USING SIMULATION MODELING TO DEVELOP A GOLF COURSE FLOW DSS

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ABSTRACT

A model-based decision support system (DSS) for operating and designing golf course systems is presented in this paper. The DSS is based on a simulation model that accurately represents the variability and interactions that impact pace of play on a golf course. Research shows the economic benefits of understanding the impact of policy and design on golf course play, specifically throughput (rounds played) and cycle time (round length). The DSS model was developed using MS-Excel and @RISK, a Monte Carlo simulation package. Using MS-Excel offers a much greater degree of transferability and usability than traditional standalone discrete-event simulation software.

Keywords: Golf simulation, gate management

INTRODUCTION

The golf industry is big business. In 1999, golfers spent $16.3 billion on green fees [18]. Because of the Tiger Woods effect on popularity, the number of golfers is increasing, creating the need for more courses. Over 400 new courses are being constructed per year [18]. Golf courses, like most business operations, are designed and operated to be profitable. Many factors influence profitability. This paper focuses on improving profits by increasing throughput (the number of golfers playing golf per day) of a golf course. The approach used in this paper is unique in that we apply proven math-based modeling technology to model golf course daily throughput.

Daily golf course play is a stochastic system where random events (lost balls, weather, and poor shots) and interactions (waiting for the group in front of you) heavily impact the pace of play. Although complex, daily golf course operations are very similar to other complex systems such as:

- A manufacturing plant where parts are moving from production process to process
- A distribution network where transportation devices (trucks, boats, planes, …) move from location to location
- An emergency room at a hospital where patients wait for treatment

In all of these examples, performance is impacted by variability and interactions. However, these examples and other complex systems have been analyzed with math modeling. Therefore, a golf course system should be a candidate for math-based analysis.

Before proceeding, the first question to be addressed is 'Is there potential for math modeling to increase profits by improving throughput?' Consider a course with a $35 green fee, 12 hours of daily playing time, and an average round taking 4.5 hours. A modest 10% improvement in weekend/holiday rounds yields a 16% increase in throughput and over $100,000 increase in annual revenue. Certainly, the potential exists.

The objective is to demonstrate a math-based model that accurately represents the daily play at a golf course that can be the basis for a design and operations improvement decision support system. A model-driven DSS that represents daily play at a golf course is beneficial for both designers and course managers. In both, qualitative measures and experience are the primary tools. Little empirical knowledge exists that provides the quantitative impact on throughput. For example, how much do the following impact throughput: fairway width, length of course, elevation changes, bunkers, green size …? Certainly, designers know that the above impact pace of play. However, quantifying the impact is much more difficult. One study has shown that the number of bunkers and the hilliness of the course did not influence revenues [16]. Similarly, course managers have questions regarding throughput. How much do the following impact throughput: tee-time intervals, shotgun starts, group size (2, 3, 4, 5...), carts vs. walking …? Increasing throughput and controlling, or at least forecasting, cycle time are two of the most important factors in revenue management [10].

The ultimate objective is to create a science of golf course play by representing golf course play with a math-based model**.** A model of systems allows studying the system without the consequences of experimenting on the actual system. The benefits are reduced time and costs and increased safety and creativity. If the model used only once to solve a problem, it has been a useful tool. If the model can be used again, in a changing environment, with several variables at the control of the user, the model is then a model-driven decision support system. The most used method for modeling systems with variability and interactions is discrete-event simulation (DES). In general, simulation refers to a broad collection of methods and applications to mimic the behavior of real systems. Simulation models can be physical or logical (mathematics).

DES is a venerable and well-defined methodology of operations research and many excellent explanatory texts exist [11, 14, 17]. The methodology is particularly useful in evaluating interdependencies among random effects that may cause a serious degradation in performance even though the average performance characteristics of the system appear to be acceptable [15]. Additionally, simulation models are intuitive, which is an important reason for their longtime and continuing application to complex systems. As such, DES has been used to study manufacturing systems [1, 3, 4, 7, 8, 12, 13], supply chains [2, 5, 6], business processes, and the healthcare industry.

