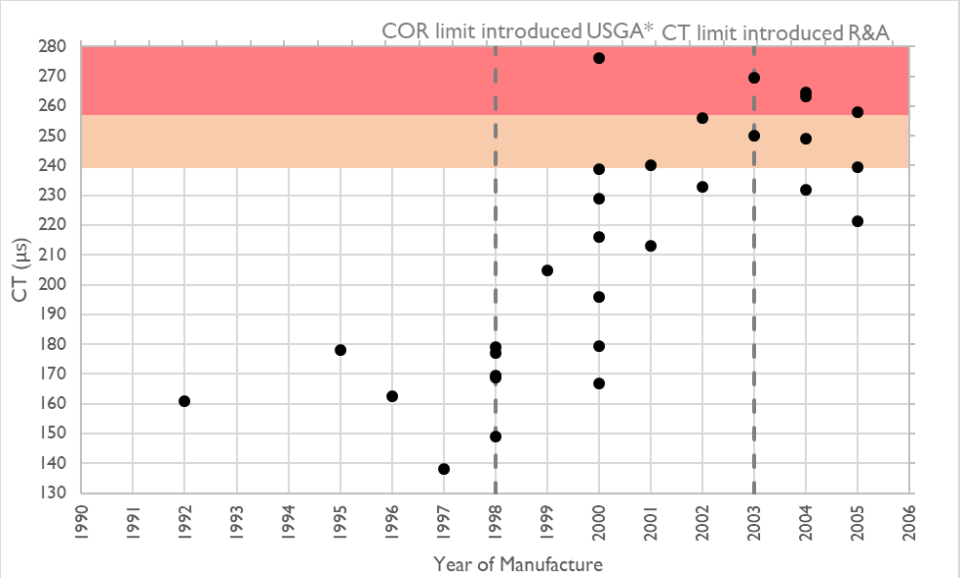


Figure 24 Changes in driver clubhead characteristic time (CT) over time for a selection of clubheads.

A characteristic time of 239 + 18 µs correlates to a coefficient of restitution of 0.822 + 0.008 (R48 - Review of Driver Clubhead Characteristics 1992-2018), which was the conformance limit introduced by the USGA in 1998 and The R&A in 2003 (R32 - History of Equipment Rules) and then included in the Rules for all golfers in 2008. Although it is dependent on properties of both the club and ball, an increase in coefficient of restitution of 0.01 (approximately corresponding to 20 µs in characteristic time) yields an approximate distance increase of about 1.7 yards for a clubhead speed of 120 mph (R19 - Effect of Equipment on Distance - Driver). The observed increases in the coefficient of restitution of clubs between 1990 and the early 2000s are responsible for increases in driving distance of around 9 yards at elite male golfer swing speeds.

Club length is another significant contributor to greater clubhead speed and therefore distance. For example, the current limit on club length is 48 inches, although few golfers today use driver shafts longer than 46 inches. An increase in driver club length from 46 inches to 48 inches could typically yield an increase in distance of around 1.3% (R18 - Effect of Club Length on Potential Distance), which would represent an increase of 1.5 miles per hour for a long driving elite player who now has a swing speed of 120 miles per hour. Such an increase in shaft length would therefore be expected to result, on average, in an increased driving distance of between 4 and 5 yards for such a player, in the absence of other effects (for instance changing swingweight).

3.2.1.2 Contributions to hitting distances of other clubs

Iron clubs have also changed significantly in the last several decades. In analysing the differences in iron distance, one first needs to adjust for the differences in loft between past and present irons that are identified with the same number. Over the last four decades, iron club lofts have decreased on average by around 4° (R21 - Effect of Equipment on Distance - Irons). For example, today's 7-iron is about the same loft as a 6-iron of 1970.

The progression of the strengthening of iron lofts is shown in Figure 25.

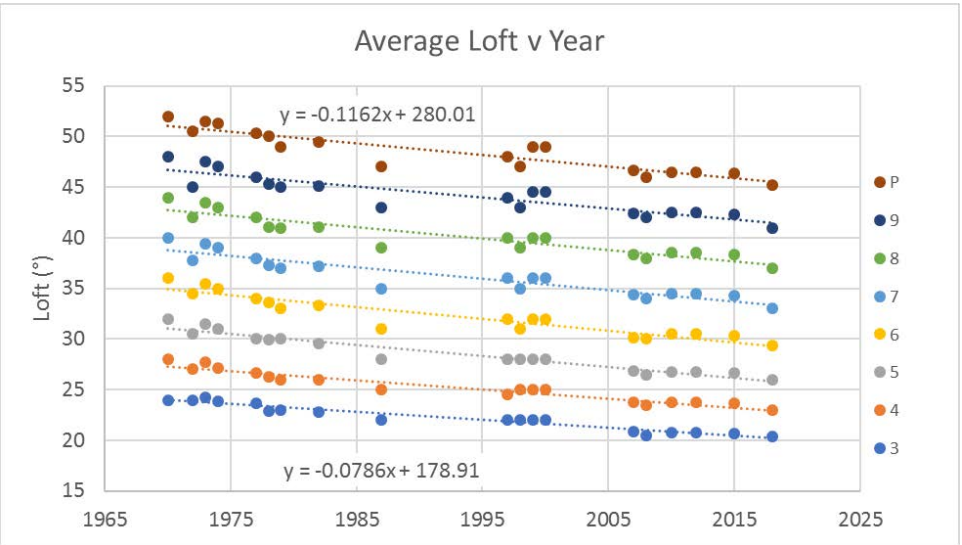


Figure 25 Changes in typical iron loft over time

Typical length of irons has also been increasing over the same period as shown in Figure 26. On average, irons are about one inch longer today than they were in 1970.

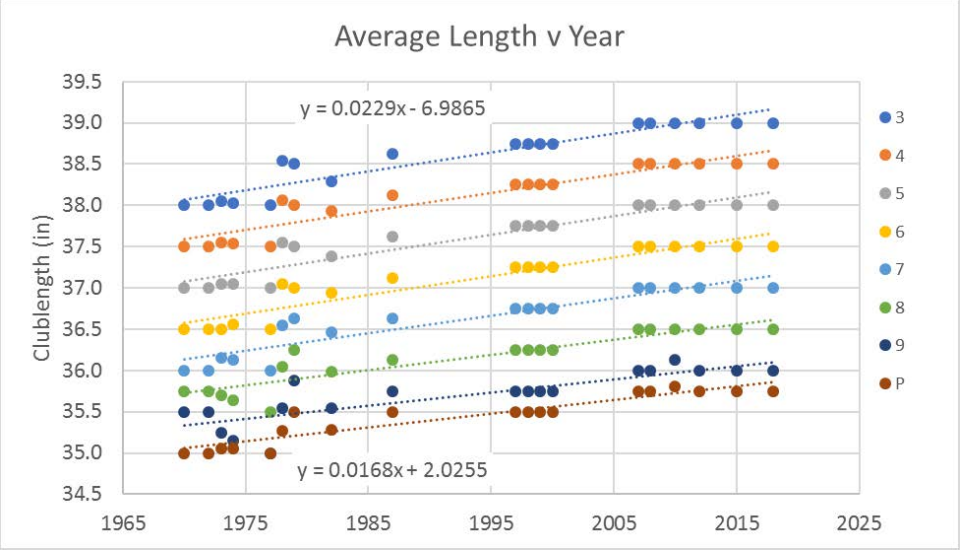


Figure 26 Changes in iron length over time

The decrease in loft and the increase in shaft length both contribute significantly to increased hitting distances for these clubs as compared to past irons of the same number.

Perimeter weighting of irons, resulting in increased moment of inertia, has likely contributed to increased iron distance as well, as discussed for drivers in Section 3.2.1.1. Spring-like effect has been introduced in some irons with thinner-faced, hollow rather than solid constructions, but in general not to the extent seen in driving clubs and fairway woods.

Similar trends have occurred in fairway woods. Since the late 1970s, the average length of 3-woods has increased from just over 42 inches to just over 43 inches today. Five-woods show a similar trend from 41.25 inches in the 1970s to nearly 42.5 today. Likewise, standard lofts of both 3 and 5-woods have decreased roughly a degree in the same period. Along with changes in length and loft, fairway woods have also become larger. Modern fairway woods have volumes in the 160cc to 180cc range, nearly the same as drivers in the early to mid-1990s. With the larger volume also came increased

moment of inertia. The thin-faced design of drivers has also made its way into fairway woods and hybrids leading to increased coefficient of restitution.

While distance increases from increased moment of inertia and spring-like effect in fairway woods, hybrids and irons are generally more modest than that of the driver, along with the changes in loft and length they are contributors to increased hitting distance with these clubs.

3.2.1.3 Contributions to hitting distances of golf balls

The performance of golf balls has changed significantly over the last 25 years, with many of those changes contributing directly to hitting distance increases. The most significant change in golf balls in this period has been the replacement of the wound-core golf balls used since the early 1900s with the multi-layer, solid-core balls that are ubiquitous today. Multi-layer solid construction golf balls is not a new innovation, but many golfers continued to use wound golf balls until as late as the beginning of the 2000s. Typically, multi-layer, solid-core balls spin considerably less than wound-core balls at typical driver impact angles (R20 - Effect of Equipment on Distance - Golf Balls). This is an important factor for driver shot distance because decreases in spin can directly contribute to increases in distance. For example, referring to Figure 27, a decrease of spin of around 250 rpm can lead to an increase in distance of as much as five yards at a swing speed of 120 miles per hour.

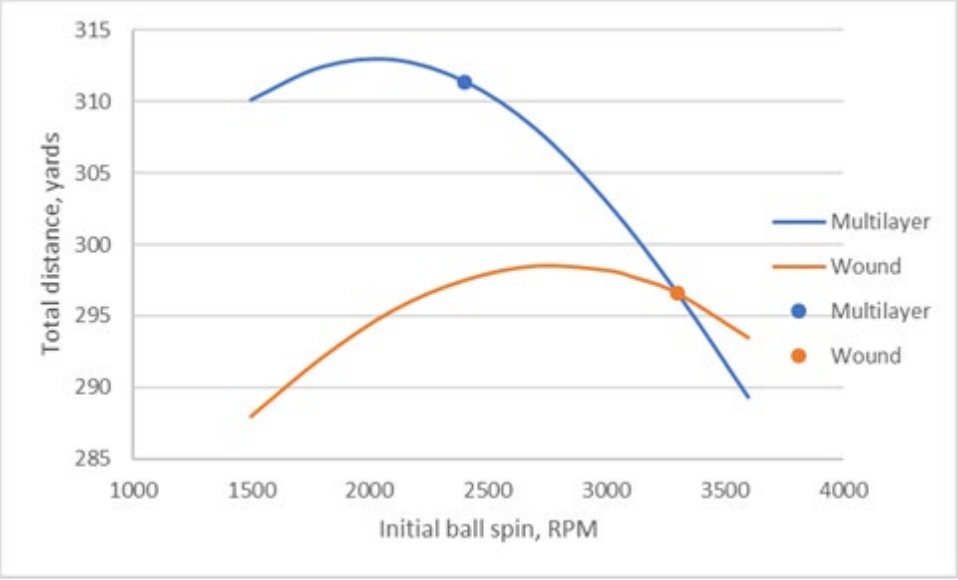


Figure 27 Effect of spin on overall distance for a wound-core ball and a multi-layer ball - assuming a launch speed of 175mph and launch angles of 9.5°and 11.5°, respectively. The figure shows that the wound-core ball has a higher spin rate than the multi-layer ball at the ball testing conditions (shown by the dots) and that the multi-layer ball has improved aerodynamics at almost all spin rates.

A comparison of a popular, older, wound-core golf ball and a popular, modern, solid-core golf ball suggests that the latter has both improved aerodynamics and is optimized for a lower spin rate. It can be seen in Figure 27 that for the impact speed typical of elite male golfers, at a spin rate of 3000 rpm, the aerodynamic improvement of a modern solid-core ball was calculated to be worth approximately ten yards over a traditional wound-core ball. The distance at the Actual Launch Condition spin, utilised in the conformance testing of golf balls, is shown by an orange dot in Figure 27. A review of the role of golf ball aerodynamics and dimple design was compiled for this study (R20).

The coefficient of restitution of the impact between the club and the ball, previously discussed in Section 3.2.1.1, is also dependent on ball material and construction. As impact speed increases, more energy is lost in the collision between the clubhead and the golf ball resulting in a lower coefficient of restitution. However, the stiffness of a golf ball can significantly reduce this decrease in coefficient of restitution, especially for the impact between the ball and a clubhead having significant spring-like effect. A golf ball with a lower stiffness will have a lower coefficient of restitution reduction at higher clubhead speeds (R19 - Effect of Equipment on Distance - Driver, Figure 28).

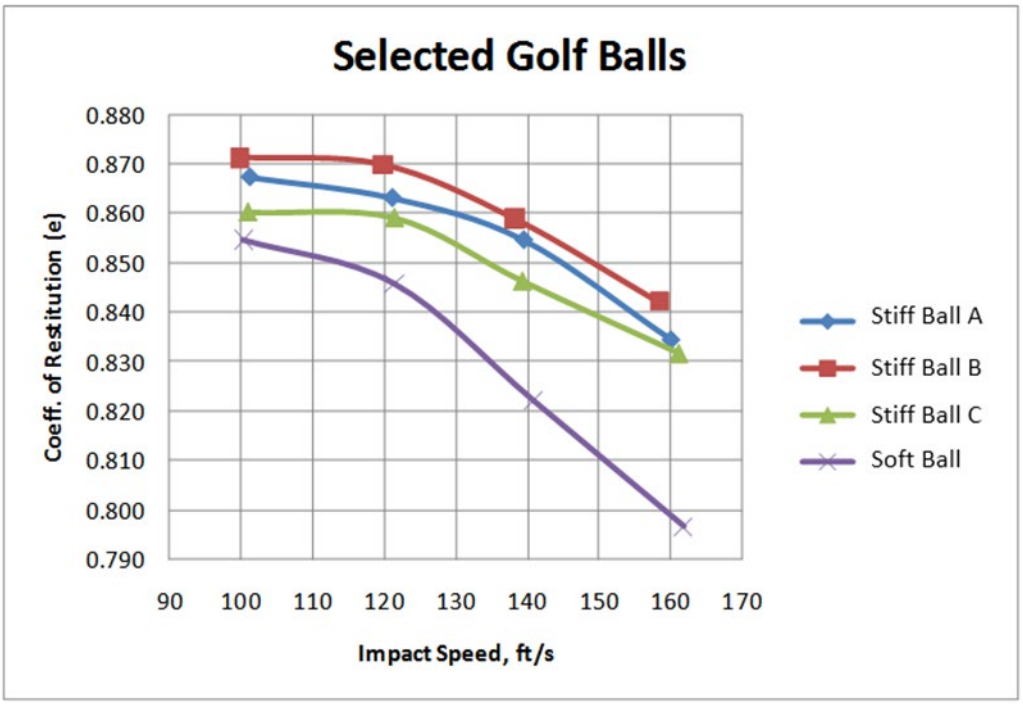


Figure 28 Coefficient of restitution for four golf balls with different stiffness properties. Coefficient of restitution is higher than the limit imposed on the clubhead due to differences in measurement technique.

It can be seen in Figure 28 that the difference in the coefficient of restitution (and thus the resulting launch speed and distance) between a soft ball and the stiff balls (A-C) is much greater at high impact speeds than at low ones.

3.2.2 Contribution of players to hitting distances

Broadly speaking, the golfer can contribute to hitting distance in three main ways:

- Athleticism
- Swing technique and swing parameters such as swing speed, launch angle and initial spin rate
- Course management strategy

Modern golfers are often identified as being more athletic than in previous generations (R40 - Player Interview Findings) and as having a strong focus on strength and flexibility training, overall health and fitness. Among other things, this athleticism can allow the golfer to generate more clubhead speed, which is an important factor in determining the overall distance of a golf shot (R55 - The relationships between driver clubhead presentation characteristics, ball launch conditions and golf shot outcomes, Journal of Sports Engineering and Technology 2014 228:242). There is evidence that clubhead speed for elite players has increased along with increases in distance. For example, Figure 29 shows that the 90th percentile of average clubhead speed of players on the PGA TOUR is high and has been increasing and likewise that the 90th percentile of average clubhead speed increased by 1.3 mph between 2007 and 2018 (R08 - Annual Driving Distance Report - 2019; Figure 29) and by 1.7 mph between 2007 and 2019.

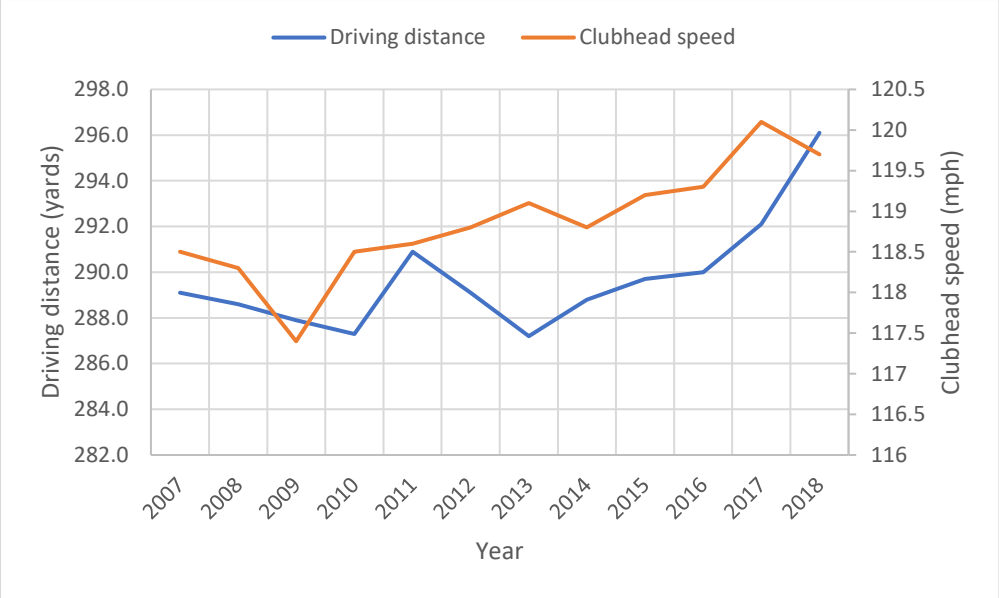


Figure 29 Changes in the 90th percentile of average clubhead speed on the PGA TOUR from 2007 to 2018 alongside changes in driving distance over the same period

Studies also indicate that the average clubhead speed for a tour professional is greater than that of low-handicap recreational golfers (R12 - Clubhead Speed), which in turn is greater than the clubhead speed of high-handicap recreational golfers (R55 - The relationships between driver clubhead presentation characteristics, ball launch conditions and golf shot outcomes, Journal of Sports Engineering and Technology 2014 228:242).

There are very few credible sources of clubhead speed for previous generations of golfers. However, at least two attempts were made to gauge clubhead speed of male elite golfers in the past (R01 - A Comparison of Clubhead and Ball Speeds at the 1957 and 2005-9 US Amateur Championships). It was found that the clubhead speed for two competitors at the 1957 U.S. Amateur was approximately 115 miles per hour. A similar earlier analysis found the clubhead speed of Robert T. “Bobby” Jones, Jr., to be approximately 113 miles per hour (R01).

Measurements of clubhead speed at World Long Driving competitions found that the average clubhead speed for male and female competitors was 145 and 116 miles per hour, respectively (R07 - Analysis of Trackman data gathered at World Long Drive events), with corresponding ball speeds of 214 and 171 miles per hour, indicating the human potential to generate swing speeds (and correspondingly ball speeds) that are much higher than the swing speeds typically generated by current professional golfers.

Various golfer physical attributes – such as height, weight, strength, flexibility and endurance – also have the potential to affect hitting distances over time as the athletic capabilities of a group of golfers improve. Data on changes in those attributes over time is generally not available. However, one exception is information showing that the reported heights of golfers on both the European Tour and the PGA TOUR have been increasing since the 1980s albeit very subtly (R46 - Relationship Between Height, Driving Distance and Success).

Not surprisingly, it was also found that both clubhead speed and average driving distance are negatively correlated with the age of golfers. Across the PGA TOUR, European Tour and Korn Ferry Tour, there is a significant relationship between seasonal driving distance and age. This relationship suggests that seasonal driving distance decreases by 0.49 yards for every year in age on the PGA TOUR, by 0.54 yards on the European Tour and by 0.46 yards on the Korn Ferry Tour (R02 - Age and its Relationship to Driving Distance and Success).

Another factor that is helping golfers improve their performance is the use of technology, especially launch monitors. Advanced technology has increasingly allowed golfers to measure and understand how changes in swing technique or equipment can influence the ball launch and shot outcome. The availability and accuracy of launch monitors have increased significantly over the last decade (R22 - Effect of launch monitor technology on performance in golf) and, along with other similar techniques, this is allowing players to optimize their equipment and swing to achieve increased distance (R40 - Player Interview Findings). As well as providing accurate, objective feedback about a shot or change in equipment, the increased use of launch monitors helps provide an increased understanding of ball striking and ball flight at all levels of playing ability (R22).

The use of technology, coupled with the use of adjustable clubs (R32 - History of Equipment Rules), has also facilitated a rise in equipment fitting. For example, data shows that over the last decade the launch conditions of professional male golfers have become slightly more favourable, in terms of distance (R22, Figure 30), and that certain equipment changes can be used to produce distance-enhancing changes in these launch conditions, such as the use of a lower spinning ball (R22, R20). The use of launch monitors can help a player achieve increased distance through the optimisation of equipment and launch conditions.

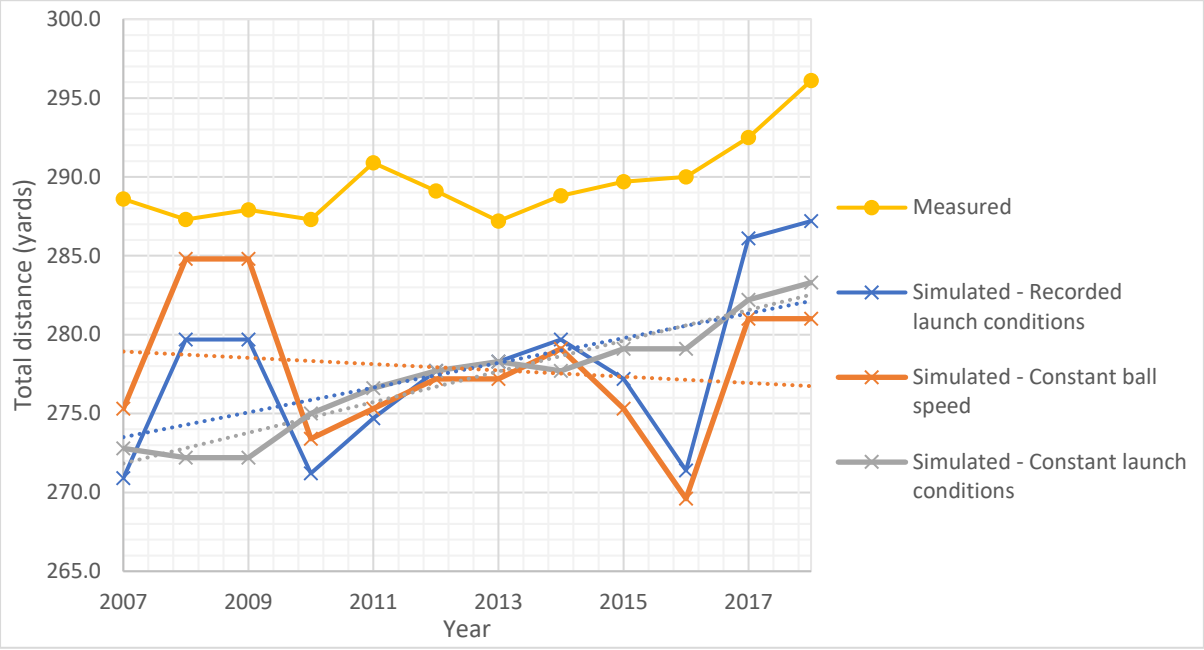


Figure 30 Measured driving distance on the PGA TOUR and the results of simulations with recorded launch conditions, constant ball speed and constant launch conditions

Distance Insights Report

According to a white paper by Trackman (a popular launch monitor brand), an average male amateur golfer has significantly lower ball speed, higher spin and lower launch angle than optimum for distance, given their clubhead speed.

In addition to player physical abilities, swing technique and equipment fitting, their strategic playing choices also can be a contributor to distance. The most direct and measurable manifestation of such strategic choices is club selection off the tee (R38 - PGA TOUR data from Shot Link (2016-18)), because the club used obviously has a direct bearing on the resulting driving distance. To illustrate using data from the PGA TOUR concerning par 4 holes, Table 2 demonstrates that the choice of club off the tee is strongly influenced by the length of the hole, which in turn strongly influences the resulting driving distance.

Table 2 Driving distance, approach shot length and club selection for par 4 holes (PGA TOUR). It should be noted that there are only two holes in the 225-274 bin, both of which are 274 yards long.

Hole Length Range (y)	Average Hole Length (y)	Average Drivers Used	Average Driving Distance (y)	Average 2nd Shot Distance (y)
225-274	274	14%	268	25
275-324	302	47%	266	48
325-374	357	27%	257	102
375-424	404	46%	272	134
425-474	449	79%	290	162
475-524	489	94%	299	191
525-574	536	96%	328	210

While it is not possible to evaluate the effect of all the possible individual configurations of hole layout, hazards, trees, property lines and other features that may affect distance, it was found that when club selection is accounted for as a factor, average drives on par 4 holes are 1.1-1.6 yards longer for every 10 yards of extra hole length and 1.0-2.3 yards longer for every 10 yards of extra fairway width. Further, club selection and driving distance depend on the players' average driving distance. In general, shorter hitters tend to use driver off the tee more often than longer hitters (R11 - Club Decision Making Model).

Simulations were performed of a sample men's professional tour to help assess the role of course setup on strategic choices of at least this cohort of golfers (R44 - Playing Strategy on the PGA TOUR). It was found in the simulations, that hole length and fairway width (including extreme cases of all fairway and no fairway) not only impact the strategic choices of individual golfers but may have long term influences on the skillset of golfers most likely to succeed.

3.2.3 The contributions of course conditions, setup and layout to distance

The condition of the playing surfaces (especially the firmness and height of cut of the turf), the topography of the hole (especially uphill/downhill), the nature and location of other potential obstacles and terrain features (such as bunkers), and environmental conditions (temperature, elevation, humidity, etc.) can all affect hitting distance.

Changes in agronomic practices since the late nineteenth centuries have impacted fairway turf conditions which, in turn, can have an impact on distance through bounce and roll, as were summarized in Section 3.1.

It was found that the three most significant controllable parameters that can affect bounce and roll were moisture level (and, associated with this, firmness of turf), mowing height of grass and mowing direction; in addition, grass type and organic matter level can impact bounce and roll (R03 - Agronomic Impacts on Bounce and Roll Distance).

The landing conditions of the drive are also a contributor to distance. On the fairway, testing indicates that the bounce and roll of tee shots is most strongly influenced by the impact angle, with a steeper impact angle having shorter bounce and roll. Impact spin and impact speed are also significant factors (R10 - Bounce and Roll Testing at Philadelphia Cricket Club (Militia Hill Course), R04 - An investigation into Ball-Turf Impact Characteristics, R45 - Preliminary Results of Turf Testing At Pinehurst #2 Spring 2005).

Given that turf firmness depends on soil moisture content, precipitation may be expected to impact distance. As an example, it was found that driving distances on the PGA TOUR and European Tour were approximately four yards shorter on days when there was rain compared to days on which there was not rain (R23 - European Tour Weather Conditions and Relationship with Driving Distance, R39 -PGA TOUR Relationship of Days with Rainfall and Driving Distance, Figure 31).

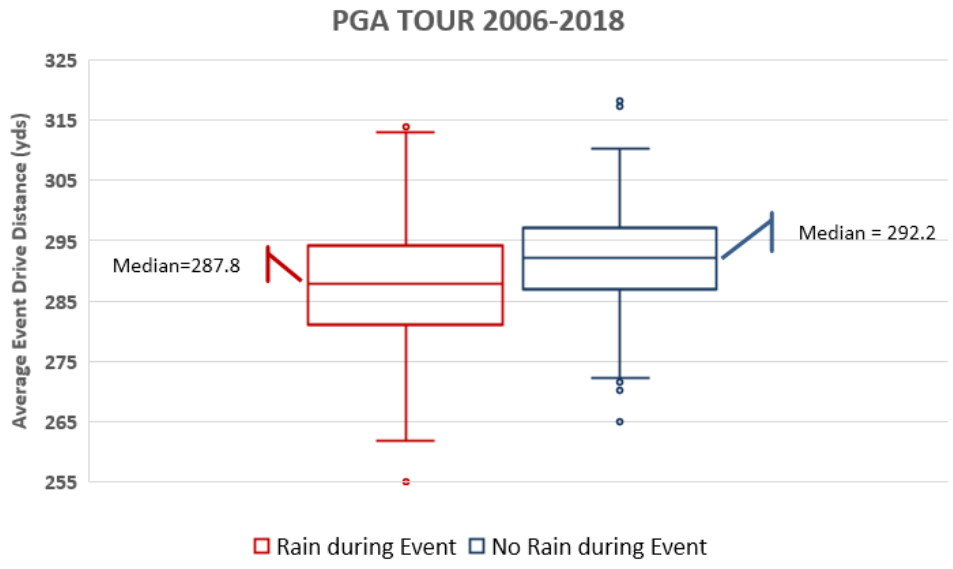


Figure 31 Difference in driving distance for PGA TOUR events with and without rain between 2006 and 2018

Enhanced irrigation systems led to greater water usage, and associated with this greater nutrient usage, by golf courses in the 1970s, 1980s and 1990s, but since 2000 increasing emphasis has been placed on water conservation practices and technologies, and nutrient management. The resulting general trend at many courses toward drier and firmer fairways in the future builds upon the already significant reductions in the consumption of water and nutrients that have been realized by many

golf courses since the early 2000s (R30 - Golf Course Water Use and Costs - Past, Present and Future; GCSAA, Golf Course Environmental Profile – Phase II Water Use and Conservation Practices on U.S. Golf Courses; and GCSAA, Golf Course Environmental Profile – Phase II Nutrient Use and Management on U.S. Golf Courses). Since drier (and therefore firmer) fairways are often recommended as best management practices, and given the increasing cost and scarcity of irrigation water in many regions (see Section 5.2.2.2), as well as increasing costs of nutrients, it can be expected that these increasingly common practices are likely to be adopted at even more courses in the future, with the result that fairway firmness will continue to contribute to increasing hitting distances in the future. While less significant, it was found that hotter weather also contributed to increased driving distance and that increased wind contributed to lower driving distance (R23). Simulated drives show that a drive travels roughly 3 extra yards for every 10°F increase in air temperature (ball temperature and humidity have a much less pronounced effect.) And while each 1mph increase in tailwind can add a little over 2 yards to a drive, if the wind is against the player it will cost nearly 3 yards per 1 mph of wind speed.

4. Analysis of golf course lengths

An historical review and analysis of golf course length is guided by a general understanding of terminology relevant to the subject matter:

- For analytical purposes, the “length” of a golf course is considered separate and distinct from a course’s “playing length” during any given competition.
- Course length is defined in this section as the total length from the longest set of tees listed on the scorecard.
- Where information is available concerning the length of a specific tournament or championship round, it is referred to here as “playing length.”
- Where subtle discrepancies may exist between the tee length listed on a scorecard, or in compiled data concerning competitive events and the actual length of the hole on a particular day of play, these are typically minor and attributable to small differences in tee placement and/or hole locations.

4.1 History of course and playing lengths

There is a wealth of data available showing both golf course and tournament playing lengths over a long period of time. Golf course scorecards and elite tournament scorecard lengths (including professional and amateur, male and female, and international, national and regional events) have been archived. In general, the historical information indicates that course and playing lengths have been increasing for more than a century and that these increases are strongly associated with the long-term increases in hitting distances across all levels of the game. Information from elite competitions for both men and women show a high correlation between their hitting distances and the tournament playing lengths.

Over 4400 reported lengths of golf courses from the United States between 1890 and the present were compiled and analysed. As shown in Figure 32, the long-term trend for more than a century has been for the overall length of courses in the U.S. to increase in length (R24 - Evolution of Golf Course Lengths Globally).

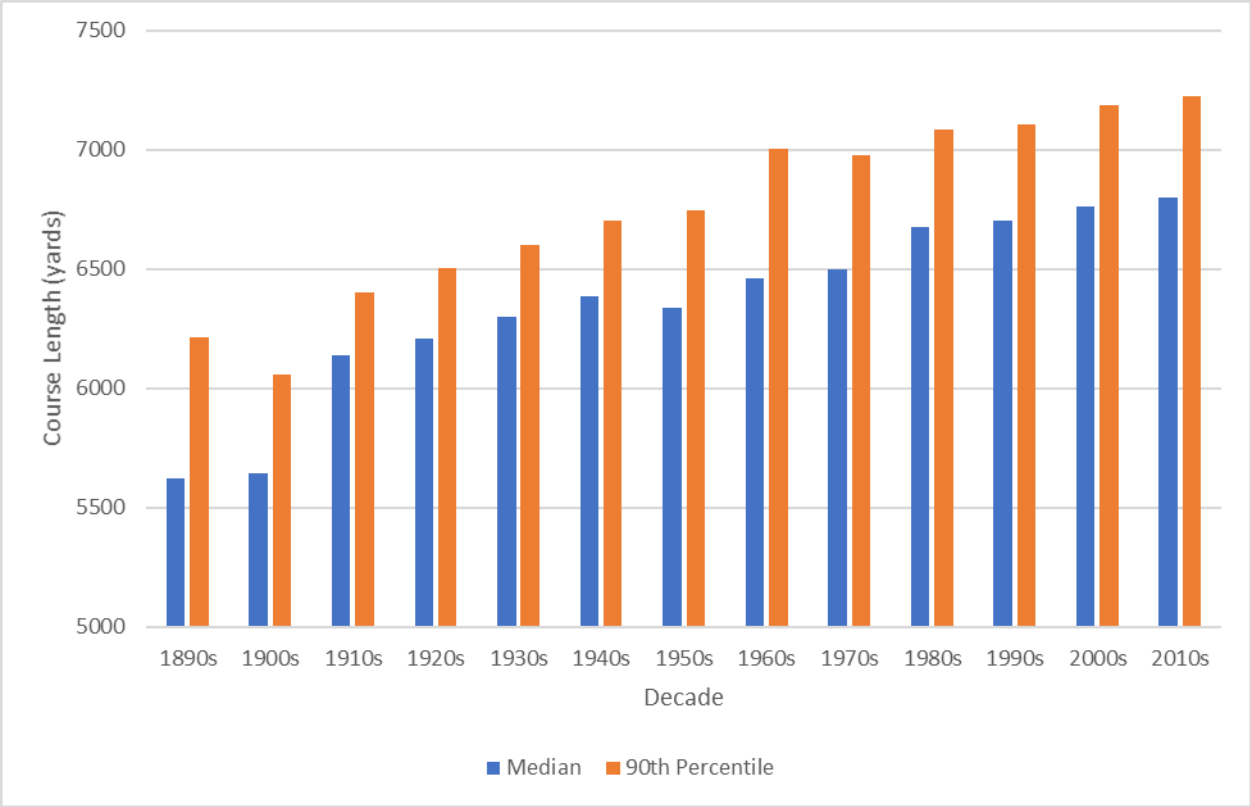


Figure 32 Evolution of golf course length (longest tees) in the U.S. by decade

Within the long-term trend shown in Figure 32, between 1900 and 1919, coinciding with the introduction of the Haskell ball (see Section 2.1.3), there was a particularly large increase in median course length (about 600 yards), and likewise a several-hundred yard increase in the length of the longest courses (as indicated by the 90th percentile). In the next several decades, there was growth averaging about 6 yards per year in the median course length and 9 yards per year in the 90th percentile course length. Then from the 1960s through the current decade of the 2010s, there was another period of growth averaging about 7 yards per year in the median course length and 5 yards per year in the 90th percentile course length. Overall, both median and 90th percentile course lengths increased by about 1200 yards from the 1900s to the present.

Outside of the U.S., the earliest documented golf course lengths were from the 1880s in the United Kingdom. In addition to the U.S. data, an additional 3300 data points were collected and analysed from four other worldwide regions (R24 - Evolution of Golf Course Lengths Globally). Since the 1880s, golf courses in other countries or regions outside of the U.S. show an overall global trend of lengthening (again, as measured from the back tees). While data and overall trends are presented for four regions, there was not enough data available to be able to confidently calculate decade to decade rates of change. Figure 33 shows the overall long-term trend of median golf course lengths for these regions and the U.S.

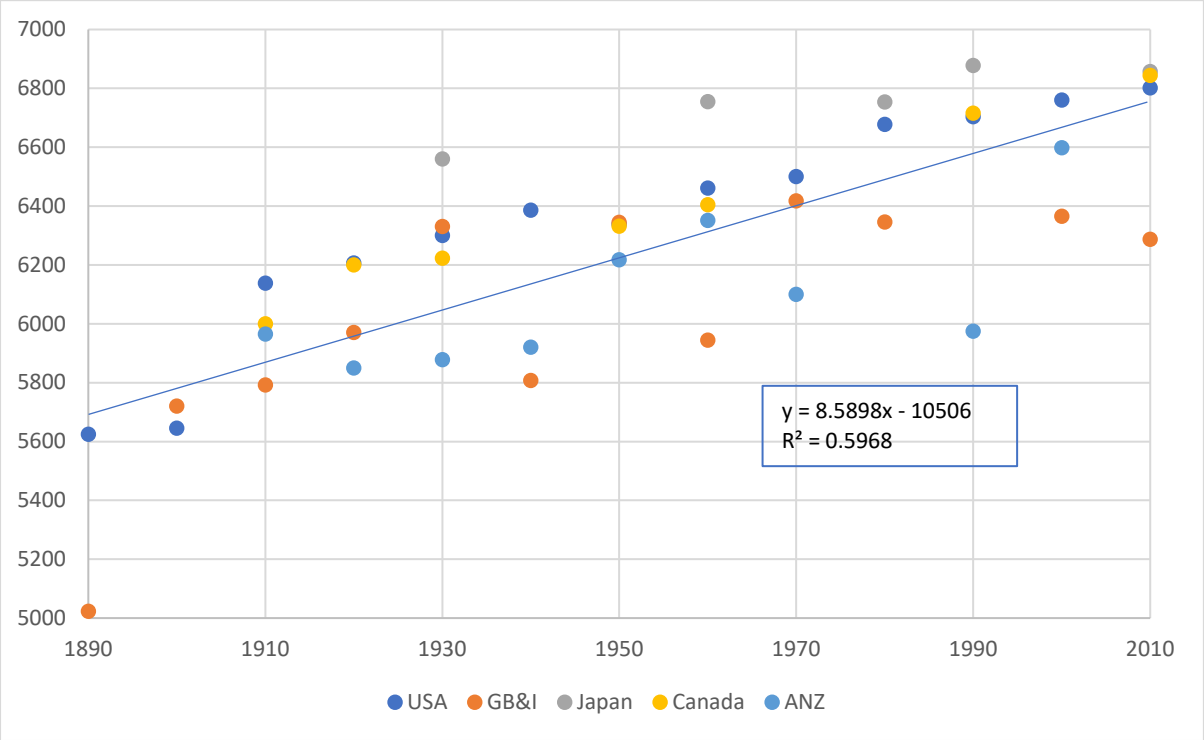


Figure 33 Long-term golf course lengths median trend for the U.S., Great Britain & Ireland, Japan, Canada and Australia/New Zealand

A search of online sources documented recent golf course lengthening projects (R24). The purpose of this effort was not to develop a comprehensive list of recent projects, but rather to identify projects that are representative of current and continuing trends in golf course lengthening. Projects to lengthen golf courses (typically described in online sources as "renovation," "re-modelling" or "master planning" efforts) recently have been completed or are underway in many countries around the world. Typically, these projects include the construction of new tees to lengthen courses, noting four examples of courses that have been lengthened to more than 7500 yards and one example of a course that has been lengthened to more than 8000 yards and to re-position bunkers further from the tees. The variation in the amount of length added to a golf course for these examples, ranged from less than 100 yards to more than 600 yards. 11 courses added length between 100 and 600 yards.

A study of new course openings for play at U.S. golf facilities was completed by using the NGF course opening database in April 2018 for courses opened between January 2011 and December 2016 (R37 - New Course Opening Study (US)). These courses were analysed for their characteristics using scorecard data, internet searches and data available within the USGA's Resource Management System. The goal of this study was to collect available data from 48 new U.S. course openings to allow comparison to the existing course inventory. Table 3 shows that the average course length for courses opening from 2011 to 2016 is just over 6900 yards. The forward tees for these courses were in the range of 4700 – 4800 yards.

Table 3 U.S. Course Opening data 2011 - 2016

Average Course Length from All Tee Markers by Course Type (yds.)						
Tee Marker	Forward	#2	#3	#4	#5	Back
Real Estate Development	4745	4861	5615	6059	6555	6915
Just Golf	4762	4857	5607	6052	6549	6909
Resort	4773	4963	5622	6068	6564	6917

The long-term trend of increasing total golf course length is mirrored in the playing length of competitions among both male and female elite golfers at the regional, national and international levels. For example, playing lengths in tournaments run by state and regional golf associations in the United States (including over 800 reported playing lengths of events for men and women at the amateur and professional levels and in junior, senior and other defined age categories) have increased at a statistically significant average rate of approximately 7 yards per year since the 1980s (R42 - Playing Lengths of Golf Courses Used for Amateur Golf Competitions in the United States, 1979-2018). For example, the average playing length of state and regional championships designated for men and women have lengthened significantly as shown in Figure 34.

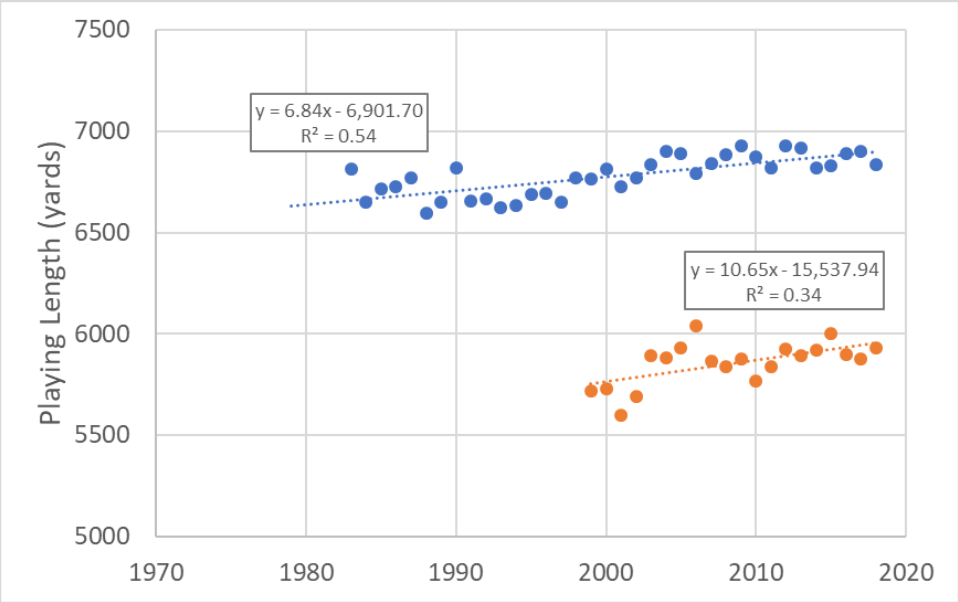


Figure 34 Average playing length of United States state and regional golf association events designated as men's (blue) and women's (orange). Playing lengths for women's events prior to 1999 where not reported in the survey responses.

This trend of increasing playing lengths over time is also reflected by the playing lengths of the U.S. Open, U.S. Senior Open and several USGA amateur championships for men, as shown in Figure 35 and Figure 36 (R25 - Evolution of Playing Lengths for Elite Competitions in the United States). Similar data is presented for The Open Championship in Figure 36.

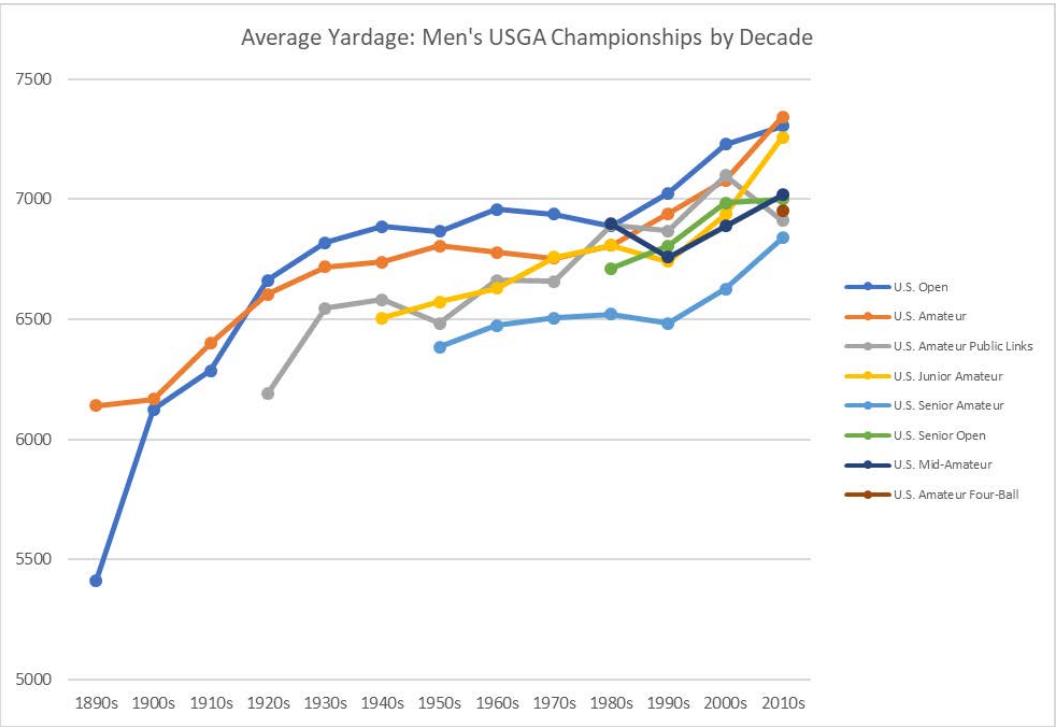


Figure 35 Playing lengths of certain USGA championships

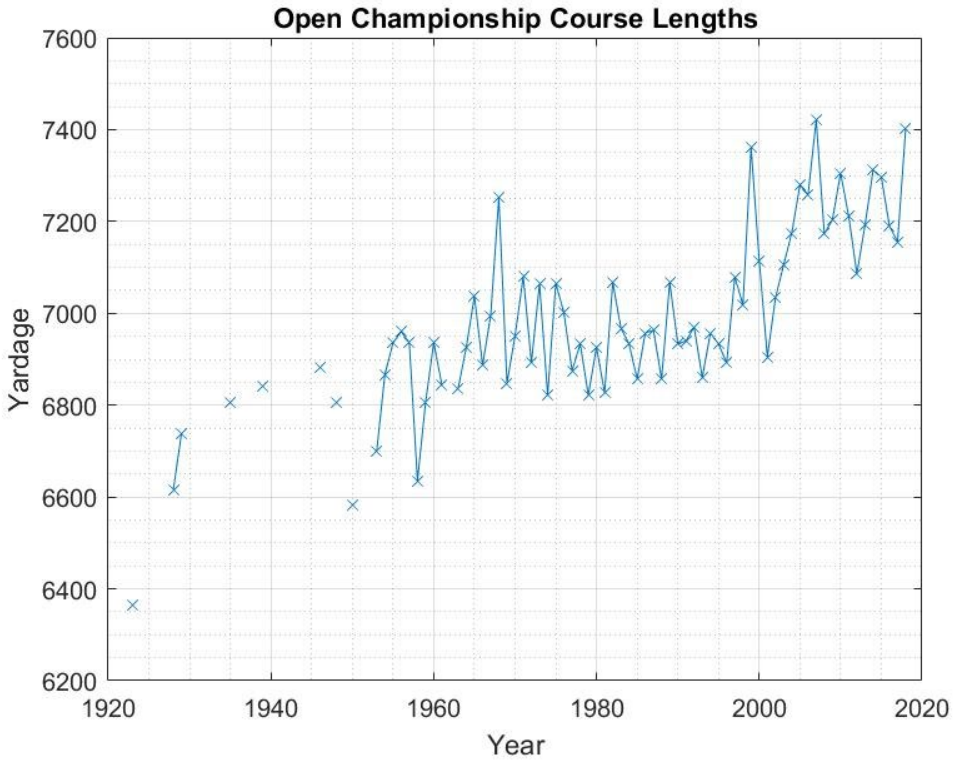


Figure 36 Course lengths of The Open Championship

Similar lengthening has occurred in tournaments held elsewhere in the world (R41 - Playing Lengths for Select Elite Competitions, ca. 1920 to Present). For example, the Australian men's and women's national open and amateur national championships have all lengthened significantly since their inception, as seen in Figure 37.

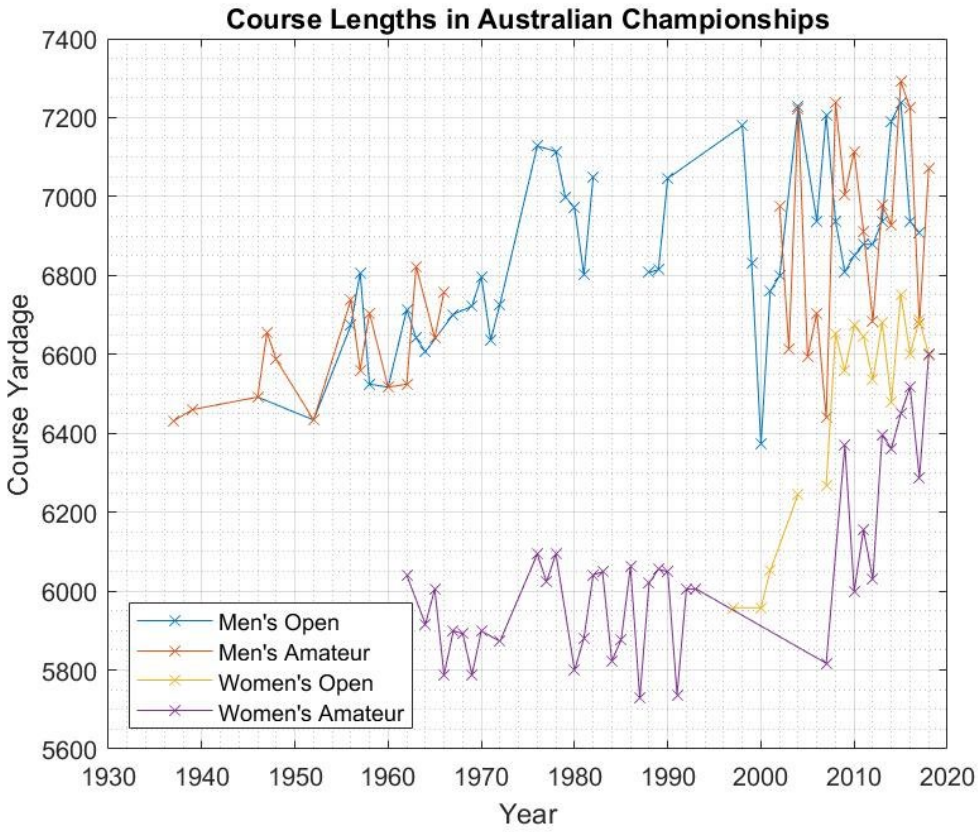


Figure 37 Increasing playing length of Australian national championships

Similar increases in playing length have also occurred on the professional tours. For example, the average playing lengths of tournaments on the LPGA Tour, the PGA TOUR and the European Tour have all increased over the past decades (R54 - The History of Elite Competitive Golf in the United States; R06 - Analysis of Playing Lengths of Golf Courses on the PGA TOUR; R36 - Lengths of Golf Courses on the Professional Tours). This is shown in Figure 38 through Figure 40, respectively. The extent of increase over time is illustrated by the fact that average playing length on the PGA TOUR in recent years exceeds the maximum playing length prior to 1950 (see Figure 39).