The literature review found one published article where simulation was applied to modeling golf course play [9]. In this model, waiting occurred only on the first tee. In a real system, many opportunities exist for waiting, and not all of them occur on the tee box. The study also assumed that rate of play was normally distributed, and a skewed distribution is more likely. The time study used to build the simulation was based on one course. A new time study would need to be done for each course you wanted to analyze.

MODELING METHODOLOGY

System Description

A golf group consists of individual golfers, usually ranging from 1 to 5. Once set, the number of golfers in a group does not change. On each hole, the group begins on the tee box and hits one at a time. The group moves towards the green once all golfers in the group have hit from the tee box. Some golfers move to the green more quickly than others depending on many factors. Having reached the green, each golfer finishes by putting (one at a time) his/her ball into the hole. Once all golfers in the group have finished putting, the group proceeds to the next hole.

The group's pace is dictated not only by its own processing time, but also by the group's immediate predecessor and the type of hole (par 3, 4, or 5). A group must wait for its predecessor to be out of the way. For example on a par 4 (or 5), a group cannot begin to hit from the tee box until its predecessor is sufficiently out of range to prevent injury by hitting someone. Because of the short distance of a par 3, a group cannot hit from the tee box until its predecessor is off the green. On par 4/5's a safe distance is between 225 and 300 yards. We define the point that allows the group behind to safely hit as a *gate* and refer to waiting for the group ahead to be out of the way as *gate management*.

On the tee box and green, individual golfers hit one at a time. Therefore, for the group, the processing times are additive. In a fairway, the golfers proceed in parallel and the slowest golfer dictates the group's pace of play.

A golf course is a terminal system. It has a definite beginning and ending as a function of daylight. For terminal systems, performance is very dependent on the system's initial conditions. For a golf course, a slow group early in the day often spells disaster for the remainder of the day in terms on the rounds played (throughput) and round length (cycle time).

Modeling Technique

The golf course system was modeled using MS-Excel and @RISK, a MS-Excel add-in. Although not a standalone discrete-event simulation software, MS-Excel has an assortment of functions that are quite capable of modeling a gate-management system. The add-in, @RISK, provided a concise method for modeling different scenarios and maintaining statistics for analysis.

The best way to illustrate the gate management modeling logic is through an example. Consider the first hole at the beginning of the day. The first two groups are modeled. Group one has the first tee time (time = 0), and group two's tee time is six minutes later. Table 1 shows the processing times for each group. Note that this table does not show event times, only processing times. Since hitting from the tee box is a serial process, times are additive, and group one takes 150 seconds. Before group two can hit from the tee box, group one needs to be out of the way. We define a gate 300 yards from the tee box that group one must be through prior to group two hitting.

Table 1. Processing times for a Par 4

Group	Golfer	Time to tee-off	Time through gate	Time to green	Time to putt
1	1	60	110	70	70
	2	30	90	60	30
	3	20	100	200 (max)	10
	4	40	140 (max)	40	70
	Group	**150**	**140**	**200**	**180**
2	5	40	100 (max)	40	30
	6	40	60	60	40
	7	60	70	70	50
	8	20	80	80 (max)	40
	Group	**160**	**100**	**80**	**160**

The golfers in group one move to the gate at different speeds, and the slowest golfer (golfer 4 in this example) is out of the way in 140 seconds (after leaving the tee box). From this gate, golfers in group 1 proceed to the green. Golfer 3 takes the longest (200 seconds). Once on the green, putting time is additive; therefore, the total putting times is 180 seconds, and the group's total time to complete the hole is 670 seconds.

Similar logic exists for group 2, except its pace is dictated not only by its tee time and processing time, but also by group 1's pace. Table 2 shows the event times. Group 2's tee time is six minutes after group 1. Since group 1 is through the gate at 290 seconds, group 2 does not need to wait for group 1 and begins to hit exactly at its tee time. However, group 2 is not as fortunate in the fairway. Group 2 takes 160 seconds to hit from the tee box and 100 seconds to reach the gate; therefore it is ready go through the gate at 620 seconds. However, it cannot get through the gate until 670 seconds because group 1 is still on the green. Therefore, group 2 waits in the fairway for 50 seconds. This delay does not prevent group 3 (not modeled) from hitting at its scheduled tee-time of 720 seconds; however, this can change as the day progresses. As often with queuing systems, once behind, it is very difficult to get back on schedule. For par 3 and 5 similar logic is needed, except par 3s have no fairway gate and par 5s can have two fairway gates.