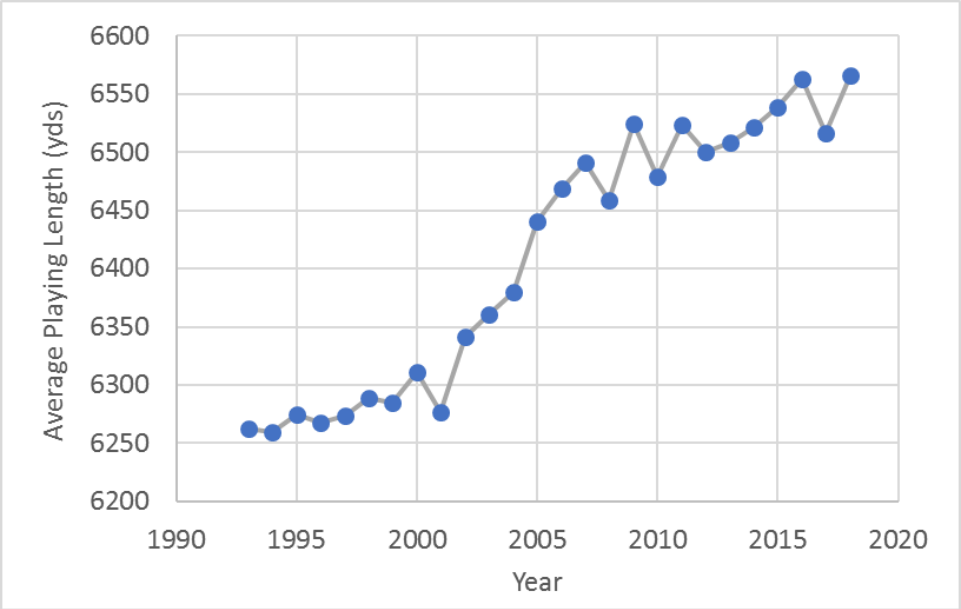


Figure 38 Increasing average length of LPGA Tour events

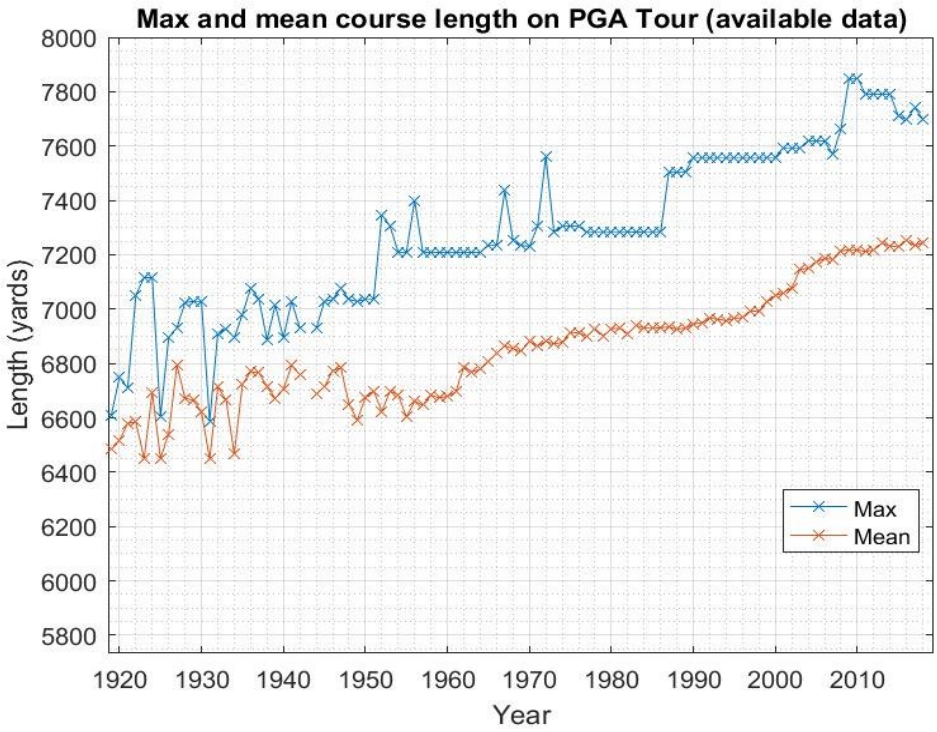


Figure 39 Increasing length of PGA TOUR events from 1929 to 2018. During that period, the average event length increases from 6500 yards to 7300 yards, an average rate of 9 yards per year.

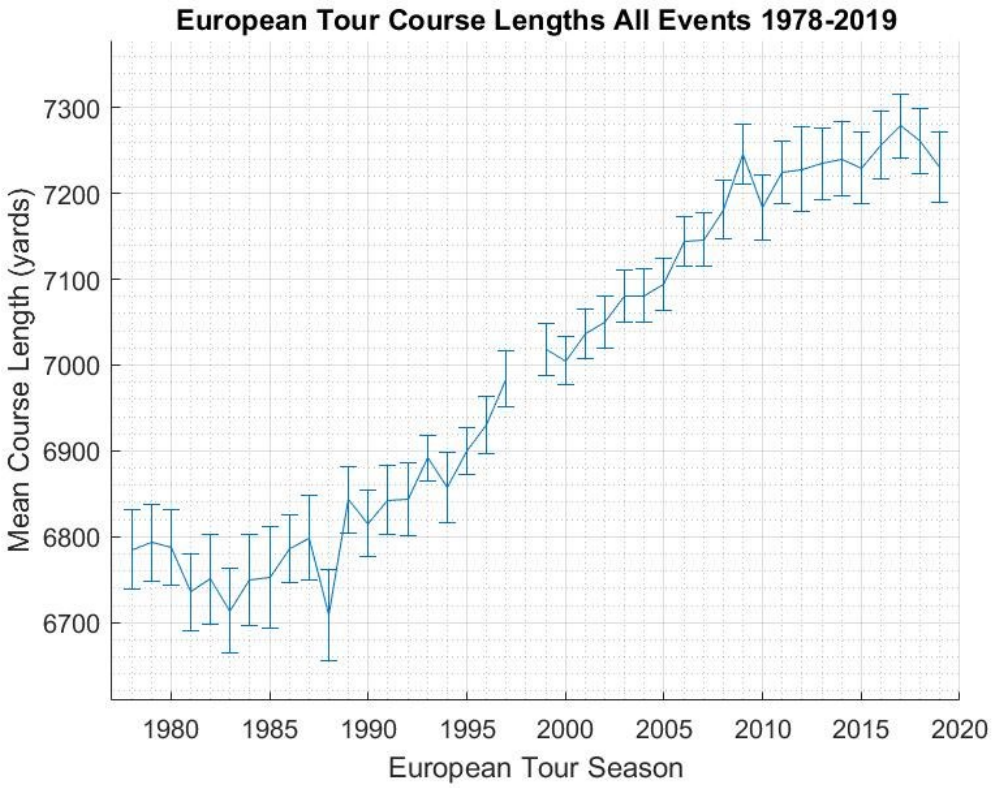


Figure 40 Average playing length of European Tour courses over time

It can be seen in Figure 32 through Figure 40 that there are consistent, long-term trends of increasing course and playing lengths and, except for the European Tour in very recent years, these trends are ongoing. Over the past 120 years, courses in the U.S. have lengthened at an average rate of approximately 10 yards per year. Over the last several decades, the playing lengths of elite championship events (both amateur and professional) have increased at a similar rate, averaging between 7 and 12 yards per year.

4.2 Relationship between hitting distance and course/playing lengths

The long-term overall increases in course length appear to be closely associated with the long-term increases in hitting distances that have occurred over the same period. Although golf courses can become longer for other reasons as well, the more than 100 years of history and data indicate that increases in course length typically occur, after a time lag, in response to increases in hitting distance. Likewise, increases in tournament playing length over time appear to be strongly related to increases in hitting distance for players in those tournaments.

4.2.1 Early contributors to course lengths

Information on the contributors to course lengths before 1980 was collected through an extensive literature review, with priority placed on contemporary source materials (R53 - The History and Evolution of Hitting Distances and Golf Course Lengths Before 1980). Relevant sources consulted for this project included: 1) commentary on individual golf courses and golf course design in contemporary golf periodicals; 2) similar content in contemporary newspapers and non-endemic

magazines; 3) monographs about golf course architecture and golf course architects; and 4) histories of individual clubs and courses. Given the nature of the information available, it is not realistic to associate discrete changes in course lengths with any individual factor. More important is to simply identify the developments that may have contributed variously to increases in course lengths.

This analysis suggests that increases in hitting distances have been the most significant contributors to course lengthening over the past 120 years and that increases in course lengths during that period have closely corresponded with continuing increases in hitting distances. Before 1900, the largest contributors to course lengthening were the tendencies to standardize golf courses to 18 holes and to imitate certain golf courses that were considered models. For purposes of illustration, the history of course lengthening can be divided into four eras.

4.2.1.1 Before 1850

Little is known about the character and evolution of the few golf courses that existed prior to the mid-1700s. A survey of Scottish golf courses from the first half of the 19th century shows that the number of holes varied from four (Peterhead) to 18 (St Andrews), with more than 50% of courses having eight holes or less. Contemporary texts indicate that individual holes ranged in length from 100 yards to 600 yards, while overall course lengths ranged from less than 2000 yards (Fortrose) to nearly 6400 yards (St Andrews). The variation in overall course length is principally a reflection of the variation in the number of holes from course to course.

4.2.1.2 Circa 1850 to Circa 1900

The first appreciable increases in golf course lengths occurred toward the end of the 19th century, driven by the expansion of many golf courses to 9 or 18 holes. This move toward standardization was precipitated by the emergence of the Royal and Ancient Golf Club of St Andrews as a rule-making authority for the game by the 1890s and reflected the fact that the St Andrews rules stipulated that a round of golf comprised 18 holes.

Standardization was also realized through the imitation of exemplary golf courses. Efforts to identify and describe the best golf courses in the British Isles first appeared in magazines and books in the 1880s. The number of articles written on this topic grew significantly in the 1890s and the content expanded beyond description of golf courses to include critique of the elements and characteristics of golf courses that provided the best tests of the game. Importantly, a consensus emerged from these discussions on the essential elements of a test of golf: 1) that a round of golf should require a player to use every club in the bag; and 2) that over the course of a round, a player should be required to demonstrate a full range of skills with these clubs. Many who wrote on the subject shared a strong belief that the length of each hole should be built around the length of one, two or three full shots (and specifically the typical lengths of a full shot by a highly skilled player). Looking collectively at these developments, it is apparent that the courses held in highest esteem at the time – and therefore those that were imitated – were 18-hole courses that often approached and exceeded 6000 yards in length.

Finally, it is noted that late 19th-century lengthening of golf courses corresponded with the modest increases in hitting distances, but the extent to which increases in hitting distances contributed to course lengthening at this time is not clear. The exception to this general trend toward lengthening were the small number of courses constructed to serve women's clubs in the British Isles and the United States that were typically in the range of 1500 to 2300 yards and typically comprised nine holes.

4.2.1.3 Circa 1900 to Circa 1930

The expansion in golf participation and the concurrent surge in course building that started in the 1890s accelerated in many countries around the world in the first decade of the 20th century. At the same time, the new rubber-core Haskell ball that was introduced in 1898, together with other advances in equipment, course conditioning and swing technique, were leading to substantive increases in hitting distances. Contemporary sources confirm that the rubber-core ball's effect on hitting distances was the primary reason cited for significant course lengthening during the years immediately after it began to be widely used. As the design and manufacturing of the rubber-core ball improved over the three decades following its introduction, resulting increases in hitting distances continued to place pressure on course lengths.

Concurrently, the rapid growth in the number of golf courses in the U.S. and UK in the early 20th century created competition for customers and club members, and contemporary sources suggest that distance and difficulty were two of the criteria around which courses competed. In some under-supplied markets, courses were lengthened simply to accommodate more golfers. In these ways, market forces drove the first generation of professional golf architects to design longer and increasingly sophisticated golf courses with multiple tees to continue to challenge all players.

An important observation to help explain the recurrence of lengthening was made by the influential British golf writer, historian and critic Bernard Darwin, who in 1912 wrote an essay on the relationship between the nature of a golf course and its influence on a golfer's approach to playing the game. Essentially, Darwin's essay argued that longer courses foster longer drives; and, in turn, that longer drives foster longer courses. It was a clear recognition that hitting distances and course lengths are interrelated and that the relationship is cyclical.

4.2.1.4 Circa 1930 to present day

The onset of the Great Depression and World War II brought golf course construction virtually to a halt from 1930 through the late 1940s in many countries where the game was well-established, with the notable exception of the United States, where federal public works programs led to the construction of more than 350 public golf courses. When course construction resumed in the post-war years, demand to toughen and lengthen golf courses in response to incremental increases in hitting distances and low scoring led to incremental growth in course lengths. Evidence of these changes is best seen in the work of Robert Trent Jones, Sr., whose designs established a new precedent for long and challenging golf courses that influenced trends in golf course architecture worldwide.

In the 1950s, many golf course architects began to favour the use of multiple teeing areas to provide both variable length and substantial length to their designs. Ultimately, this approach led many courses to shorten forward tees and significantly lengthen the longest tees. Beginning in the 1960s, the integration of golf courses with planned housing developments in some projects principally in the United States may have led to incremental course lengthening that provided for more golf course frontage and thereby increased the total market value of the development.

Increases in hitting distance, together with increased competitive pressures and the perceived marketing value of long, so-called "championship" courses, have contributed to course lengthening up to the present day, notwithstanding the decline in golf course development associated with the global financial crisis of 2007/2008 (D. Hueber, The Changing Face of the Game and Golf's Built Environment, 2012). These economic pressures curtailed investment in major capital projects, including the construction of new golf courses and new golf course developments, as well as projects

to renovate and expand existing golf courses. With recent recovery in some of the major economic markets, golf course construction and renovation has resumed and it can be seen that the latent need to address increases in hitting distance is again driving course lengthening efforts (R24).

4.2.2 Relationship between hitting distances and course/playing lengths in professional golf

In more recent decades, the evidence of the strong correlation between longer courses and longer hitting distance is also shown by the increase in the playing length in elite competitions. The largest source of data in this regard comes from the LPGA Tour and PGA TOUR.

As described in Section 2.2.1, the PGA TOUR has been consistently measuring driving distance on two holes at each of its events since 1980 and there also is other information from certain other elite male tournaments going back as far as 1940. As shown in Figure 41, the average course lengths and driving distances in these tournaments are highly correlated.

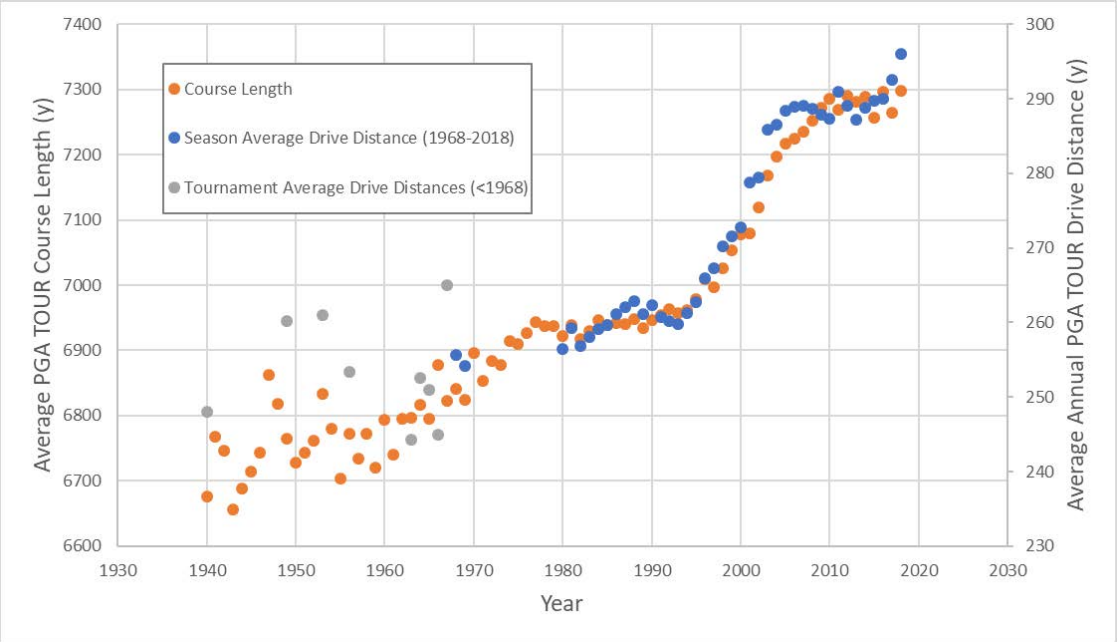


Figure 41 Season long annual average driving distance (measured holes) on the PGA TOUR (1968 – 2018 in blue). Tournament average driving distance measurements (prior to 1980 in gray) superimposed on average course length (orange)

In fact, for the period from 1968 to 2018, the coefficient of determination (R^2) of the correlation between average annual driving distance and average course length is 97%. It can also be seen in Figure 42 that earlier episodic data points (gray) appear consistent with the regression of the more robust 1968 through 2018 data points.

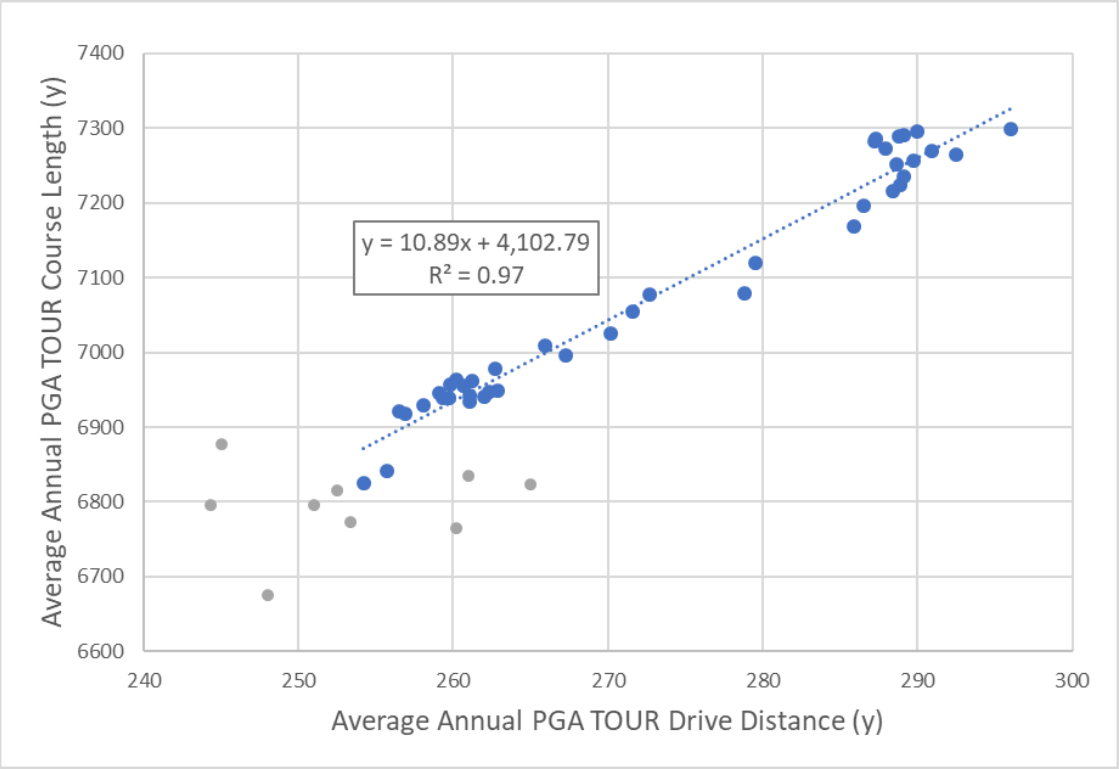


Figure 42 Correlation of annual average driving distance (measured holes) to average course length on the PGA TOUR (1980 – 2018 in blue) with other sources of driving distance measurements (prior to 1980 in gray).

The LPGA Tour average driving distance data available since 1993 also shows a strong statistical correlation between driving distance and playing length. This relationship is strengthened by incorporating a five-year delay between driving distance and course length (in other words, the course length most closely tracks driving distance five years in the past), as shown in Figure 43.

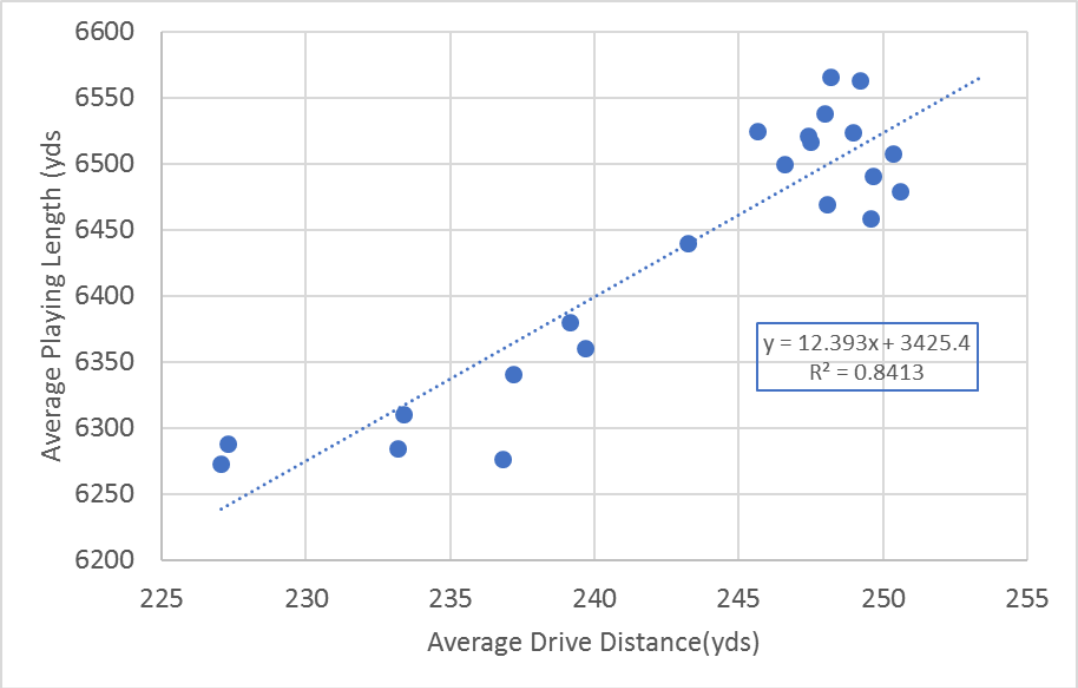


Figure 43 Correlation between annual average driving distance and annual average playing length with a 5-year offset in playing length. Annual average driving distance (measured holes) on the LPGA Tour (1993 – 2018).

4.2.3 Evolution of the Length of the Top 100 Courses in the U.S.

Golf Digest has produced a biannual ranking of the top 100 golf courses in America since 1975. When the average length of these courses is compared to the average annual drive distance on the PGA TOUR, it was found that the drive distance is an excellent predictor of the average length of the top 100 courses, six years later as shown in Figure 44 (R26 - Evolution of the Length of the Top 100 Courses).

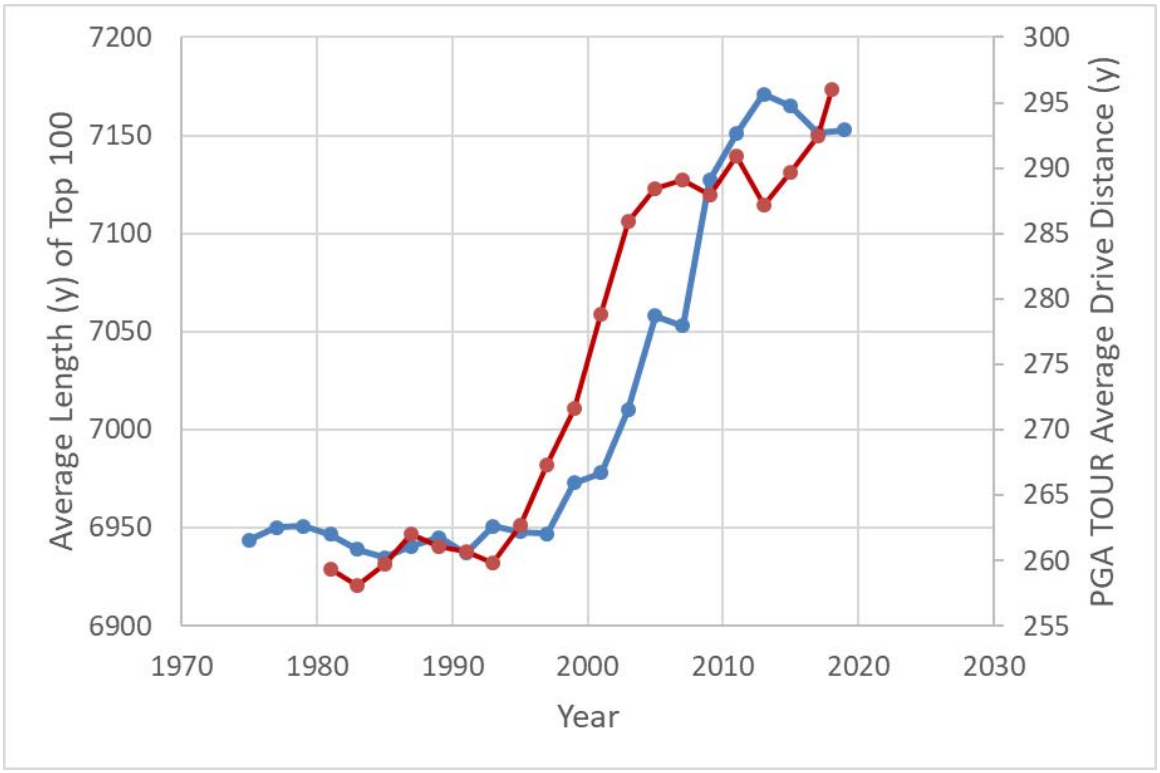


Figure 44 Average length of Golf Digest Top 100 courses (blue) and PGA TOUR average annual drive distance (red)

Of the 100 courses in the 2019/2020 Top 100 listing, 18 have hosted at least one major championship since 2000. It was found that those 18 courses have lengthened significantly more than the other 82 courses on the list.

4.3 Availability and length of other tees

The previous parts of Section 4 focused on the evolution of the length of golf courses from the longest set of tees, as well as on playing lengths in competitions for elite golfers. Almost all courses have other tee options that are shorter than the back tees for use by golfers with different hitting distances. It is challenging to gather information that allows a detailed assessment of the evolution of the length of such multiple tees, because tee options have increased over time and vary from course to course and because there is no standard way of identifying individual tees. Information was compiled to help assess the evolving length of two categories of such tees: the second-longest tees on a course and the most forward (shortest) tees on a course.

4.3.1 Second longest playing length set of tees

The second longest tees were tabulated from U.S. scorecard data starting in the 1950s until today to understand how these tees have changed in relation to the back tees on golf courses (R24). As shown in Figure 45, the median of the playing length of the second longest tees is increasing over this period at a rate of about ¼ yard per year (which is not statistically significantly different from zero). Using the same data set, the 90th percentile of second longest tees playing length is increasing at a rate of 4 ½ yards per year.

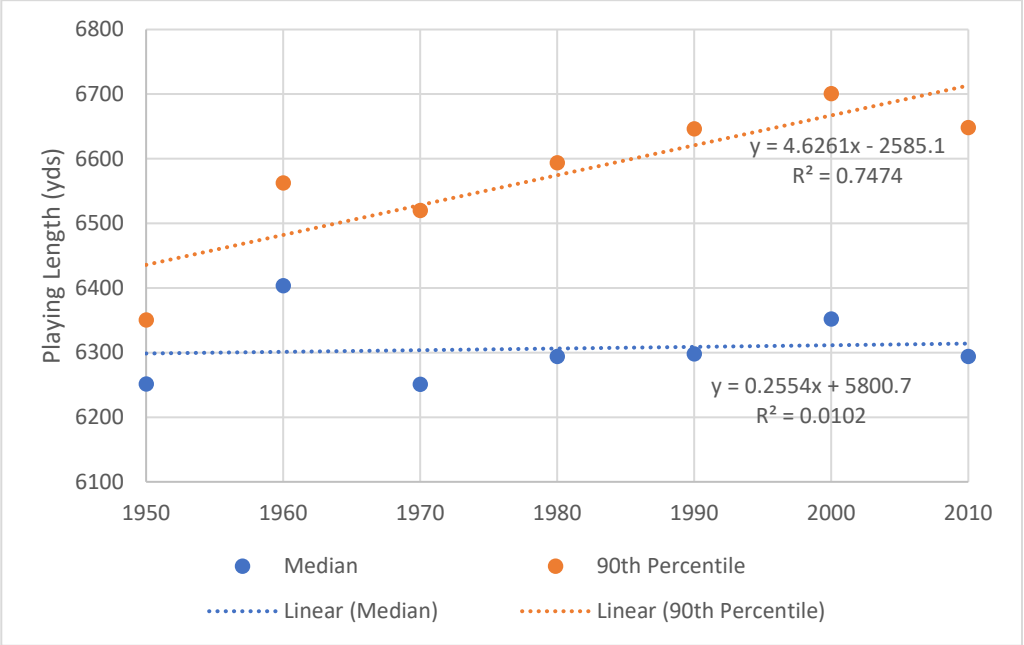


Figure 45 Playing Length of the second longest tees: 1950s to 2010s

4.3.2 Forward tees, shortest playing length

Data also were compiled on the shortest length tees at U.S. courses, R24. Figure 46 shows that the median forward tee length was over 6000 yards for the decades of the 1910s through the 1950s for golf courses in the U.S. After the 1950s, both the median and 10th percentile, representing the shortest courses available, have declined through the 2010s to a median of 5267 yards.

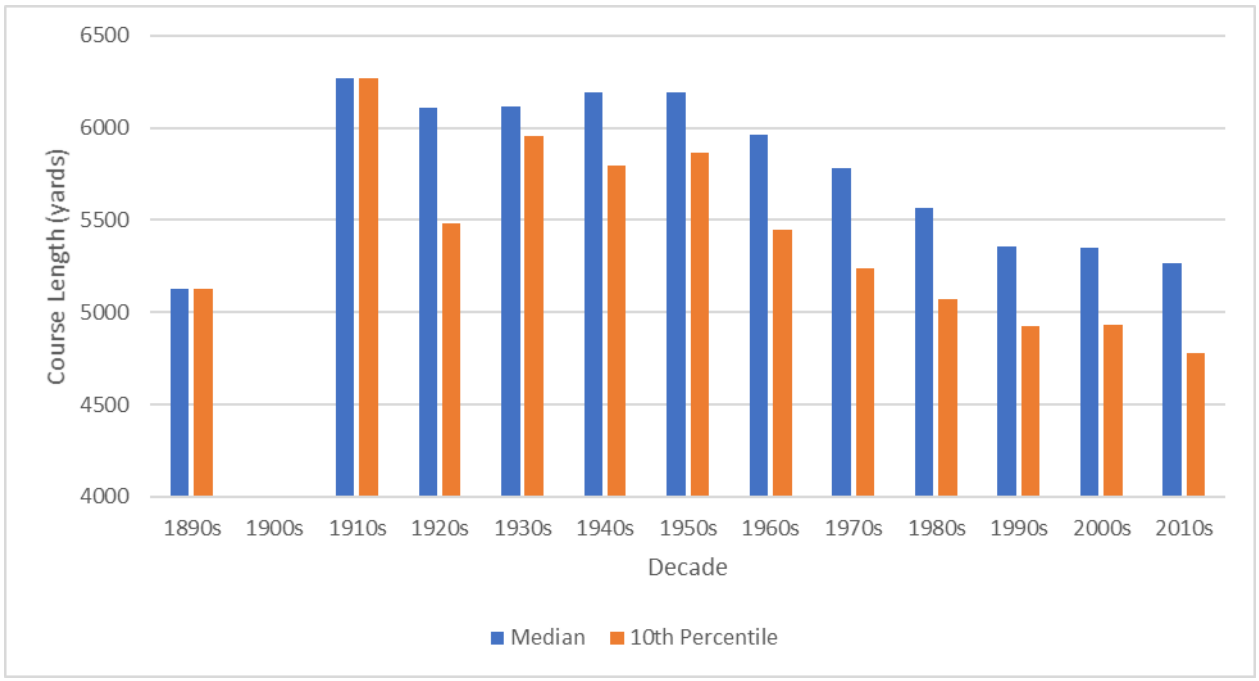


Figure 46 USA Golf Course Playing Length by decade – most forward tee

4.4 Forward tee lengths in relation to hitting distances

Most golf courses offer a variety of playing lengths to accommodate differences in golfer skill level including driving distance. A long standing concept in golf is that a golfer will reach a green in regulation on most holes with well-played shots -- a tee shot on a par-3 hole, in two shots on a par-4 hole or with three strokes on a par-5 hole. Shorter hitting golfers may seek out shorter playing lengths in order to have a similar playing experience compared to other golfers capable of longer hitting distance or even compared to themselves in previous times due to aging or injury. The playing length available and selected in combination with a golfer's driving distance affects their golfing experience.

4.4.1 Availability of forward tees for shorter hitting golfers

For shorter hitting golfers, the shortest playing length, or forward tee, is an important reference point in their tee selection decision. In order to assess the current availability of forward tees, the USGA Course Rating database was used to inventory the playing lengths available at courses within the USA in 2018 (R43 - Playing Lengths Study (US - 2019)).

Two of the more well-known recommendations of appropriate playing lengths are "Tee It Forward" and "Longleaf." As shown in Figure 43, both recommend similar playing lengths in relation to a golfer's average drive.

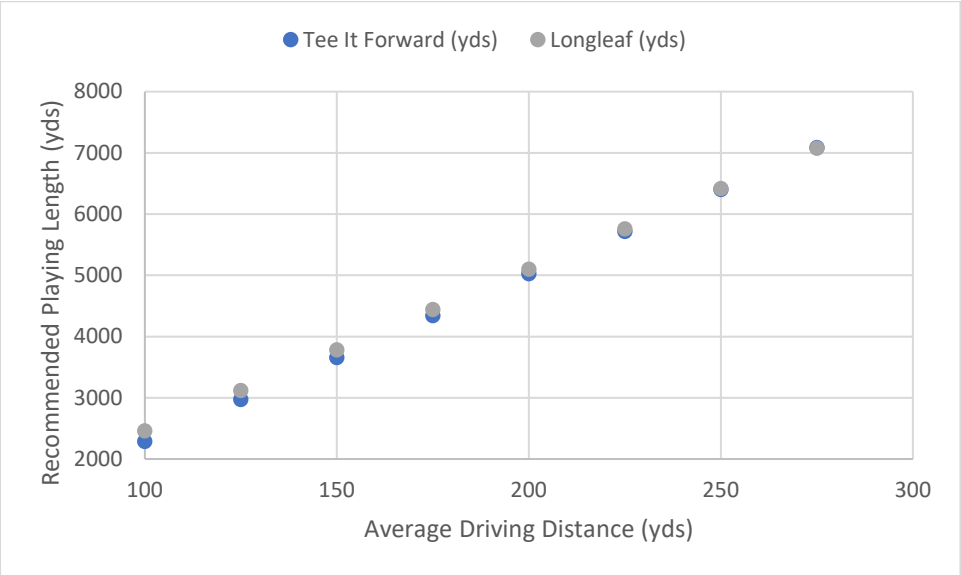


Figure 47 Comparison of playing length recommendations based on average driving distance

Previous studies have suggested that many golfers utilize playing lengths above these guidelines and may not have short enough rated tees to suit their hitting distance. For example, on a par-72 course of about 5000 yards, the length of a typical par-4 hole would be in the range of 300 yards. A golfer playing from those tees whose typical drive is in the range of 150 yards would have little or no chance to reach such a green in regulation, as their second shot would need to travel as far as the shot played from the tee with a driver.

Figure 48 shows that only 8% of U.S. golf courses offer a playing length that would correspond to an average driving distance of about 150 yards (R43 - Playing Lengths Study (US - 2019)). Also shown, about 18% offer a recommended playing length for average drives of 175 yards and about 60% offer a playing length recommended for average drives of 200 yards.

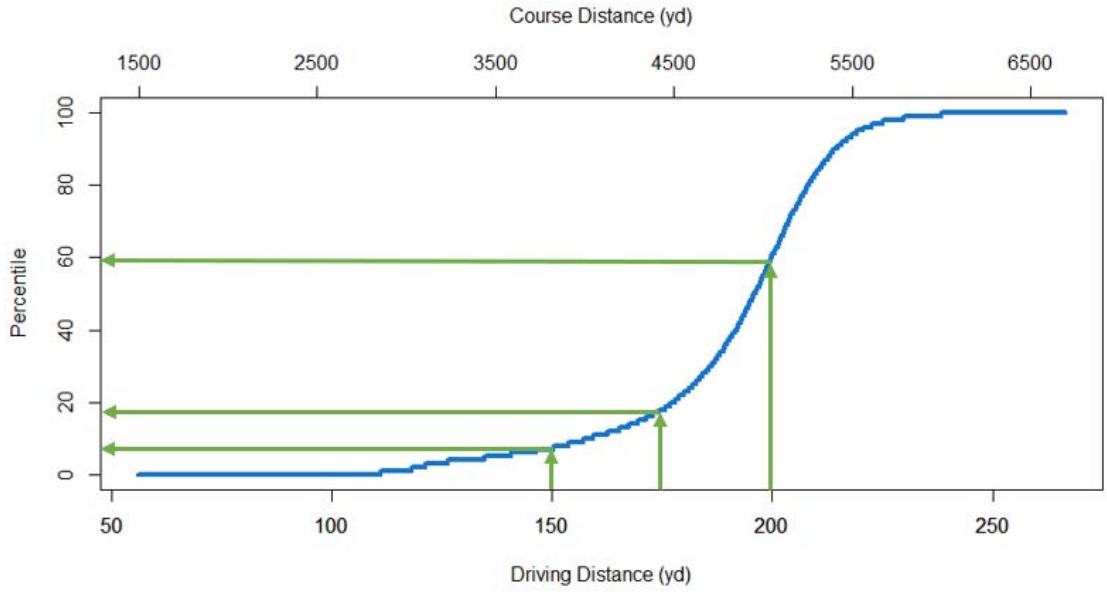


Figure 48 Cumulative distribution of the shortest playing length or forward tee based on average driving distance – U.S.

Analysis of tee lengths at courses in other regions (England, Japan, New Zealand, Japan, and Canada) exhibit similar characteristics to a greater or lesser degree (R49 - Tee Yardage Inventory).

5. Impact of increases in hitting distances and course lengths

Increases in hitting distances and golf course lengths impact the game in various ways. This section analyses this in two overall types of impacts.

The first part of this section reviews how the length of a hole, relative to hitting distances, impacts the range of skills required of a golfer. This can be analysed in two basic parts. First, when holes are not lengthened to compensate for increasing hitting distances, over time the challenges presented to, and shots played by the golfers who play from the longest tees on the course will change. This also can lead to golf courses no longer being as suitable for elite competitions from their back tees. Analysis is also presented on whether increasing driving distances are leading to driving becoming a more important skill at the expense of other skills (even in cases where courses have lengthened).

Second, when holes (and by extension the course) become longer in response to hitting distance increases (as Section 4.1 shows is often the case) additional costs are typically required to build or modify and to maintain the longer courses and other longer-term sustainability impacts may arise.

It should be noted that while this section is based on the available data which are primarily from the professional tours (and especially the PGA TOUR because of its ShotLink® system), the overall analysis is applicable to other cohorts in golf as well.

5.1 Impact of hitting distances on skills

5.1.1 Changes in the underlying challenge

As hitting distances increase, the nature of the challenge of a given hole for golfers using any particular set of tees will necessarily change when the hole itself is not modified to correspond to the distance increases. The player may be able to use a shorter club from the tee and/or the approach shots will get shorter if the same club is used from the tee; in both cases, the nature of the hole's risk/reward challenge changes as the hole becomes shorter relative to the hitting distance of the golfers who play from those tees.

On the PGA TOUR, since 2004 there have been significant changes in the approach shot distances for holes of various lengths. For example, approach shot distances in 2004 and 2011 were significantly longer than in 2018 for both longer and shorter, par-4 holes, as can be seen in Figure 49. Therefore, even over this relatively short 14-year period, the nature of the shots played on these shorter and longer holes has changed significantly.

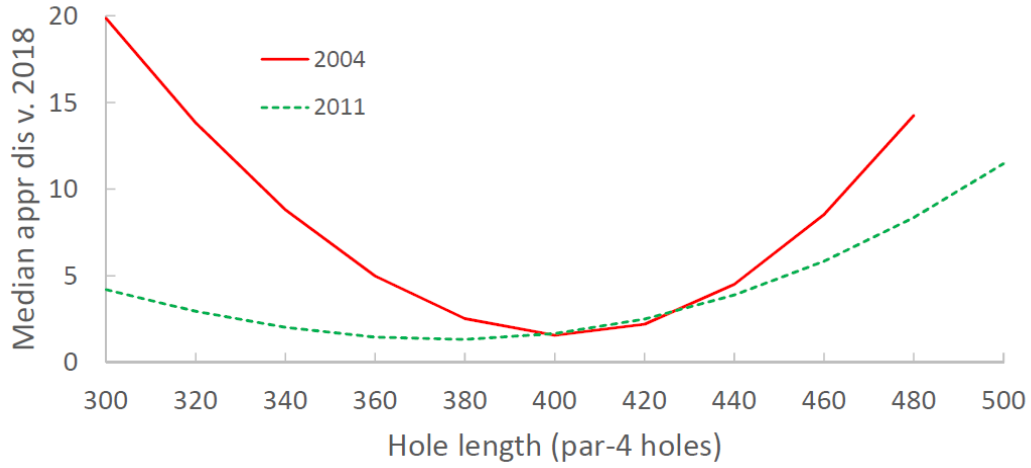


Figure 49 PGA TOUR approach shot lengths for par-4 holes (all lengths in yards) comparing 2018 to 2004 and 2011

It should also be noted that over this same period (2004 to 2018), second-shot distances on par-4 holes declined an average of 7 yards and second shot-distances on par-5 holes declined an average of 9 yards.

This demonstrates that course set up can influence driving distance in a variety of ways. Given this, a study of how course set up and hole lengths have changed was conducted. One aspect of this analysis looked at the relationship between hole lengths and approach shot lengths on the PGA TOUR (R09 - Approach Shot Distances and Hole Lengths on the PGA TOUR). This showed that average hole lengths between 2004 and 2018 have increased at approximately the same rate as driving distance on the PGA TOUR.

Figure 50 shows the distribution of approach shot lengths on par 4s in 2004 and 2018.

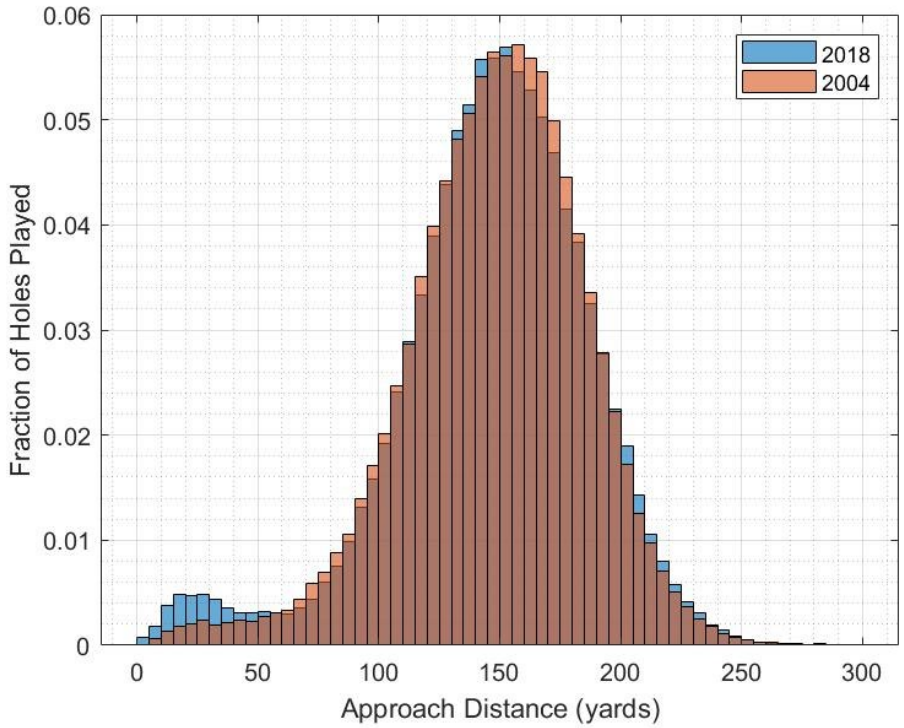


Figure 50: Approach shot distances on Par 4s on the PGA TOUR in 2004 and 2018

One interesting feature in Figure 50 is the increase in the number of approach shots from within 50 yards in 2018 compared to 2004. This can be explained by an increase in the number of short par 4s played on the PGA TOUR, despite the increase in mean par-4 length. This can be seen by looking at Figure 51.

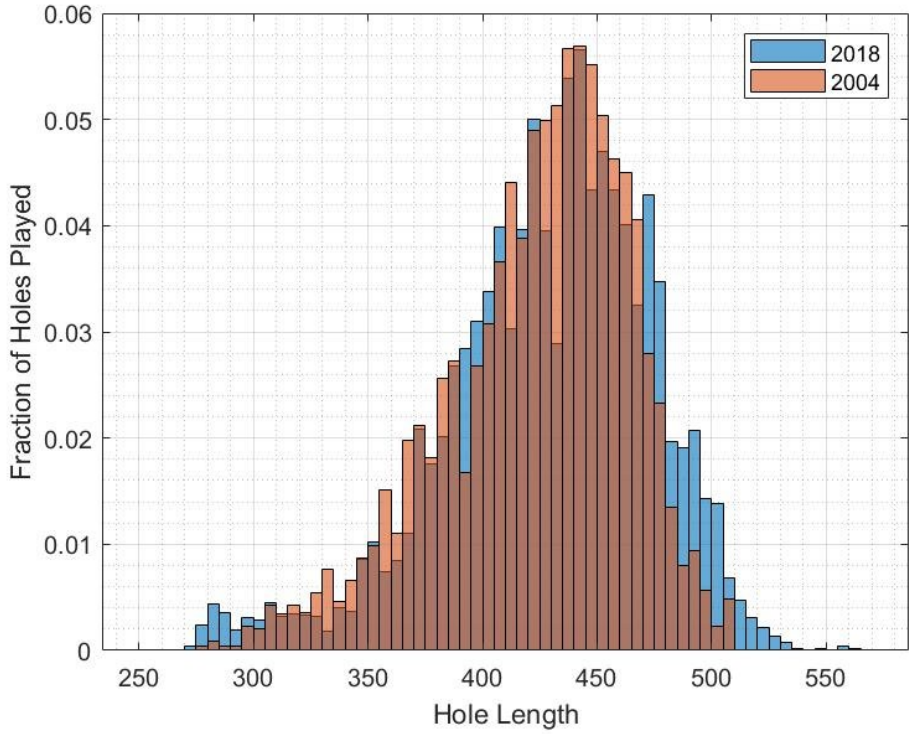


Figure 51: Distribution of hole lengths played on Par 4s on the PGA TOUR in 2004 and 2018

The average length of par 4s in 2004 was 423 yards, which by 2018 had increased to 428 yards. A commensurate increase in the median length was also observed, from 430 yards to 435 yards. However, over the same period the 1st percentile has decreased from 309 yards to 287 yards, while the 5th percentile has remained at 347 yards. This may suggest an intention to increase the number of drivable tee shots on Par 4s. It should be noted here that there are also a higher proportion of long par 4s in 2018 than in 2004, with the 95th percentile increasing from 479 yards to 493 yards.

The importance of driving distance was studied in a variety of ways for this study (R56 - The Value of Distance, R14 - Components of Superior Professional Golf Scoring From 1983 to 2018, With a Focus on Driving Distance and Accuracy). One analysis of the importance of driving distance as a function of the length of a par-4 hole on the PGA TOUR found that the importance of driving distance was highest for short and long holes and less for middle length holes. This dependence of the importance of driving distance on hole length suggests that, for holes that do not lengthen or even those that do, the skills challenged will change as hitting distance changes.

5.1.2 Relative importance of driving distance

One approach to considering the relative importance of driving distance is to compare the average distance of the top players on the professional tours to that of the rest of the field (R14). It should be noted that this analysis is performed where courses have lengthened (see Figure 38 and Figure 39). PGA TOUR and LPGA Tour shot performance data was analysed for the periods 1983-2018 and 1997-2007 respectively (note that issues with LPGA Tour data post 2007 prevented analysis for the period 2008-2018). It was found that on both tours, the importance of driving distance on scoring has increased over the periods considered for the top forty golfers each year (as measured by their total strokes gained performance).

On the LPGA Tour, for the period from 1997 through 2007, performance of the field improved on all aspects considered (scoring, driving distance, driving accuracy, greens in regulation, putts per round). However, the only statistically significant trend for the top 40 golfers was increased driving distance relative to the field (that is, while the field as a whole increased their driving distance, the top 40 golfers increased even more).

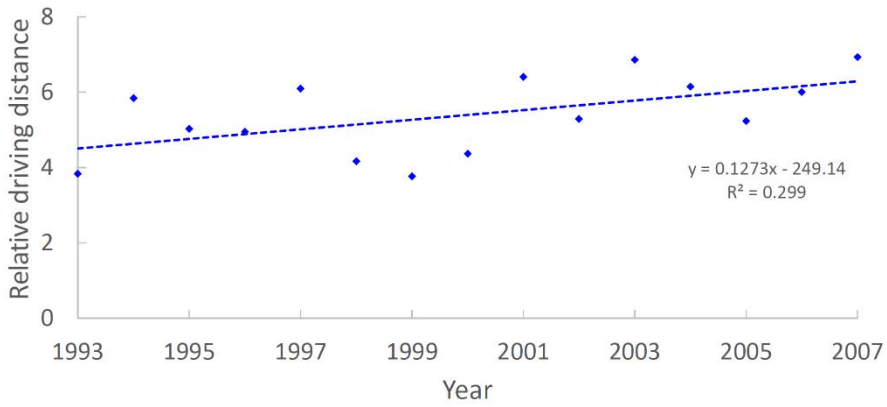


Figure 52 Driving distance of top 40 LPGA Tour players relative to field average (vertical axis in yards)

Similarly, for the PGA TOUR, the driving distance of the top 40 golfers relative to the field has been increasing since 1983 with a greater rate of increase since 2004, as shown in Figure 53.

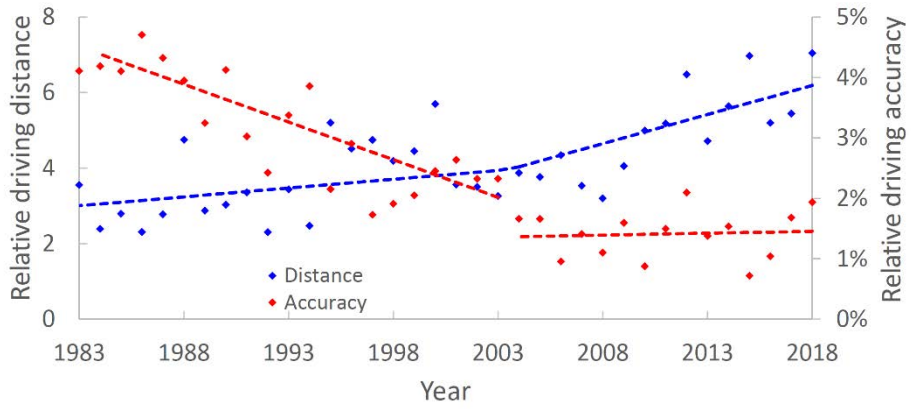


Figure 53 Driving distance of top 40 PGA TOUR players relative to field average (relative driving distance in yards)

Unlike the LPGA Tour, however, the relative driving accuracy of the top forty PGA TOUR players decreased significantly during the period of 1983 to 2003 (see also Figure 56).