Table 2. Event times for a Par 4

Group	Tee-time	Off tee-box	Through gate	To green	Off green
1	0	150	290	490	670
2	360	520	670	750	910

Data

The modeling approach used is gate management. For accurately representing to-gate times, data were collected by a class of Operations Management students as a data analysis exercise. Four different types of data (500+ values) were collected from five different local courses. Each type of data fit a triangular distribution. See table 3 for the type of data and triangular distributions values for the minimum, mode, and maximum. Note that the tee box and putting values are times (seconds), and the other values are rates (yards/second). The rates allow transit times to be determined on any hole on any course by dividing the hole-specific distance by the randomly generated rate.

Table 3. Data Values

Data Type	Description	Min	Mode	Max
Tee box time (seconds)	The time for an individual golfer to address and hit the ball on the tee box. No waiting time included.	25	46	65
Tee box to gate (yards/second)	After leaving the tee box, an individual golfer's rate while reaching an arbitrary (but identified) point/gate in the fairway.	0.167	1.50	3.25
Gate to green (yards/second)	From an arbitrary (but identified) point/gate in the fairway, an individual golfer's rate while reaching the green.	0.28	1.76	3.33
Putting time (seconds)	The time for an individual golfer to complete putting and leave the green.	14	63	90

A good decision support system separates input data from modeling logic; thus, developing a tool that can be applied to many different systems. Our model-driven DSS separates course data from the modeling logic. Therefore, if a new course is to be analyzed, only the input data must be modified. The modeling logic takes into account which hole is a par 3, 4, or 5 and represents the gate management system accordingly. The input data structure with some sample data (first 3 holes) is shown in Table 4. The first hole is a par 5. The first fairway gate is 275 yards from the tee box. The next fairway gate is 200 yards from the first fairway gate. The green is 25 yards from the second fairway gate, and the second hole's tee box is 50 yards from the first green. The second hole is a par 4; therefore, it does not have a second fairway gate. The third hole is a par 3; therefore, it does not have any fairway gates.

Table 4. Input Data

Hole	Par	Distance	To Gate 1	To Gate 2	To Green	To Next Hole
1	5	500	275	200	25	50
2	4	400	280	-	120	70
3	3	180	-	-	180	60
…						

Assumptions

1. No play-through logic (same group order throughout the round).
2. Gates are hole-specific, not golfer-specific.
3. No golfer designation except quantity. Carts/walking, fast/slow, good/bad, straight/erratic, long/short … are not included.
4. No course designation except par and distance. Water, bunkers, rough height, elevation changes … are not modeled.

Although not modeled in this research, substantial opportunities exist for incorporating the assumptions as modeling parameters in subsequent research.

Validation, determining that the model accurately represents the real system, relied primarily on experience and expert judgment. Avid, if not talented golfers, the authors have a wealth of experience of how long a round can be played without waiting as a single or in a group. Similarly, the modeling of a busy course accurately reflected upwards of 5 hours for a weekend round of golf.

ANALYSIS OF TEE TIME INTERVALS AND SHOTGUN STARTS

As an initial analysis, a typical busy course (four golfers per group) was analyzed to determine the tradeoff of tee time intervals and rounds played. In addition, a shotgun-style approached was also modeled. Shotgun starts fully load the course (a group on each hole in this example) immediately at the beginning of the day and reload the course approximately five hours later. Figure 1 shows the results from a 100-day simulation. Since the system is terminal, no warm up period is required.