There are complications in comparing traditional performance statistics such as driving accuracy, putting average, greens in regulation and driving distance, such as the fact that each is measured differently. Some are in percentages, some are counts of strokes, others are measured in distance. One way of simplifying the comparison (albeit admittedly with a more complex measure) is to employ a strokes-gained analysis

A full description of strokes gained is beyond the scope of this document, and may be found in one of reports in the library compiled for this project (R14). At its most basic, Strokes Gained enables each shot to be analysed in terms of the strokes saved or lost compared to an average golfer for a cohort. As a simple example, assume that it takes the average LPGA Tour golfer 1.5 strokes to hole out from 10 feet (half the time she makes the putt, half the time she needs a second putt). If a player makes a 10-foot putt, she will have gained 0.5 strokes on the field. If another player misses

and takes two putts from 10 feet, she will have lost 0.5 strokes on the field. By summing the strokes gained and lost for every shot, it is then possible to assess a golfer's performance relative to the field. It is also possible to apportion a player's strokes gained or lost for drives, approach shots, bunker, shots, etc. such that it is then possible to understand the importance of those skill sets to their success.

As an example of such an analysis over time, Figure 54 shows the relative apportioning of strokes gained for the top 40 golfers on the PGA TOUR each year from 2004 through 2018.

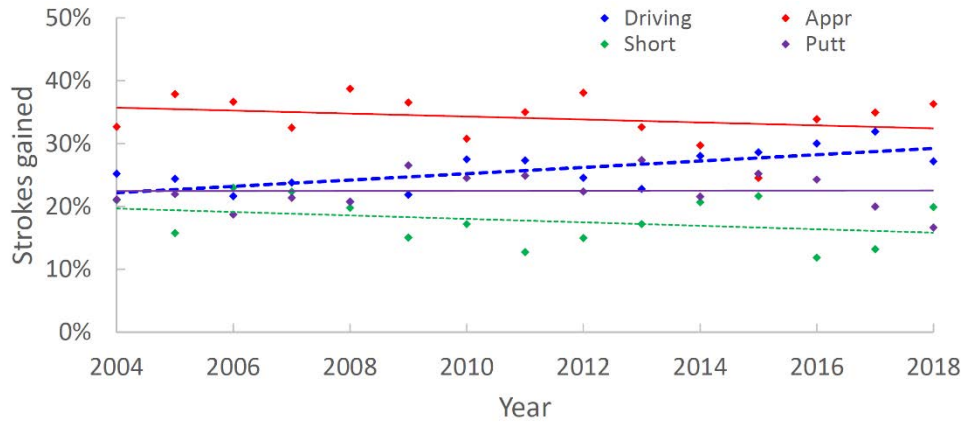


Figure 54 Apportioning of total strokes gained for the top forty golfers on the PGA TOUR by driving, approach shots, short game and putting

It can be seen in Figure 54 that driving (distance and accuracy), approach shots, short game, and putting are each a significant contributor to the total strokes gained (and therefore success). The only skill that is increasing in importance over this time however is driving. Partitioning the skill of driving into distance and accuracy, it can be seen in Figure 55 that this increase in importance is attributable to the increase in importance of driving distance.

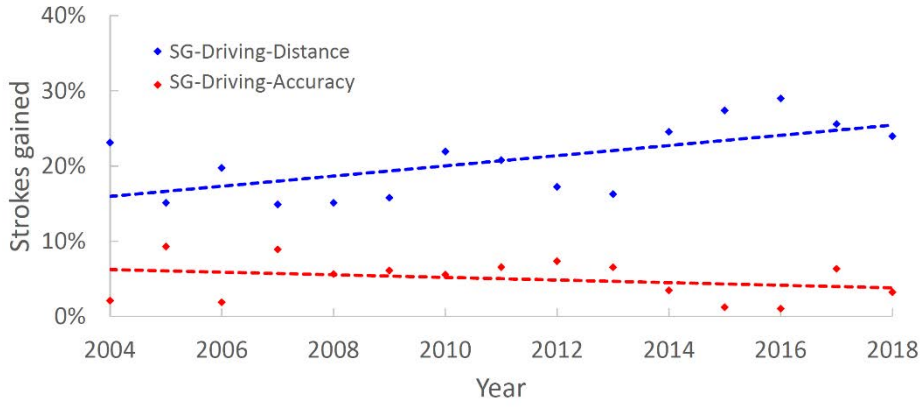


Figure 55 Portion of total strokes gained attributable to driving distance and driving accuracy. Increase of distance is statistically significant

It should be noted that these observed changes in the importance of driving distance over time on the professional tours do not involve an analysis of how driving distances have changed over time in relation to hole lengths or overall course lengths and therefore do not provide further information on whether the range of shot types played and skills used by players in these tournaments has been changing.

Lastly, it was found on the PGA TOUR that the average benefit of hitting distance to the field depends significantly on the golf course (R56 - The Value of Distance).

Within this study (R56) the value of distance was defined as the number of strokes 1 yard in driving distance is worth on a single hole or round. This study found that the correlation between driving distance and various positive statistics, such as birdie making, bogey avoidance and greens in regulation (GIR) % has increased over the last three decades on the PGA TOUR. This increase has been most noticeable over the last decade. Over the same period, there has been a steady decrease in the correlation between driving accuracy and these statistics. Further, the reward for being 1 standard deviation longer than the field has increased relative to the reward for being 1 standard deviation more accurate than the field. The range of average driving distances of players has increased over time on the PGA TOUR, while the range in other statistics has decreased.

On a shot-by-shot level, between 2004 and 2018, the value of distance for a player 15 yards longer than the field has ranged from +0.97 strokes gained per round to +1.07 strokes gained per round. Although there are no general trends in this value over this period, there has been a slight decrease in the last three years.

It is worth noting that the value of driving distance in the women's professional game is higher than in the men's game. On the LPGA Tour, the value of driving distance is 50% larger than the PGA TOUR, while the value of driving accuracy is the same. Similarly, the value of driving distance in the amateur game is around 50% higher than that of the male professional game. Within the amateur game, the value of driving distance for female players is 50% higher than that for male players. This demonstrates that as the average driving distance of the population increases, the value of driving distance for that group generally decreases. Although, this does not necessarily apply to an increase in average driving distance for a given group, see Figure 55).

A further insight can be gained by grouping players based on their scoring average and studying their driving distance and driving accuracy characteristics over time. These groupings are defined as elite players (players with a scoring average above 1.5 standard deviations better than the mean over the season in question), above-average players (0.4 to 1.5 standard deviations better than the mean), average players (-0.4 to 0.4 standard deviations better or worse than the mean), below-average players (-0.4 to -1.5 standard deviations worse than the mean) and poor players (more than -1.5 standard deviations worse than the mean). For each of these groups, the average number of standard deviations above the mean in driving distance and driving accuracy was calculated. Figure 56 shows where the average of each of these groups in standard deviations fall in a selection of PGA TOUR seasons between 1983 and 2018.

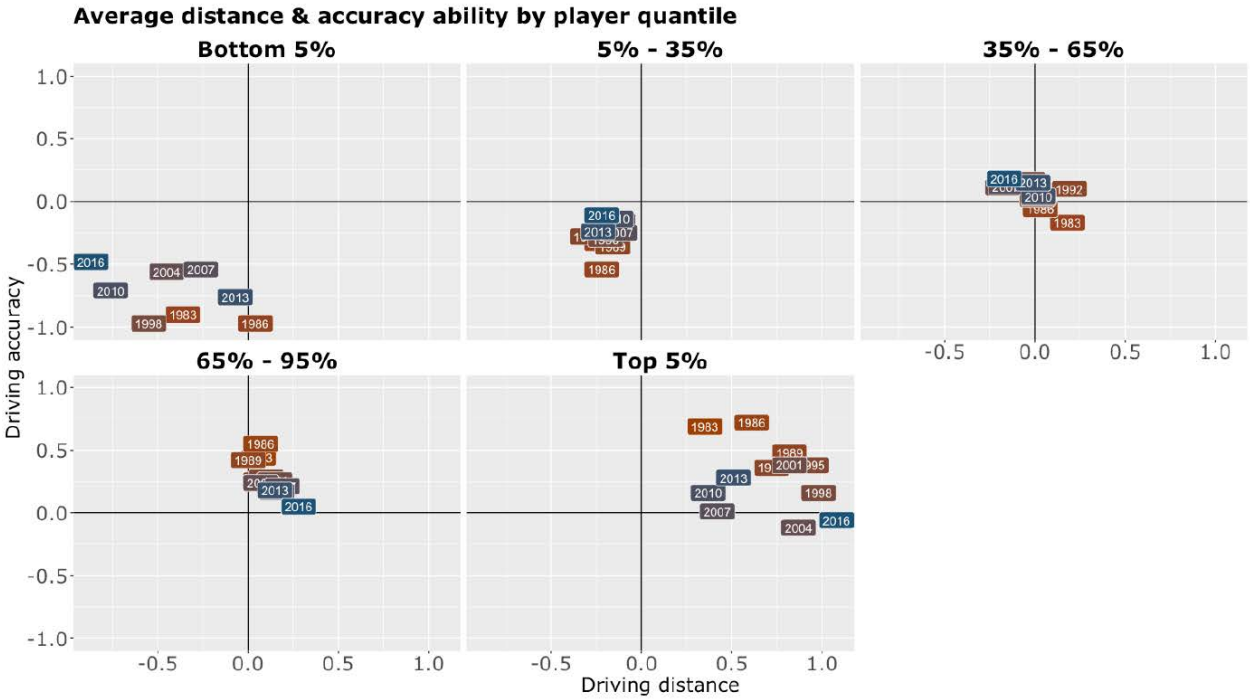


Figure 56: Driving distance and driving accuracy of each group (defined by their scoring ability, quantified by strokes gained) plotted by average number of standard deviations above the mean over a range of PGA TOUR seasons

Considering the Top 5% group, it can be seen that over time these players are driving the ball further and less accurately in comparison to the tour average. For instance, in the period between 1983 and 1988 the Top 5% group had an average driving distance 0.58 standard deviations above the field, and driving accuracy 0.70 standard deviations above the field, and in the period between 2013 and 2018 these values had shifted to 0.81 for distance and 0.16 for accuracy. Further, in 2004 and 2016, players in the Top 5% group were actually less accurate than the tour average. This suggests there has been a shift in the profile of player who are in the Top 5% group compared to the rest of the tour.

An analysis was done on the correlation of various skill measures (driving distance, driving accuracy, greens in regulation, scrambling, sand saves, putting average) to money list rank (R50 - The Correlation between Tour Performance and Success Rankings). This was done as far back as possible for the PGA TOUR (1980), European Tour (1988) and LPGA Tour (1993).

It was shown that the relative importance of the correlation between driving distance rank and money list rank compared to the other skill measures decreased between 1980 and 2014 on the PGA TOUR, however since then it has increased. Now, it ranks second only to the correlation between Greens in Regulation rank and money list rank. On the European Tour, the correlation between driving distance rank and money list rank has been ranked 4th, 5th and 6th among the various measures since 1999, and on the LPGA Tour it has been ranked 2nd, 3rd or 4th between 1993 to 2003, and 5th since 2010.

5.2 Impact of hitting distance increases on golf courses

Section 4.1 showed that increases in hitting distances over time are correlated with in long-term increases in course lengths and tournament playing lengths. This section discusses the impacts of

increasing course lengths on the footprints and playing surfaces of golf courses and on costs for course construction, renovation and maintenance.

5.2.1 Impact of hitting distance increases on footprints and playing surfaces

An analysis of aerial maps of 80 U.S. courses, 15 additional courses that host or have hosted men's professional tournaments, nine Australian courses, and nine Japanese courses was conducted to assess changes over the history of the course (R33 - How golf courses change (Global)). These aerial maps went as far back as the 1920s and included the most recently available images.

Figure 57 shows an illustrative example of some of the ways in which an individual hole has changed over time, including changes in response to hitting distance increases. This is presented purely as an example and not as a representation of any particular types or sets of holes or changes.

Figure 57 Illustrative example of the evolution of a hole. Fairway size reduction is illustrative of observed trends of reducing fairway area. Added tees, repositioning of greens, adding or repositioning fairway bunkers are illustrative of changes to holes in response to increased distance

For the 80 U.S. golf courses, Table 4 lists the total footprint (i.e., total area of the golf course) as shown in both the earliest and most recent aerial images available, as a function of the decade the course was built.

Table 4 The average footprint by decade and percent change over the study period (80 U.S. golf courses)

Decade Opened	Average Footprint Earliest Map (acres)	Average Footprint Most Recent Map (acres)	Change (acres)	Percent Change
1920s	147.1	159.2	12.1	8.26%
1930s	143.6	151.2	7.6	5.29%
1940s	152.1	152.9	0.8	0.52%
1950s	157	162	5	3.19%
1960s	147.7	147	0.7	-0.49%
1970s	150.8	144.4	-6.4	-4.25%
1980s	175.2	176	0.8	0.44%
1990s	222.6	213.6	9	-4.08%
2000s	202.3	201.1	1.2	-0.60%
2010s	229.8	229.8	0	0%

Table 4 shows significant differences in average course footprint based on opening date, with newer golf courses tending to have a larger average footprint. Courses built between the 1920s and 1970s have an average footprint of 152.8 acres, while courses built since 1980 have an average footprint of 205.1 acres.

Footprint is impacted by course length as well as by other factors, such as routing style, real-estate considerations and safety offsets (R35 - Impact of Safety Margins and Routing Style on Footprint). However, all else being equal, it was found that the increasing length of a golf course results, on average, in larger footprint. Figure 58 shows the current footprint of the 80 U.S. golf courses compared with their current, maximum scorecard length.

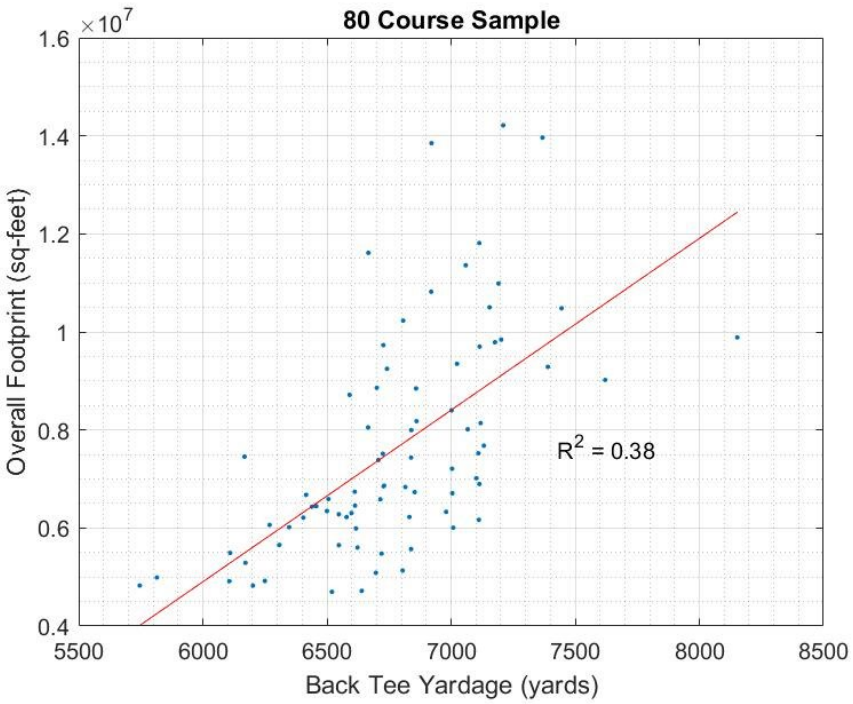


Figure 58 Current length and footprint of eighty U.S. courses. The slope of the regression line is 350230 ft²/100 yards or 8 acres/100 yards

It can be seen in Figure 58 that there is a statistically significant correlation between the length and footprint of a typical golf course but there are obviously additional factors influencing footprint. For every 100 yards in length, courses in the 80 U.S. courses sample are currently 8 acres larger on average. Added length did not always result in added footprint; for example, courses from the 1940s were in the bottom half of the average footprint rankings, but were tied for having the longest average back tee yardage in the final map year. Again however, all else being equal, it was found that additional length results in a larger overall footprint.

Fairways tend to consume the largest share of maintenance resources of any of the maintained surfaces on a course (greens, tees, bunkers, rough). Table 5 compares course fairway acreage of the first and last aerial maps, by decade opened.

Table 5 Comparison of fairway acreage by decade opened (80 U.S. course sample)

Decade Opened	Average Fairway Area Earliest Map (acres)	Average Fairway Area Most Recent Map (acres)	Change (acres)	Percent Change
1920s	41.13	24.93	-16.2	-39.39%
1930s	41.41	23.64	-17.77	-42.91%
1940s	40.92	23.66	-17.26	-42.18%
1950s	41.94	23.43	-18.51	-44.13%
1960s	32.54	25.04	-7.5	-23.05%
1970s	33.1	23.2	-9.9	-29.91%

1980s	24.08	21.41	-2.67	-11.09%
1990s	24.58	24.37	-0.21	-0.85%
2000s	26.21	25.26	-0.95	-3.62%
2010s	31.2	31.2	0	0%

It can be seen in Table 5 that fairway acreage of older courses was significantly larger than newer courses and that, since the earliest map, fairway acreage of older courses has been significantly reduced. The acreage of the most recent maps indicates that, except for golf courses opened in the 2010s, fairway acreage averages approximately 24 acres and age of the course does not appear to be a predictor of fairway area.

The specific reasons driving total fairway area reductions were not analysed in this research, but these reductions were likely the result of several factors such as irrigation coverage, mowing heights and patterns, maintenance and fuel costs, equipment innovation and the proximity of trees. In general, the desire to control overall maintenance costs by converting fairway to rough areas (which require fewer resources to maintain) was also likely a factor given that fairway maintenance costs have increased in response to increased golfer expectations about the quality of those playing surfaces.

These trends suggest that there is some control over fairway area that is independent of overall course footprint. Despite such steps to reduce fairway acreage over time, all else being equal, there remains a statistically significant correlation between course length and fairway area (approximately 0.7 acres of additional fairway per 100 yards of length) as shown in Figure 59.

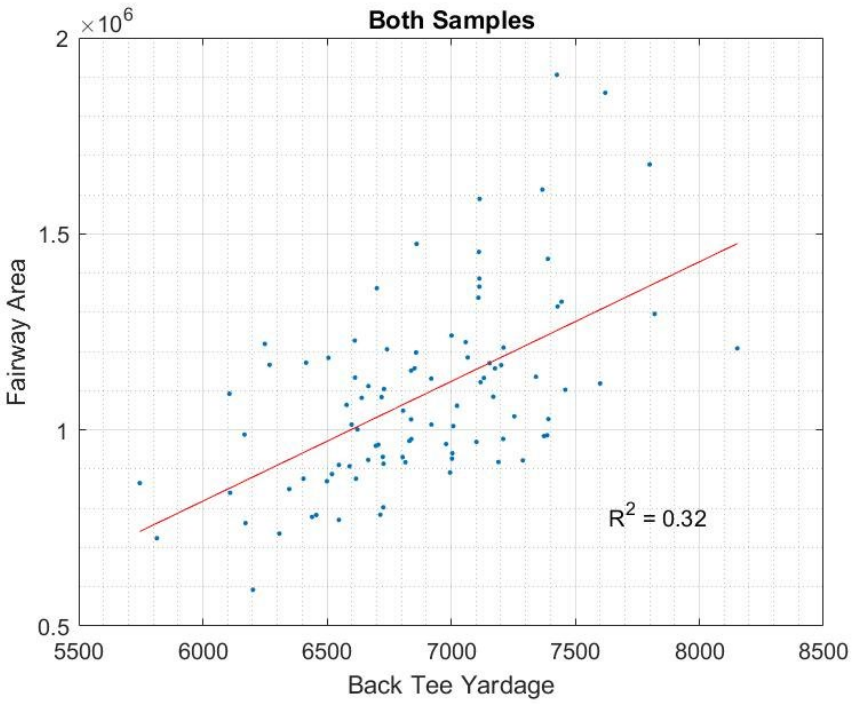


Figure 59 Comparison of maximum current scorecard length and fairway area (80 U.S. courses and 15 tournament courses). The slope of the regression line is 30500 ft²/100 yards or 0.7 acres/100 yards

The study also found that, on average, golf courses have added 17.8 new tees since the course opened, or about one new teeing ground per hole. On average, a single teeing ground averages approximately 1500 square feet in maintained area.

The evolution of a wide range of other golf course design features was considered in the study of aerial maps, many of which are not impacted by distance. A complete review of all the parameters considered was compiled (R33 - How golf courses change (Global)).

In addition to the U.S. golf course samples, a smaller sample of Japanese and Australian courses were analysed. It was found that the trends observed for these international samples were qualitatively and quantitatively like their American counterparts, with certain differences:

- Courses that have hosted men's professional tournaments had significantly larger total footprint, larger fairway area, more tees, longer distances from the back tees to fairway turnpoints, and several other key differences compared with U.S. courses that have not
- The total average footprint and fairway areas of Japanese courses are smaller than in the U.S.
- The total average footprint of Australian courses is smaller than in the U.S., but the average fairway area is larger
- Practice areas in Japan and Australia are on average both shorter and smaller than in the U.S.
- Centreline spacing is smaller in Japan and Australia than in the U.S.

5.2.2 Impact of hitting distance increases on golf course renovation, construction, and maintenance

Construction, renovation and maintenance costs for golf courses vary widely and depend on many factors, and this section will consider the impact of hitting distances on average costs in each of these areas.

5.2.2.1 Estimating the cost of course construction associated with increasing length

Added course length, either in renovating an existing course or in building a new one, necessarily increases construction costs. Because each golf course is different, and the scope of work associated with lengthening can vary widely, a review of typical golf course construction costs that may be influenced by distance was compiled (R15 - Construction Cost Estimate of Distance Impacts). Examples of course renovations in Australia show the diversity of strategies, tactics and debate during the redesign process.

The features impacted by distance can include additional back tees, additional bunkers, expanded fairway area and longer practice ranges. Typical size and scope of these design adjustments were estimated with the Golf Course Builders Association of America (GCBAA) Cost Guide Tool and other recent pricing sources used to calculate estimated costs. The GCBAA Cost Guide uses 2010 construction pricing data and New Jersey was chosen as the location for a sample course.

Costs associated with renovations to existing courses and new construction were identified, including costs that would affect both types of projects and those that would affect only one of them. For example, in a new construction project, a new bunker would not be added to adjust for increased distance because current driving distances would be factored into the initial design.

These cost estimates are based on typical modern construction specifications and are intended to represent an average project. It is certainly possible for these features to be more, or less, expensive based on adjusted specifications or the unique circumstances of a given site. Note also that the cost of additional land to accommodate a larger course (as found in Section 5.2.1) or hole lengthening is not included but can be significant.

A summary of the construction costs is provided below in Table 6. A detailed breakdown of these summarized costs is provided in R15 - Construction Cost Estimate of Distance Impacts.

Table 6 Comparison between construction costs for course features

Project	New	Renovation	Scope	Typical Cost (USD)
New tee	✓	✓	1000 ft^2 tee, 2000 ft^2 surround, 25 yards behind previous tee, including irrigation, cart path	$11900
Bunker		✓	1000 ft^2 bunker, 4000 ft^2 shaped surrounds	$9100
Fairway Expansion	✓	✓	Per acre	$28000

Practice Range Expansion	✓	✓	25-yard expansion, 290' wide (1/2 acre increase)	$14900

5.2.2.2 Impact of course length on golf course maintenance costs

For further context on the impact of hitting distance on course operations, Figure 60 summarizes representative maintenance costs data from a variety of sources for the United States over a period of approximately 100 years (R17 - Costs of Golf Course Maintenance – Past, Present and Future).

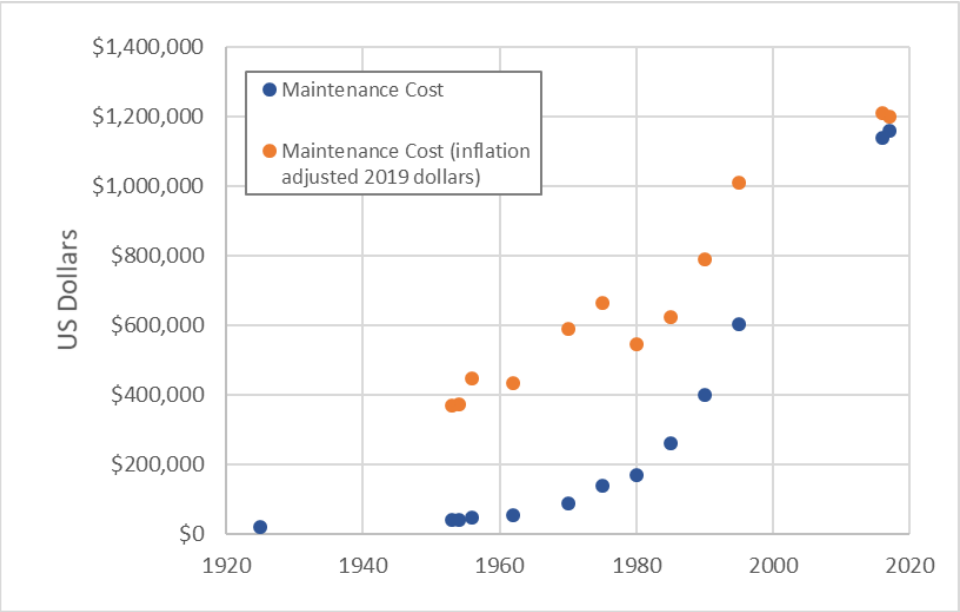


Figure 60 Evolution of typical golf course maintenance expense (actual dollars in blue, inflation adjusted to 2019 dollars in orange)

It can be seen in Figure 60 that typical maintenance costs have increased significantly over time, greatly outpacing inflation. These costs have increased for a variety of reasons, many of which are attributable to steps taken to improve playing conditions (course consistency, green quality, etc.). However, it was shown in Section 5.2.1 that, all else being equal, increasing golf course length tends to increase the total footprint and the fairway areas. Maintenance costs at any individual course vary widely and depend heavily on the expectations of their golfers. Table 7 shows the results from a detailed survey of 37 representative U.S. golf courses concerning the average per acre costs to maintain various course areas.

Table 7 Average annual maintenance costs of major playing surface areas

Putting Greens	Tees	Fairways	Bunkers	Rough
Average Cost per Acre				
$68469	$7902	$8604	$40507	$1762

It was found in Section 5.2.1 that, on average, all else being equal, 100 yards of additional course length corresponds to 8 additional acres of total footprint and 0.7 additional acres of fairway. Each of these has cost implications. On average, the additional 0.7 acres of fairway for 100 yards of increased length adds about $6000 in annual maintenance costs for an individual course.

The additional 8 acres of footprint per 100 yards of increasing length is not necessarily all maintained turf. According to the GCSAA, the median golf course had approximately 50 acres of maintained rough (Golf Course Environmental Profile, Phase II, Volume IV Land Use Characteristics and Environmental Stewardship Programs) on U.S. Golf Courses. As discussed above, the total footprint of a golf course averages between 150 and 200 acres depending on when the course was constructed. Therefore, between one quarter and one third of the total footprint of the course is maintained rough. It should be noted that this is likely to vary immensely, especially globally, but it is used for illustration. Assuming the low end of that range (i.e. 25%), the additional footprint would, on average, include 2 acres of maintained rough, adding an additional $3500 in annual maintenance costs.

It was found in the aerial mapping study that golf courses have added, on average, 17.8 teeing areas per course. Therefore, if it is assumed that, due to increased length of the golf course, one additional tee per hole (average 1500 square feet per tee) has been added to accommodate today's wider range of hitting distances, the average additional annual maintenance costs would be $5000. As noted, this does not assume any future escalation in the cost inputs.

5.2.2.3 Maintenance resource scarcity and costs

Resource costs (including water, labour, energy, nutrients and pesticides) have been increasing and are expected to continue increasing (see Section 5.4.3). Golf course superintendents have been reducing their consumption of these resources in response to increasing costs and regulatory and other pressures and are expected to continue to face supply and pricing challenges (GCSAA, Golf Course Environmental Profile – Phase II Reports (various)).

A detailed analysis of resource consumption for golf course maintenance is beyond the scope of this report on distance. Information on the cost and availability of maintenance resources have been compiled in separate reports (R16 - Costs and Availabilities of Maintenance Resources and R30 - Golf Course Water Use and Costs - Past, Present and Future). Water cost and availability is a particularly notable example. For example, as shown in Figure 61 the median golf course costs for water in most regions of the United States have increased and dramatically so in some regions.

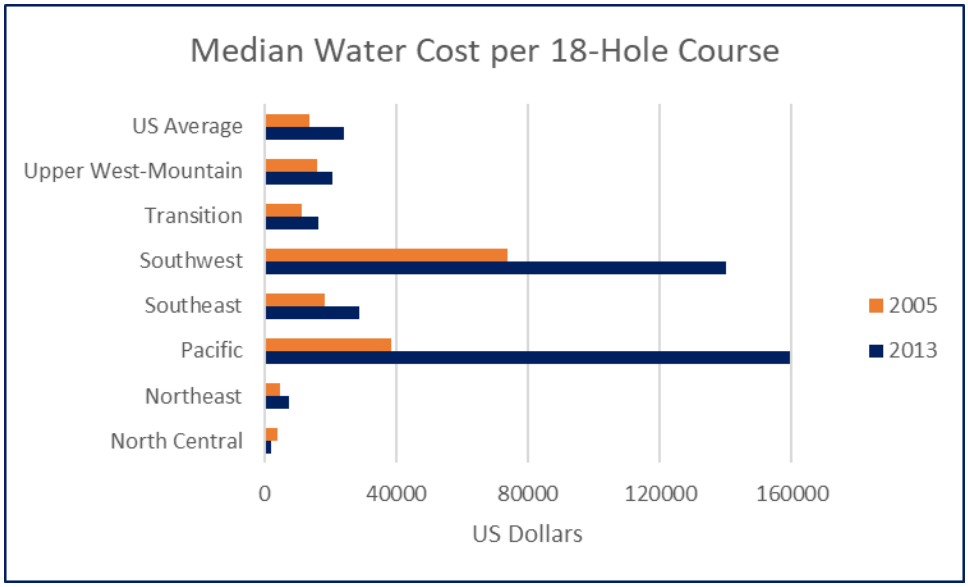


Figure 61 Median water cost by region in 2005 vs. 2013. Source GCSAA.

The U.S. Department of Energy's Federal Energy Management Program recently calculated that municipal water rates across the U.S. increased at an average rate of 4.1% from 2008 to 2016, significantly greater than inflation.

According to the United Nations, global water use will continue to increase by approximately 1% annually until 2050. In 2012, the U.S. intelligence community projected that freshwater availability would not meet the demands for food and energy production in many countries by 2040, hindering global food markets and economic growth, especially in North Africa, the Middle East, and South Asia. This has produced a general climate of conservation and global pressures to reduce water consumption. These pressures obviously have far greater importance than merely their potential effect on golf, but they will continue to affect golf courses as well. For example, many countries with large golfing populations experience periodic and chronic droughts further limiting the availability of water. For example, Figure 62 shows a map of the current rainfall deficiency for Australia (Australian Government Bureau of Meteorology) and the location of that country's top 100 golf courses (https://www.top100golfcourses.com/golf-courses/oceania/australia):

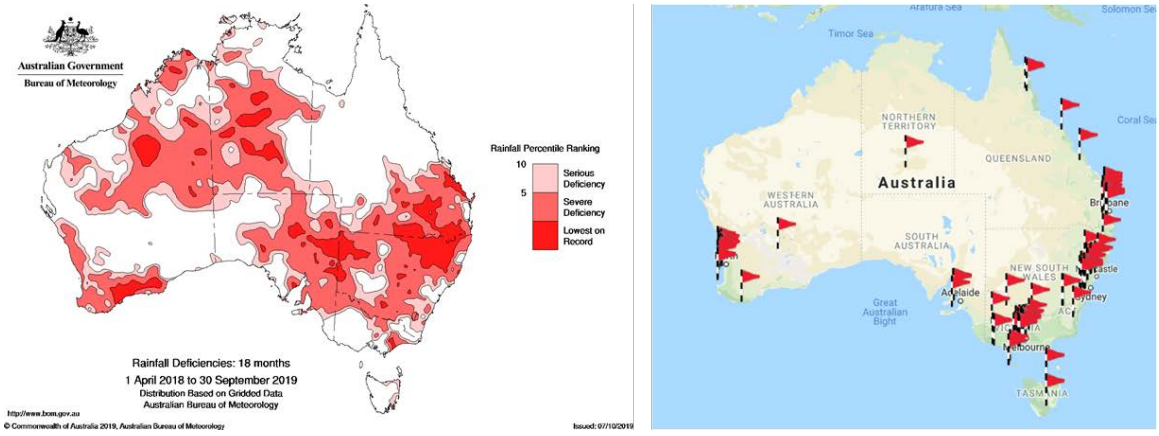


Figure 62 Rainfall deficit and top 100 golf course locations in Australia

For example, it can be seen in Figure 62 that many of Australia's top golf courses are in areas which are currently experiencing below average rainfall. Similarly, South Africa, another nation with a large golfing population, is currently experiencing debilitating drought and the need for drastic conservation measures.

Other golf course operating costs are significant and growing as well. Labour costs are typically the largest component of a course maintenance budget, often one-third to one-half of the total cost to maintain the course. The Conference Board in 2016 predicted that average annual wages would grow by 3.1% in the U.S. from 2015 to 2020. This estimate was equal to that for the UK and slightly less than the projections for Australia (3.8%) and Canada (3.4%) over the same timeframe.

Gasoline and diesel fuel are consumed by many of the non-stationary machines used to maintain the golf course. The U.S. Energy Information Administration projects that retail gasoline and diesel fuel prices will increase by between $0.76 and $0.82 per gallon from 2018 through 2049.

The use of nutrients and pesticides also produces significant maintenance costs at courses. Fertilizer prices are linked to several industries and directly affected by agricultural commodity prices, transportation costs, and the cost and availability of natural gas. Overall, worldwide fertilizer prices dropped 0.6% in 2019 (and phosphorous prices reached a 10-year low), but prices are expected to rise 2.2% in 2020. Fertilizer regulations reported by golf courses, most commonly for phosphorous-containing fertilizers, have increased from 2006 to 2014 and often include timing, location, or buffer-strip application, restrictions that are designed to reduce runoff of nutrients into surface waters. In the U.S., the increased federal regulation of pesticides has increased pesticide development costs, caused mergers among manufacturers, reduced overall pesticide registrations, and limited the development of pesticides for minor commodities such as turfgrass grown on golf courses. These trends are likely to continue, which further strains the supply of effective pesticides for golf course maintenance.

The costs and restrictions of resources have been driving superintendents to improve practices resulting in conservation and reductions in costs. Despite these efforts, it was found that significant costs to maintain golf courses are associated with increases in golf course length.

5.2.2.4 Impact of course length on land use

Increasing course lengths also have broader potential effects on the long-term sustainability of golf courses, such as a need to address the following issues:

- Accelerating population growth and urbanization in many regions is contributing to rising land values and increasing efforts to use open spaces, leading to golf course closures where planners and developers see a better use for the land. In some places, these land use pressures on golf courses are exacerbated by environmental challenges such as desertification, sea-level rise and coastal erosion (United Nations, Transforming Our World: The 2030 Agenda for Sustainable Development).
- Pressure to protect threatened species and their habitats is growing in many regions, presenting both a challenge and opportunity for golf courses. Well-managed courses have proven to be exemplary stewards of wildlife and pollinator habitat, which can be accomplished in various ways, including by converting maintained turf where the game is currently played into out-of-play areas (Dodson, Managing Wildlife Habitats on Golf Courses, 2000; Daniels, "Establishing Monarch Butterfly Habitat on Golf Courses," 2019; GCSAA, Golf

Course Environmental Profile, Phase II, Volume IV Land Use Characteristics and Environmental Stewardship Programs).

5.3 Impacts on Pace of Play

The length of the golf course and hitting distances can both impact the pace of play and the time to play. In its simplest form, increased course length would result in increased transit time (walking or riding). For example, Tiger and Salzer (Daily Play at A Golf Course: Using Spreadsheet Simulation to Identify System Constraints, Transactions on Education, Vol 4. No. 2 pp. 28-35) studied recreational golfer movement around golf courses. Tiger and Salzer estimate that recreational golfers transit a course at a rate between 70 and 90 yards per minute. Therefore, for example, a golf course with 500 yards added, without congestion, could take between 5.5 and 7 minutes longer to play, on average. Where added distance also requires players to walk back to tees for example, the time to play may be further increased.

Pace of play on a congested golf course is a more complex phenomenon influenced by many factors, such as bottlenecks and waiting times which can influence the movement in sometimes counterintuitive ways. In order to assess this, full simulations for recreational and professional golf (both men and women) were conducted (R34 - Identify the Effects of Distance on Pace). The simulation considered the incremental effect of changes in both hitting distances and course length on overall round times.

If hitting distances and golf course lengths on the PGA TOUR between 1969 and 2019 are compared (referring to Figure 41, an increase in average driving distance of 45 yards and an increase in course length of 450 yards), the simulation indicates round times are 4.5 minutes longer in 2019 than 1969 due to distance.

Over the same period, driving distances and course length at the U.S. Women's Open have been recorded. On average, the driving distances have increased by 40 yards while the course length has increased by 685 yards. The simulation indicates that over that time, the time to play has increased by 5.3 minutes due to distance.

6. Golf stakeholder perspectives and opinions on hitting distance

In complement to the scientific study of distance presented in Sections 2 through 5 of this report, global golf stakeholders' perspectives (e.g., golf course architects, recreational golfers, golf course owners, etc.) were secured through multiple research mechanisms including surveys to provide a range of viewpoints on the topic of distance in golf.

The goal of the global golf stakeholder research was to hear existing opinions as of 2018 – both from business-to-business (B2B) golf stakeholders and business-to-consumer golf stakeholders (B2C). The respective research projects were not in any way developed with the intent to "crowdsource" viable approaches or "solutions" relative to the topic of distance in golf.

The survey questions were not developed with reference to, or based on, the scientific study of distance and survey respondents obviously did not have access to the scientific study of Distance Insights (i.e., Sections 2 through 5) prior to forming or sharing their perspectives.

Stakeholder input was gathered by two research partners. Sports Marketing Surveys Inc Ltd (SMS) was commissioned to secure perspectives across a wide range of golf's stakeholders and across a

diverse geographic area. Global Golf Advisors (GGA), given their expertise in understanding the business of golf courses and golf course operations, was also commissioned to report on the specific perspectives of golf course owners, operators and related golf facility professionals.

6.1 Global stakeholder research overview

The global stakeholder research conducted by SMS sought to gather opinions from each designated stakeholder group with respect to the following overarching question:

Considering your role in golf, how if at all, has distance (i.e. how far shots travel on a golf course) affected you, and how is distance likely to affect you in the future?

Below is relevant to opinions gathered:

- An online attitudinal survey (67,862 respondents from 115 countries, available in 10 languages, 70% male/30% female participation) was launched on September 18, 2018 and closed November 8, 2018. The survey was relevant to all stakeholder categories with common questions across all respondents as well as specific questions designated for certain stakeholder categories (R27).
- Telephone interviews were held with individuals selected from the largest three golf markets across all stakeholder categories. A total of 232 interviews were completed across the United States, United Kingdom, and Japan (R27).
- Two online interactive forums with a total of 91 participants were facilitated in two languages (English and Japanese) across the three largest golf markets. The forums provided an opportunity for participants to discuss relevant prompts and topics as a group by interacting and responding to each other and the moderator (R27).
- Group meetings provided additional opportunities for face-to-face interviews with golf course administrators and golf course architects (R27).
- Face-to-face and telephone interviews with current and retired professional golfers were held to compile their thoughts on the topic of distance in golf. A total of 41 player interviews were completed with golfers of different tours, gender, average driving distance, tenure on tour, active vs. retired, and country association (R40).
- Attitudinal segmentation using factor analysis was completed on the two types of stakeholder categories as defined: consumers (golfers) and industry (R27).

Stakeholder research gathered opinions on distance in golf at present (i.e., 2018) as well as stakeholders' predictions on how distance may influence them as golf stakeholders – or the game, more broadly – in the future. While some stakeholders did share their views on viable approaches, considerations or "solutions," respondents were not given an explicit opportunity to do so. Mostly top-line results are presented in this section. Some results are broken down by country or other demographic segments within the corresponding report(s) housed in the Distance Insights report library.

Stakeholders in golf were divided into 12 categories. Table 8 shows these groupings:

Table 8 Stakeholder Categories of Golf's Stakeholder Groups

Media	Tournament Golf Spectators	Championship Committees	Golfers
Tournament broadcast media Endemic golf media	Live on-site Broadcast viewer	Elite amateur Professional	Recreational Elite amateur Professional

		Recreational	
Facility Maintenance Vendors Chemicals Supplies Equipment	**Golf Equipment Manufacturers** Golf ball Golf club Other golf equipment	**Golf Course Construction Professionals** Golf Course architects Golf Course builders	**Golf Administrative Organizations** USGA/R&A National unions PGAs
Course Facility Professionals Owners Superintendents General managers	**Golf Professionals/ Teachers** Teaching professionals College coaches	**Equipment Retailers** Pro shops Big box sporting goods Golf specialty On-line vendors	**Non-Golf Stakeholders** Municipalities Regulatory agencies Corporate sponsors

As part of the online qualitative survey instrument, participants were asked if they would be willing and interested to take part in further work. For those who volunteered and were chosen at random, SMS performed an additional study focusing on golf fans who identified themselves as "highly engaged":

"For highly engaged golf fans, 90% of which have followed golf for more than 10 years, …."

A golf fan was defined as someone who watches golf on TV, follows it online or through the media, or attends live golf events. This supplemental research project had three broad objectives:

- Understand the nature of how fans engage with golf
- Secure an understanding into what skills are valued in the game from a fan's perspective
- Gain insight into what contributes to "success in golf" at the highest level

The details of this supplemental work can be found in R28 - Global Stakeholders Perspectives: Fan Deep Dive and are also highlighted in this section.

Below is relevant to the golf fan research:

- The golf fan survey was available in English and launched on January 28, 2019 and closed on February 15, 2019.
- The survey was distributed electronically to 3,888 individuals with 1,633 respondents from two countries (UK [603 respondents] and U.S. [1030 respondents]). Approximately half of the respondents had been following golf for more than 30 years with another 20% for 20–29 years.
  One online interactive forum with a total of 68 participants was facilitated in English. Online forums provided an opportunity for participants to discuss relevant topics in groups by interacting and responding to each other as well as to the moderator.

Lastly, as part of work commissioned for the Distance Insights project, Global Golf Advisors performed a global survey of golf courses and golf facilities (R17 – Costs of Golf Course Maintenance - Past Present and Future). The survey was sent to 225 individuals including club managers, architects, owners, management companies, resort operators and builders of which 50% were in North America, 25% in the United Kingdom, and 25% across the rest of the world.

6.2 Summary of Stakeholder Perspectives on Distance

The SMS global stakeholder perspectives research has been compiled in a detailed presentation included in the corresponding Library of Reports (R27 - Global Stakeholders Perspectives). At over 300 pages in length, only highlights of the presentation are summarized in this section.

It is notable that individual responses vary widely on most areas related to the topic of distance in golf. While average values show some opinion differences between stakeholder categories, the variation of perspectives within stakeholder groups is larger than the variation in central tendencies between stakeholder groups. This is important to consider when reviewing the highlighted results and – relatedly – the full Global Stakeholders Perspectives Final Report (R27).

6.3 Perspectives on changes in hitting distance and the causes

6.3.1 Recreational Game

Golfers were asked about their thoughts on the game of golf in general, and the role of distance in golf.

57% of those asked believe that recreational golfers are hitting shots further than five years ago. These respondents were asked, "how often do you see drives that are hit 'too long' when you are playing?" Figure 63 shows that 6% regularly see "too long" drives, 26% occasionally, 40% rarely and 28% never see "too long" drives. But opinions vary according to the given sub-segment of golfers (i.e., recreational, elite amateur or professional).

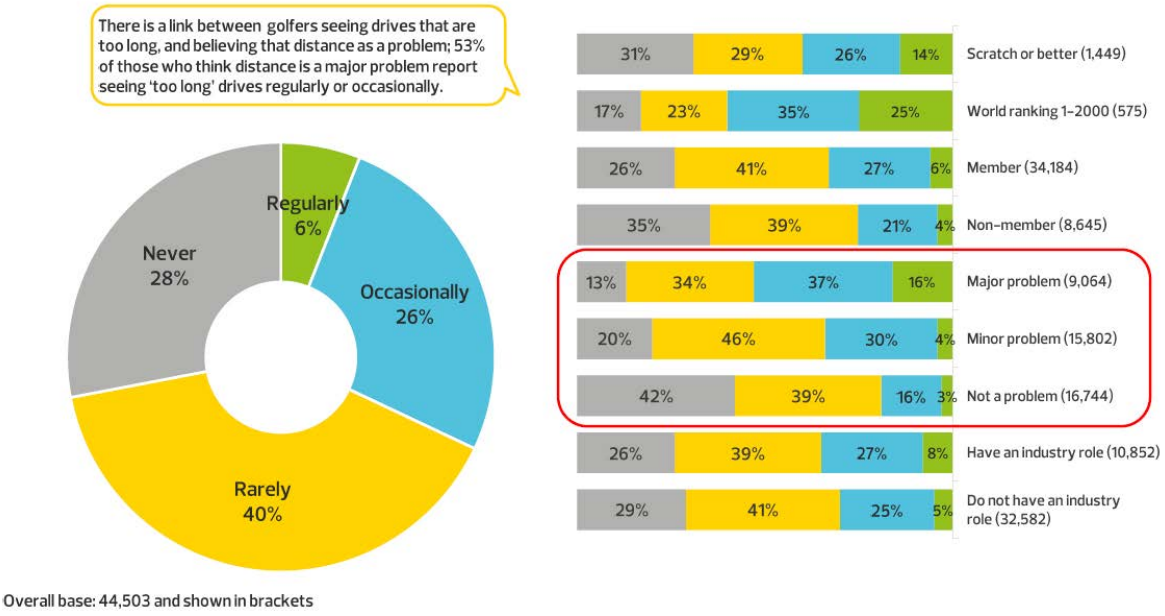


Figure 63 "When you are playing golf, how often do you see drives (from yourself or other players) that you would say are 'too long'?"

More skilled golfers, or golfers who perceive distance as "a major problem," reported seeing more drives which they felt were "too long."

Golfers were also asked about their own games. As shown in Figure 64, overall 41% believe they drive it further than 10 years ago, while 32% believe they are driving it shorter. 27% believe they

drive it the same distance as 10 years ago. However, the responses vary significantly by age as shown in Figure 64 with younger golfers losing less often and gaining more often, while older golfers are losing more often than gaining.

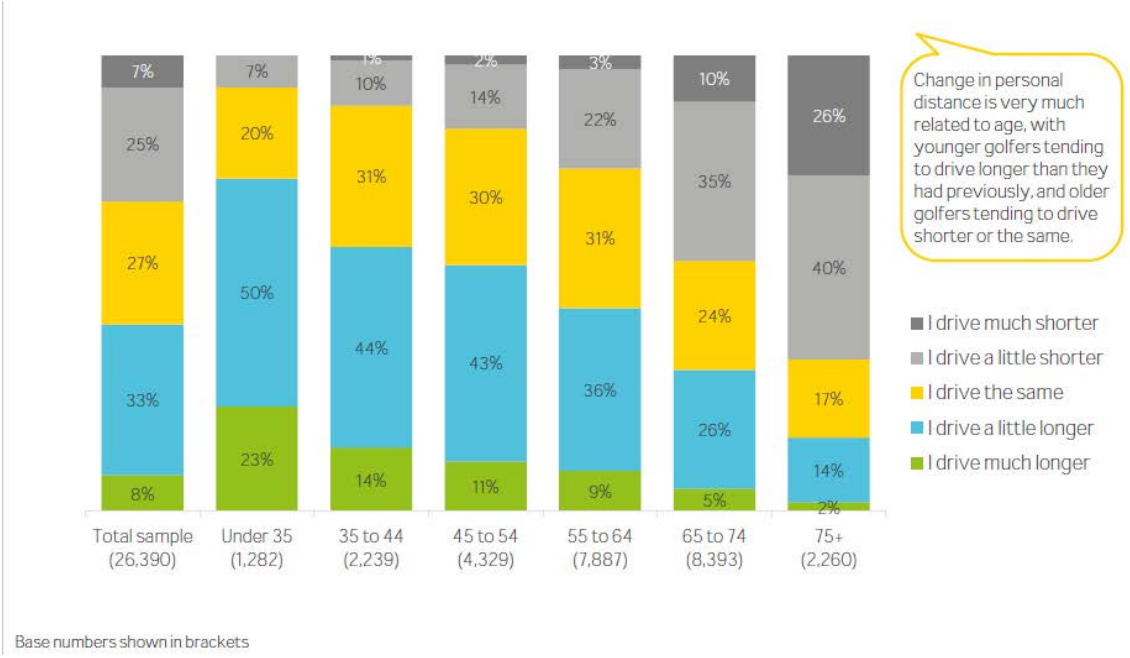


Figure 64 Effect of age on change in personal driving distance over the last 10 years

As shown in Figure 65, 98% of golfers attributed changes in their hitting distance to their skill, fitness or equipment. Only 2% believe that the golf courses they play contributed to the change in distance.

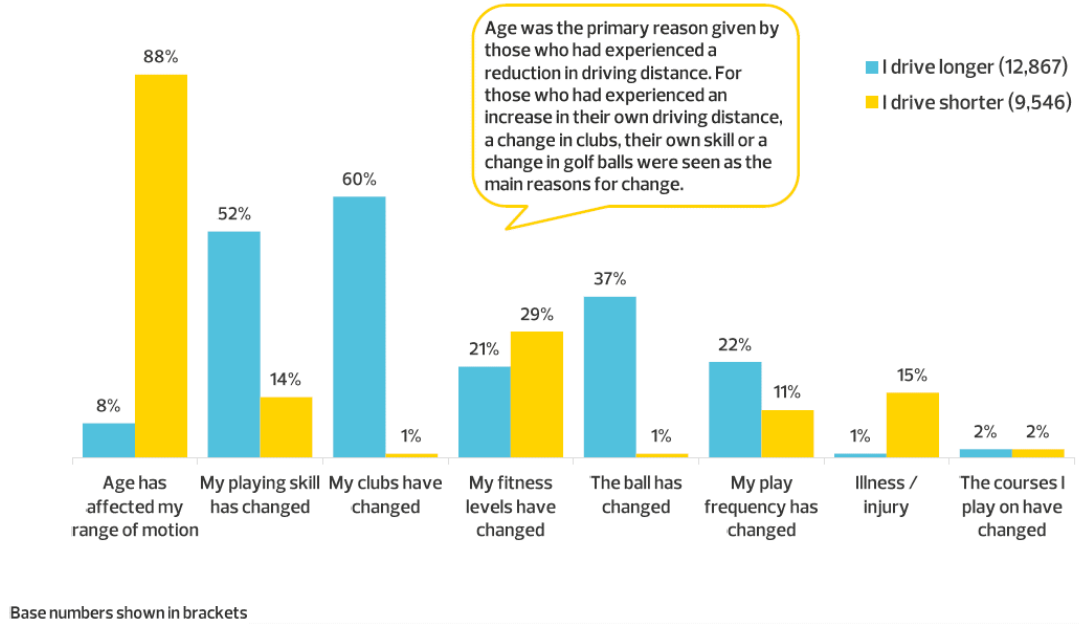


Figure 65 "Why has driving distance changed (increased or decreased) over the last 10 years?"

6.3.2 Elite / Professional Game

The survey also asked about the role of distance in the elite/professional game. 88% of golfers surveyed believe that elite / professional golfers are hitting shots further than five years ago. There is a general belief that the contributors to increases in distance at this level are due to a combination of player skill, club technology, player fitness and ball technology.

Figure 66 shows the results of respondents being asked to allocate 100 points across seven assignable contributing factors to explain the increase in driving distance over time in the elite / professional game. Overall, the top four categories account for 72 of the 100 points with general consensus of response found among the stakeholder groups.