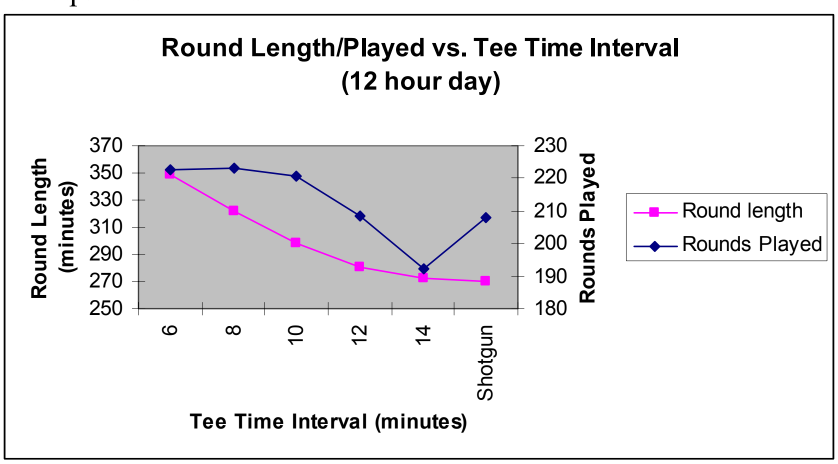

Figure 1. Tee Time Interval Analysis

The chart shows the tradeoff of throughput (rounds played) and cycle time (round length) versus the tee time interval. Short tee time intervals get more people through the course; however, the consequence is a congested course as shown by the long cycle times. For this course, a 6-minute tee time, 220 rounds of golf are completed in a day; however, the round averages six hours! Moving to a 14-minute tee time drops the round length an hour-and-a-half; however, a reduction of 30 rounds occurs. Compared to a tee-time policy, shotgun starts have two benefits: short cycle times (four-and-a-half hours) and large throughput (210 rounds). The reason is the ability to fully utilize the system from the beginning of the day. In this example, a group was assigned to each hole. Potential additional improvements are possible by putting more than one group on specific holes. Although shotgun starts have benefits, the assumption is that no-shows (golfers who have reservations, but fail to show) are minimal. Subsequent analysis, similar to airline overbooking, is needed to fully determine if shotgun starts are profitable.

Identification of course bottlenecks, i.e., holes where play is severely congested, are shown in Figure 2. It shows that holes 6, 8, and 17 are bottleneck candidates. Referring to the input data, holes 8 and 17 are Par 3s which may provide insight to course managers and designers on improvement through better sequencing or management.

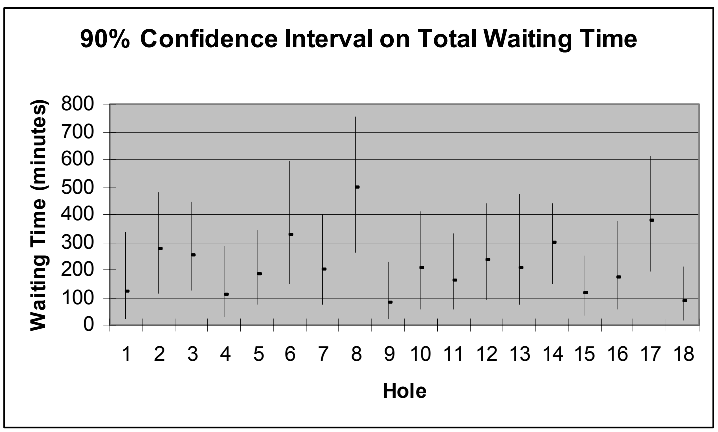

Figure 2. Identifying Bottlenecks

CONCLUSIONS AND FUTURE RESEARCH

This research shows the benefits of applying a math-based DSS to understand the impact of policy and design on golf course play. In the past, little effort has been devoted to modeling a golf course system as a complex system impacted by variability and interaction. The DSS model was developed using MS-Excel and @RISK, a Monte Carlo simulation package. Using MS-Excel offers a much greater degree of transferability and usability than traditional standalone discrete-event simulation software. Future research is plentiful. For example, more detailed data would allow additional golfer and course characteristics to be evaluated; thus providing both course managers and designers feedback on policy and design decisions.

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