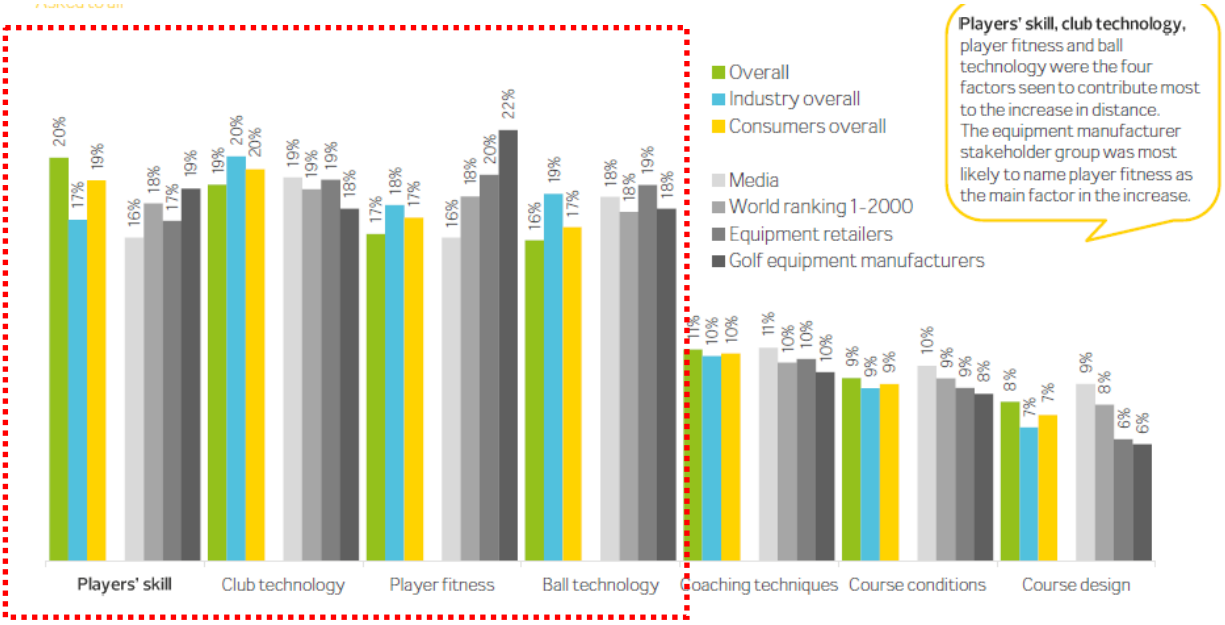


Figure 66 Attitudes to distance: contributing Factors

SMS supplemented the online global survey by interviewing 41 professional golfers over the phone. These professional golfers included men and women; those with longer, average and shorter driving distances; players from Europe, the United States, and other countries; and retired and current professional players with a range of world rankings. The goal of these interviews was to explore the perspectives of a sample of players on the topic of distance in greater detail (R40 - Player Interview Findings).

This cohort of respondents generally believed that increased distance was caused by the increased athleticism of players, improved equipment (clubs and balls), enhanced course conditions and agronomy, as well as swing and equipment optimization through new technology and innovation. These professional players' perspectives on the causes of distance mirror both the overall survey as well as the Distance Insights scientific research.

6.4 Perspectives on Impacts of Hitting Distance Increases

6.4.1 "Is distance a problem, a threat, or an opportunity?"

When asked by SMS about broad topics of importance across the game of golf, many stakeholders were more likely to identify areas aside from distance as threats to the game. Pace of play, availability of short format venues, and inclusivity / diversity were mentioned at a higher rate than distance. Most respondents when prompted, however, did have feelings about the topic of

distance. Figure 67 reflects respective stakeholder groups' feelings on whether distance is "a problem" in golf.

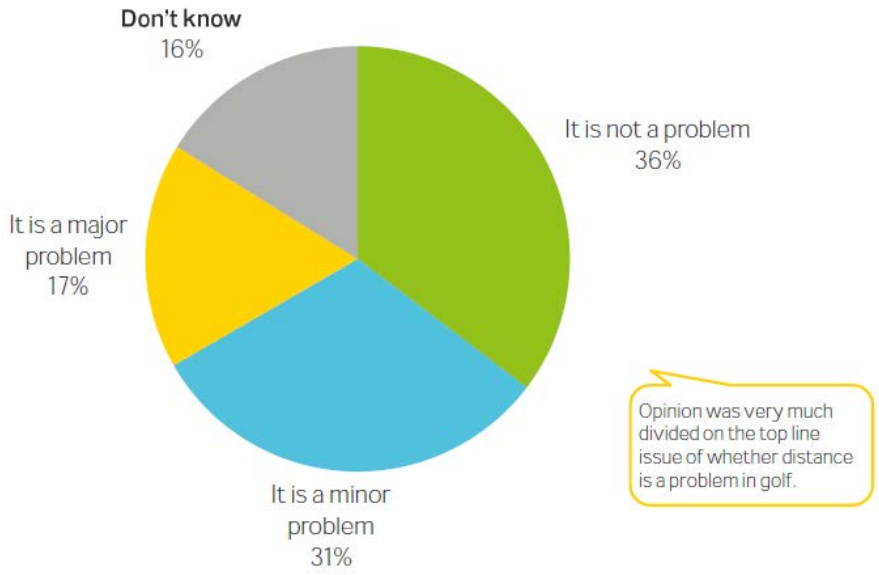


Figure 67 Is Distance in golf a "problem" overall?

Across all stakeholder groups, for those respondents who believe that distance is a major or minor problem, tee shots with the driver were most noted.

Many stakeholders did not specify distance as "a problem" at the present time, but thought that, if unchecked, it would likely become a significant problem over the next ten years. Those respondents who believe that distance is "a problem" are most likely to think it is a problem for the elite / professional game as shown in Figure 68. It is notable that distance was depicted as "a problem" both for shots that "*go too far"* OR shots that do not *"go far enough"* as each respondent was left to interpret "distance" through their own criteria without the benefit of qualifiers or additional definition of terms.

Figure 68 If Distance in golf is a problem, who is it a problem for?

Golf course construction experts are generally very aware of the issue of distance in golf and – by and large – have a negative opinion of how increasing distance is affecting the game. Many in this group share sentiment that opposes the prospect of golf courses increasing in length, unless it is specifically to accommodate championship events.

Opinions on whether distance should be looked upon as a threat or an opportunity were almost equally divided as shown in Figure 69. The variation between stakeholder groups is notable. Equipment manufacturers, as an example, were most likely to see distance (presumably, increased distance) as an opportunity, while golf course architects were most likely to see distance (again, presumably, increased distance) as a threat.

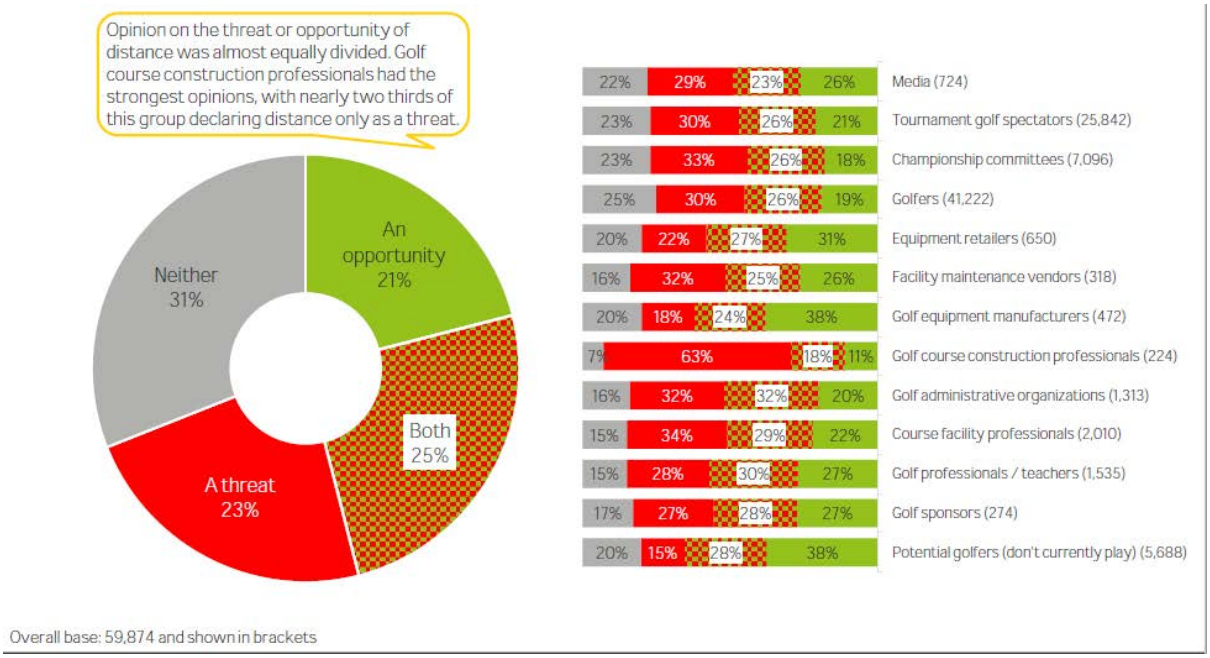


Figure 69 Is Distance in golf a threat or an opportunity?

6.5 Impacts of Distance on the Playing of the Game

6.5.1 Recreational Game

To many recreational golfers, "hitting a long drive" falls lower on their overall list of what matters to them in their golf experience. Accuracy is generally ranked more highly than distance as shown in Figure 70.

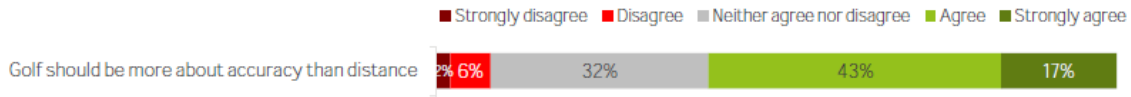


Figure 70 Attitudes about golf

For some cohorts of golfers, hitting shots a great distance is highly appealing, however. Golfers with no handicap or a high handicap generally place a higher value and enjoy long shots as indicated in Figure 71.

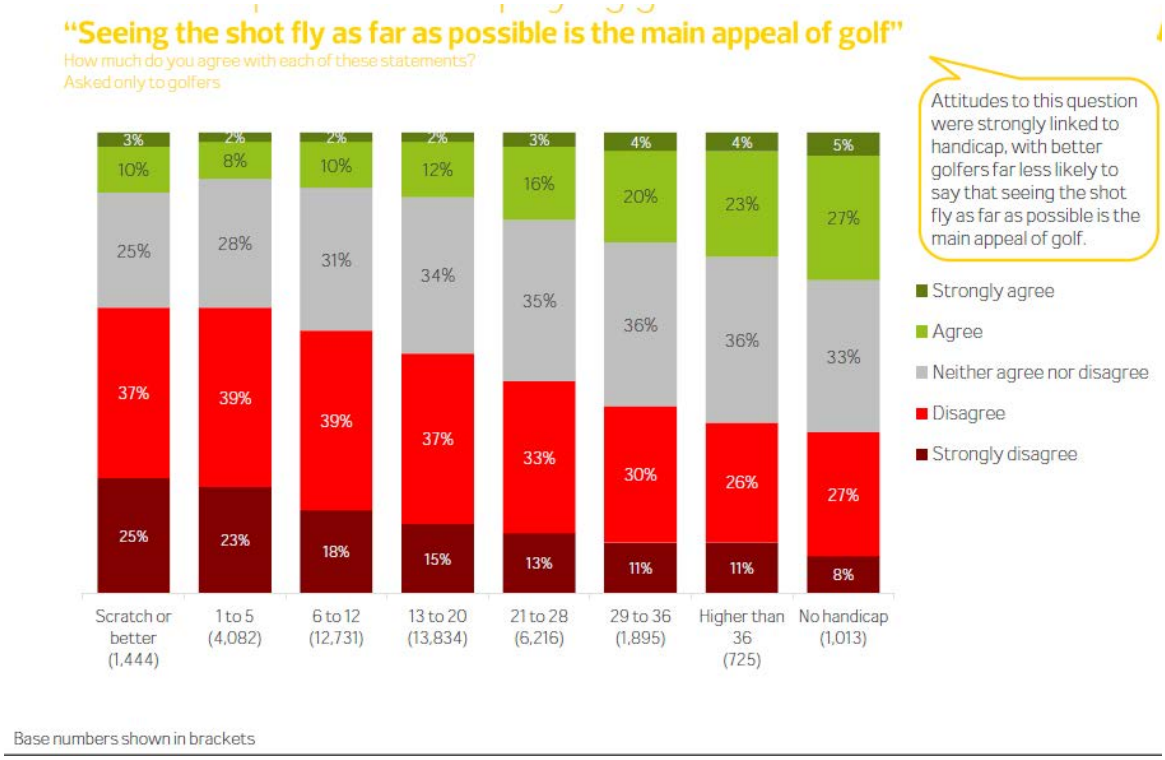


Figure 71 Effect of skill level on appeal of long shots

While 63% of recreational golfers believe that it is important to personally maintain their driving distance, these golfers did not indicate that they would seek any means necessary to do it, and – overwhelmingly – reported that they prefer to play with conforming golf equipment.

Many survey respondents believe that golfers should play a golf course length that correlates to their tee shot length, but should also enjoy the "challenge of a difficult golf course" and – as reported – do not generally select to play an "easy course" just to score well (Figure 72).

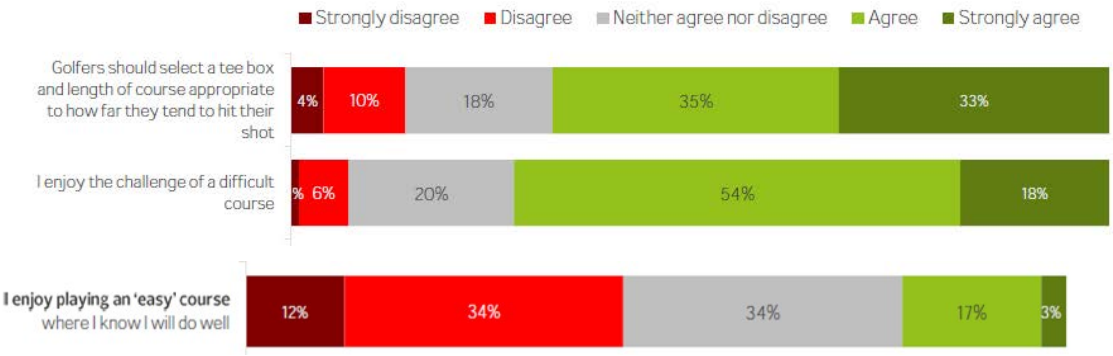


Figure 72 Golfers – attitudes to playing golf

When questioned about the importance of the connection between the recreational and the elite/professional game, many golfers believe that "male professionals play a different game" and that the gap is widening.

Throughout the survey, however, the elite/professional women's game was not mentioned in relation to distance as "a problem." Across all global markets, some respondents acknowledged that they prefer to watch female professionals because their games are more relatable.

Many golfers acknowledged that a unique and appealing aspect of golf is the connection between the recreational and the professional game.

6.5.2 Elite / Professional Game

A sample of professional golfers were asked about what they believe to be the impacts of distance in golf. While the responses were qualitative in nature given the live interview format, some notable commentary and verbatims emerged:

- On the topic of Impact on changes to the game of golf and the skills required to play, one respondent commented, speaking to the general sentiment of many in the group:
    - "*I think it's making it increasingly difficult for anyone who doesn't hit it a long way to survive in the modern game at the professional level*"
- On the topic of Modern equipment is becoming more forgiving, one respondent commented, speaking to the general sentiment of many in the group:
    - "*It's a hot debate. You know I'm so young that I don't think I knew what the old equipment was…so it's (distance) just always been there…I don't see a problem with it*."

For those professional players in the sample who did not perceive distance to be an issue in golf, the primary reasons cited included:

- Golf is more athletic now
- The game is more than only distance
- Distance is a skill in itself
- Technology and innovation help level the playing field
    - "*Everyone's on the same level playing field…my competitor has the same advantage I have. So that's where it is still fair. It's not like I'm using some inferior equipment than what they're using. So long as everyone's using the same equipment and it goes under the same rules, then it's completely fair. No one has an advantage over anyone else*."

The sample of professional players were also asked what they believe fans want to see. Main areas identified were:

- Seeing players hit shots a long way
- Players doing things that the average player cannot/something you do not see every day
- Seeing the best players challenged/tested
- The struggle and/or players making mistakes
- Escape/recovery shots
- Great battles
- Shotmaking/creativity
- Variety
- Particular (specific) players

"I think they (fans) love the idea of birdies and eagles, but I also think they like to see the best in the world struggle as well."

"I feel that they generally want to see something that they are unable to do. I think when you are watching professional sport, it brings out the 'envy in people'…showcasing the professionalism of the athletes and the limitations of the amateurs."

6.6 Golf Fan Perspectives

Golf fans watching the elite/professional game enjoy variety of their "golf viewing product", R28 - Global Stakeholders Perspectives: Fan Deep Dive. By and large, there is a low level of interest in the elite/professional game being dominated by any one element -- be it tee shots, long drives or putting.

Figure 73 indicates what golf fans find most interesting in their golf viewing experience:

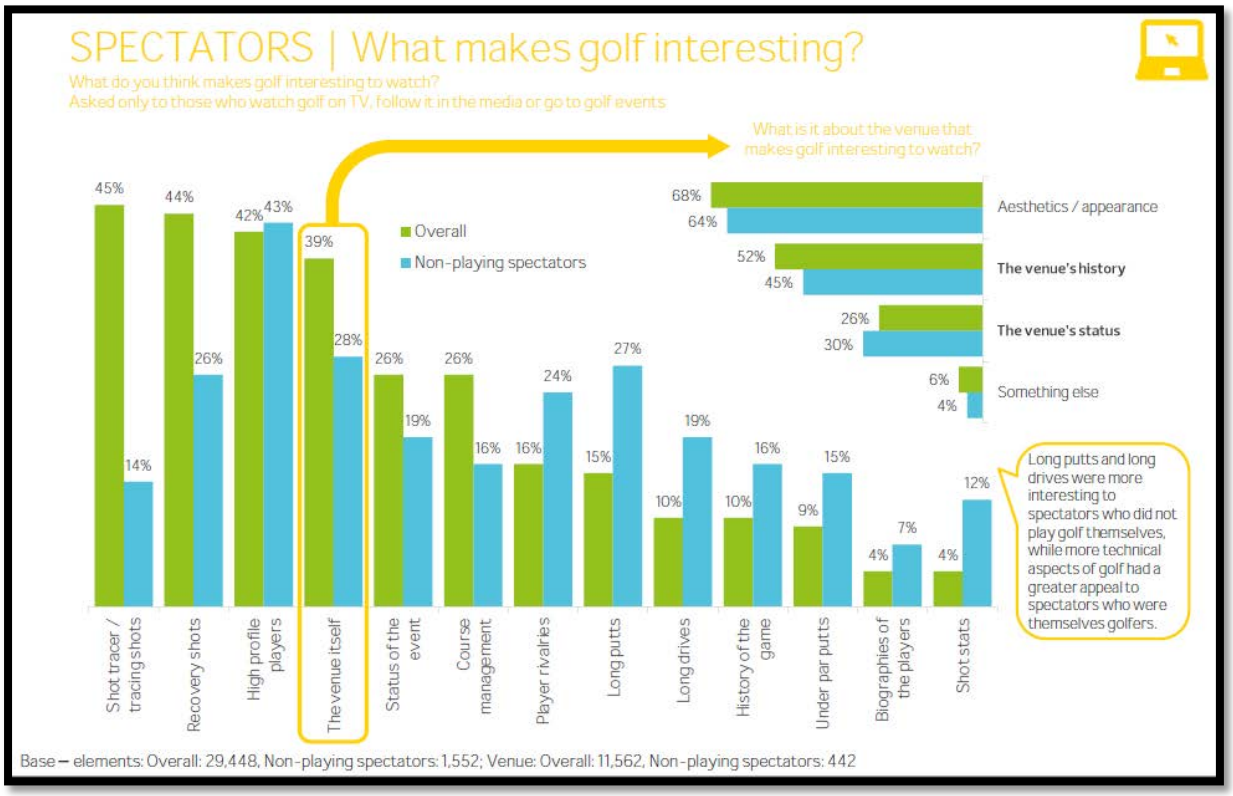


Figure 73 Golf fans – what makes golf interesting?

Just as many golf fans enjoy variety in the type of shots they see in their viewing product, golf fans also enjoy viewing a variety of golf course types, with links golf courses being the most popular. Figure 74 shares golf fans' perspectives on the types of golf courses they enjoy viewing.

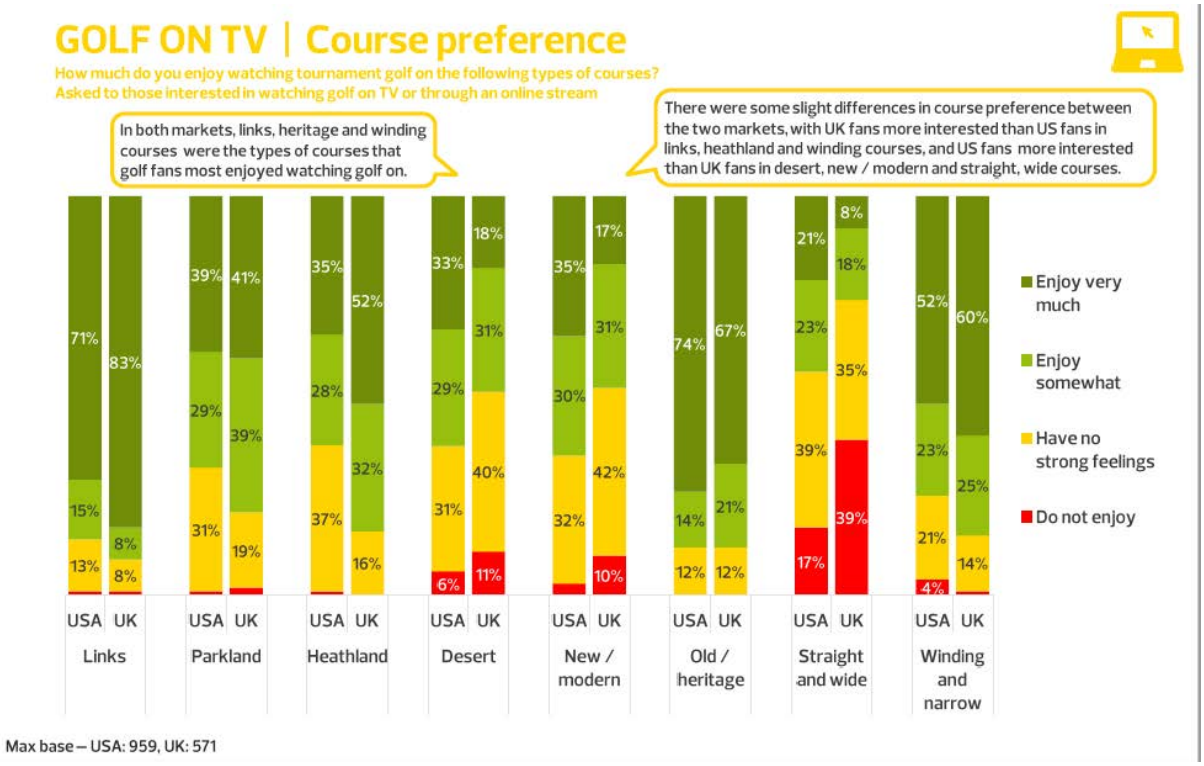


Figure 74 Golf on TV – course preference

6.7 Impacts of Distance on Golf Courses

Many respondents commented that they do not want to see golf courses lengthened, asserting that there should be no change to the golf courses on which recreational golfers play.

Figure 75 shows the diversity of opinions about how golf courses should or should not change in the wake of any future increases in shot distance.

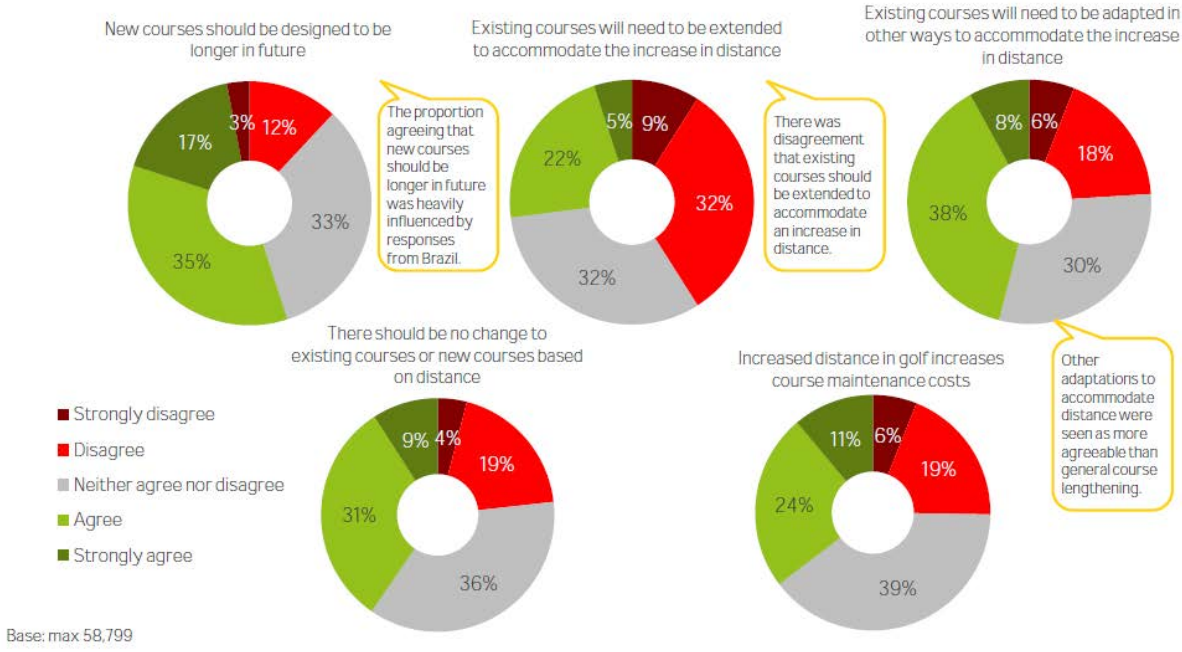


Figure 75 Attitudes to distance – the golf course

Overall, many recreational golfers are content with the length of golf courses they currently play regularly. For many recreational golfers, the concept of championship length means very little if the course is not a true championship event golf course. Most golfers' are interested in playing a golf course that has hosted a specific championship event, rather than one that meets somewhat loosely defined "championship" length requirements.

For the sample of professional golfers interviewed who felt that distance has had an impact on golf courses, the main impacts cited by this group included:

- Golf course lengthening and expansion
- Golf course providing less of a challenge and/or becoming obsolete
- Design intent being compromised
- Sustainability concerns
    - "*It certainly has an impact on the game. It will make certain courses easier than they were 10-15 years ago, but it's just one aspect of the game that has changed.*" "*How many wonderful, older courses are no longer a challenge for the top professionals?*"

Many golfers related concern with golf courses' lengthening as a method to manage distance. Golfers also had mixed opinions about whether distance is problematic for the game or a natural evolution of the modern game. Golfers further differed on whether changes were needed and what the nature of those changes should be.

According to the GGA study (R29 – DISTANCE INSIGHTS SURVEY REPORT), the shot distance attained by golfers continues to impact the perception of appropriate length of a golf course. 62% of respondents believe that the professional game impacts recreational golf, and 72% believe it impacts the size of golf courses.

However, owners and operators of golf courses still do not consider shot distance to be a significant factor impacting business metrics. Figure 76 shows that respondents estimate a 1.8% increase in revenue with a corresponding 3.1% increase in operating expenses. Also shown in Figure 76, 99% of

respondents indicate that increasing distance impacts expenses, while only 45% believe that increased distance impacts revenue.

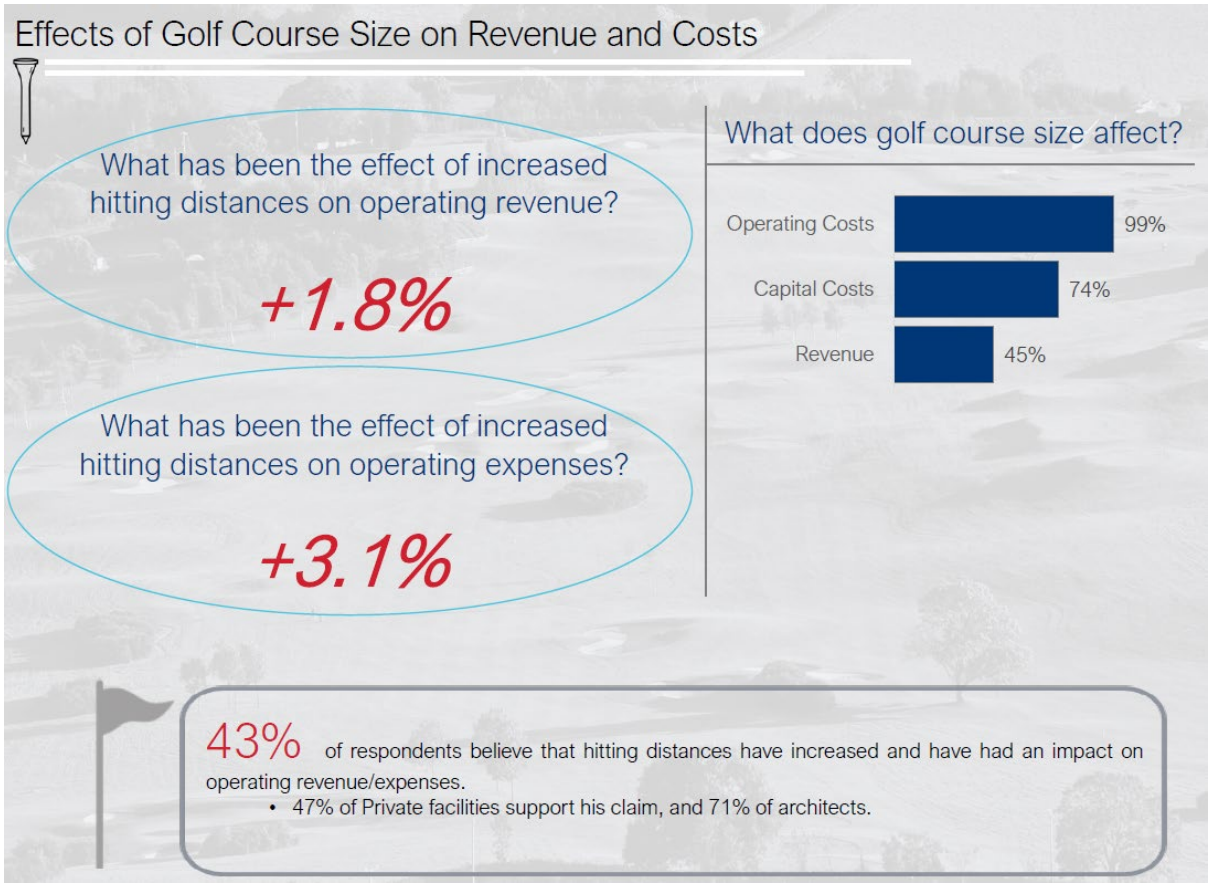


Figure 76 Effects of golf course size on revenue and costs

Figure 77 details the highest impact areas of golf course size on budget. Higher labour costs are the largest budget area impacted by longer and larger courses. Water and chemicals are second and closely lumped together in impact.

Figure 77 Effects of golf course size on costs

Outside of pressure to add longer tees due to increased hitting distance over time, comments echoed throughout the GGA survey related to a desire for enhanced focus on playability and forward tees to accommodate higher golf participation levels as shown in Figure 78. 88% of respondents noted that adding forward tees would attract more recreational golfers compared to 12% believing that adding course length would help realize that goal.

Figure 78 Impacts of recreational golfers hitting distances

Figure 79 indicates the extent of hitting distance increases with just over half of the golf facilities having modified their golf course due to increased hitting distance over the last five years.

While tee box lengthening was most common (37%), moving the location of bunkers (34%) and adding tee boxes to shorten the course (28%) were also notable changes for which the median capital cost was $250,000. When the golf course was lengthened, the average increase was 10% compared to 8% in 2013.

As Figure 80 shows, some of these modifications were due to dispersion issues averaging about $55,000 for 61% of the golf facilities responding.

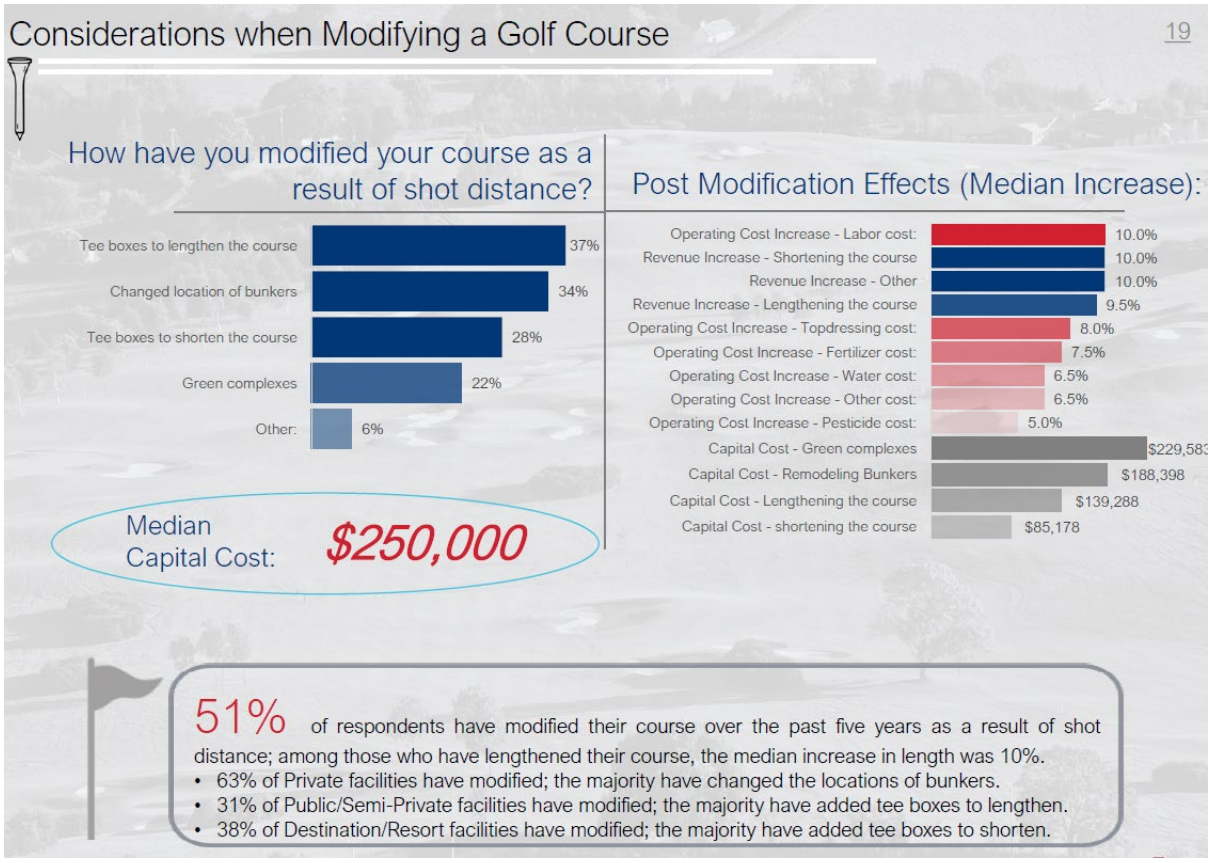


Figure 79 Considerations when modifying a golf course

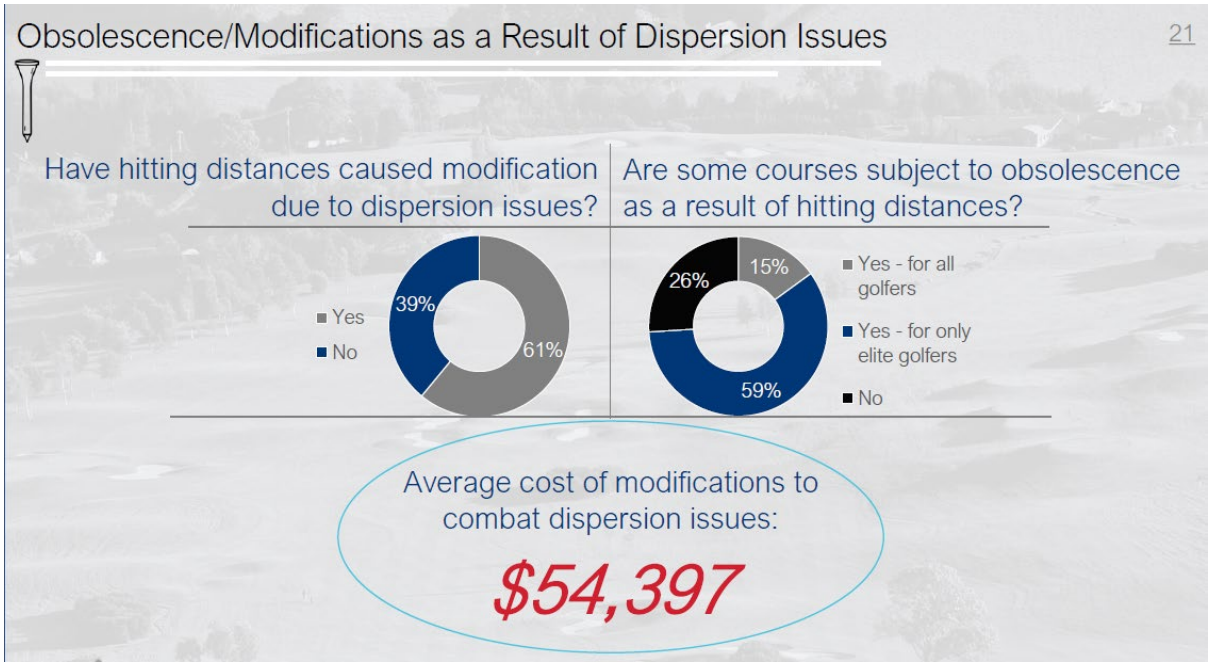


Figure 80 Obsolescence/modifications as a result of dispersion issues

6.8 Perspectives on the Future of Hitting Distance in Golf

6.8.1 Golf Success Factors

Figure 81 indicates how recreational golfers view "success in golf." Overall, "putting well" topped the list, and "long driving/tee shots" was rated lower.

Figure 81 Attitudes on success in golf

Looking in detail across all stakeholder groups, opinions on distance in golf are divided, with each stakeholder group's opinions generally motivated by their unique vantage point. Attitudes for what determines "success in golf" vary according to the given stakeholder group as evidenced by Figure 82.

Among the broad group of golfers, many variables are at play, including age and handicap. Overall, golfers ranked "using the right equipment" and "long driving/tee shots" as the element that should be least contributory to defining success in golf.

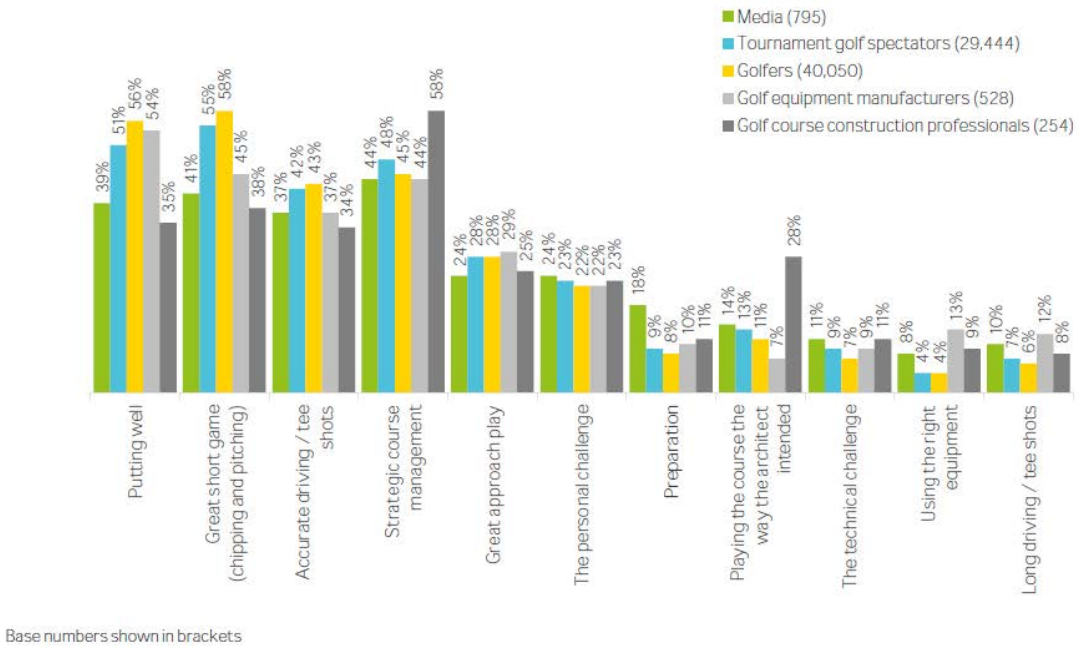
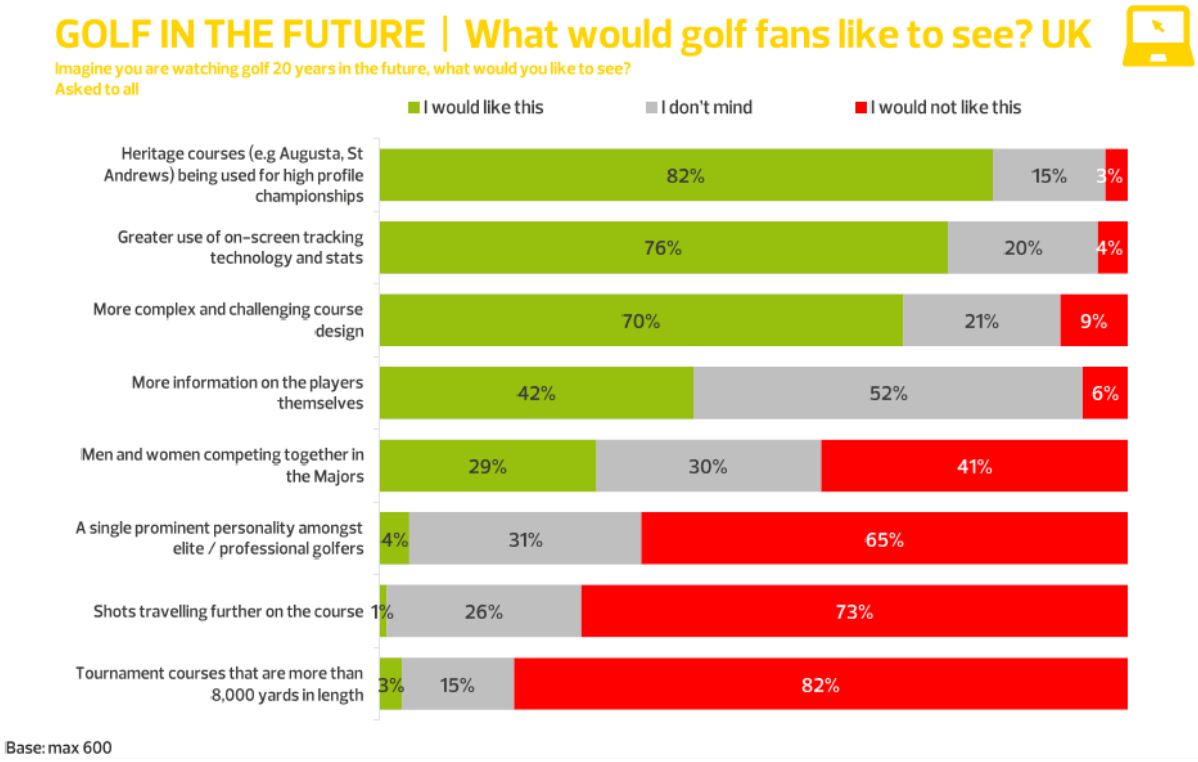


Figure 82 Selected stakeholders breakdown of what contributes to success in golf

6.8.2 The Future of Golf Courses

Greater than 80% of fans surveyed in the U.S. and UK commented that – in 20 years' time - they would still like to see "heritage golf courses" (e.g., Augusta National GC or St Andrews Golf Links, both of which were used as examples in the survey, see Figure 83) used for high-profile championships. In addition, 75% of survey respondents in the U.S. and the UK said they would not like to see tournament courses play at more than 8000 yards of length.

Figure 83 shows UK results related to what fans would like to see in the future (note that U.S. data is similar). What golf fans would *most* like to see are heritage golf courses used for high-profile championships; what golf fans would *least* like to see are championship golf courses at greater than 8000 yards in playing length.



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R03	Agronomic Impacts on Bounce and Roll Distance	Study on the relationship between bounce and roll and turf characteristics including moisture, cutting height and grass species
R04	An investigation into Ball-Turf Impact Characteristics	Report from 2006 on ball turf interaction experiments conducted at a selection of courses within the UK, with consideration of the ability to predict bounce and roll
R05	Analysis of Amateur Driving Data 1996-2018	Bi-annual report on amateur hitting distance based on measurements using the same U.K. courses from 1996 to date. Also includes comments on scatter and launch conditions and more recent data acquisition
R06	Analysis of Playing Lengths of Golf Courses on the PGA TOUR	Historical review of playing lengths on the PGA TOUR including comments on the relationship between playing length and hitting distance
R07	Analysis of Trackman data gathered at World Long Drive events	Report on drives made at long drive events including carry distance and clubhead speed
R08	Annual Driving Distance Report - 2019	Fifth annual publication of hitting distance on the world tours which records data and data extracted from the Analysis of Driving Data report (R05)
R09	Approach Shot Distances and Hole Lengths on the PGA TOUR	Analysis of the relationship between hole length and approach shot distance over the last 15 years including a review of hole lengths for par 4s and 5s
R10	Bounce and Roll Testing at Philadelphia Cricket Club (Militia Hill Course)	Report from 2011 documenting experiments on bounce and roll characteristics collected in Philadelphia examining variables like inbound angle
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R12	Clubhead Speed	Review of clubhead speeds from recent years and comments on some historical information
R13	Comparison of historic (1964-1966) tournament performance data with its modern equivalent	Data extracted from the archive gathered by the Golfing Society of Great Britain's Scientific Working Group in the construction of the seminal work "The Search for the Perfect Swing"

R14	Components of Superior Professional Golf Scoring From 1983 to 2018, With a Focus on Driving Distance and Accuracy	Study on metrics and their relative importance in determining success for the last 35 years
R15	Construction Cost Estimate of Distance Impacts	Review of the costs associated with golf course construction and how this has been impacted by hitting distance
R16	Costs and Availabilities of Maintenance Resources	Report on the scarcity and cost of resources such as water, labour, energy, nutrients and pesticides, together with regulatory considerations
R17	Costs of Golf Course Maintenance - Past, Present and Future	Review of golf course maintenance costs over the last 100 years with an enhanced focus on the last decade
R18	Effect of Club Length on Potential Distance	Report from 2016 on the relationship between club length and potential hitting distance with reference to scientific works and simple calculations
R19	Effect of Equipment on Distance - Driver	Simple calculations to estimate the impact of driver characteristics on hitting distance
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R23	European Tour Weather Conditions and Relationship with Driving Distance	Analysis of driving distance data on the European Tour and how it relates to information available from Tour weather reports
R24	Evolution of Golf Course Lengths Globally	Course lengths from 1890 onwards including discussion of forward, middle and longest tees.
R25	Evolution of Playing Lengths for Elite Competitions in the United States	Long term analysis of course lengths used for elite competitions in the U.S. dating back to 1890
R26	Evolution of the Length of the Top 100 Courses	Statistical analysis of the length of the Top 100 golf courses in the U.S. since 1975
R27	Global Stakeholders Perspectives	Study of the question "Considering your role in golf, how if at all, has distance (i.e. how far shots travel on a golf course) affected you and how is distance likely to affect you in the future?"

R28	Global Stakeholders Perspectives: Fan Deep Dive	Study of the attitudes of people who identified as golf fans from the U.S. and U.K. Information on their perspectives on the relationship between distance and their current and future consumption of the sport
R29	DISTANCE INSIGHTS SURVEY REPORT	Study of the attitudes of facility (and multiple facility) operators to the questions of distance with a comparison to a similar study from 2013
R30	Golf Course Water Use and Costs - Past, Present and Future	Report on the usage of water within the U.S.
R31	Historical Equipment Research and Testing	Report on the evolution of equipment and its performance characteristics
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R33	How golf courses change (Global)	Study of the evolution of the footprint of golf courses and their components (tees, fairways, bunkers, greens and practice facilities) over the last 80 years with examples from the U.S., Australia, Japan and the U.K.; including some Championship courses
R34	Identify the Effects of Distance on Pace of Play	Study on the relationship between hitting distance, hole length and pace of play
R35	Impact of Safety Margins and Routing Style on Footprint	Consideration of the impact of safety margins and routing on the footprint of golf courses, including the offset to course boundaries
R36	Lengths of Golf Courses on the Professional Tours	Detailed comments on specific course lengths and other factors
R37	New Course Opening Study (US)	Report on the length and type of recent course opening in the U.S. from 2011 to 2016
R38	PGA TOUR data from Shot Link (2016-18)	Evaluation of the value of distance for holes of specific lengths separated as par 4s and par 5s
R39	PGA TOUR Relationship of Days with Rainfall and Driving Distance	Analysis of driving distance data on the PGA TOUR and how it relates to information available from weather reports
R40	Player Interview Findings	Perspectives of elite players on the topic of distance chosen to give a broad demographic from past to current and long to short players
R41	Playing Lengths for Select Elite Competitions, ca. 1920 to Present	Historical review of playing lengths used for majors and national level events
R42	Playing Lengths of Golf Courses Used for Amateur Golf Competitions in the United States, 1979-2018	A review of the playing lengths used for competitions within the U.S. for amateur golf with a historical perspective

R43	Playing Lengths Study (US - 2019)	Review of the playing lengths within the U.S. from various teeing grounds extracted from the USGA Course Rating Database
R44	Playing Strategy on the PGA TOUR	Analysis on the strategy employed on the PGA TOUR for par 4s and par 5s looking at risk/reward
R45	Preliminary Results of Turf Testing at Pinehurst #2 Spring 2005	Report from 2005 on the testing of turf conditions at Pinehurst #2 and consideration of the ability to predict bounce and roll
R46	Relationship Between Height, Driving Distance and Success	Comments on the height of tour players and the relationship with driving distance over the past 30 years
R47	Results of Robot Face Mapping	Description of robot tests for a variety of drivers with differing characteristics reporting the variation in hitting distance from scatter across the face
R48	Review of Driver Clubhead Characteristics Over Time	Data report on the changes in measured clubhead characteristics over time and how they relate to the Equipment Rules
R49	Tee Yardage Inventory	Review of playing lengths available at golf courses outside the U.S.
R50	The Correlation between Tour Performance and Success Rankings	Tour performance analysis studying the historical progression of metrics and their relationship to success
R51	The divide between professional and amateur golfers is growing	Comments on the growing divide between amateur and professional golfers based on a commercially available product
R52	The Evolution of Fairway Agronomy	Review of the evolution of agronomic practices over the last 100 years with comments on the relationship to playing quality
R53	The History and Evolution of Hitting Distances and Golf Course Lengths Before 1980	Analysis of historical archives focusing on the long term view of hitting distances and course lengths before 1980
R54	The History of Elite Competitive Golf in the United States	Review of event yardages over the last 130 years within the U.S.
R55	The relationships between driver clubhead presentation characteristics, ball launch conditions and golf shot outcomes	Article giving details of clubhead presentation and shot outcome for a group of 285 golfers with a wide range of skill profiles. *Betzler, N. F., Monk, S. A., Wallace, E. S. & Otto, S. R. 2014 . Journal of Sports Engineering and Technology 228(4) 242-249.*
R56	The Value of Distance	Study on the evolution of the value of distance and its relationship to other metrics, and in particular, its importance in determining success over the last 15 years