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Sharad K. Maheshwari
Editor
Hampton University

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LETTER FROM THE EDITOR

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Sharad K. Maheshwari
Hampton University

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Editor's Note: In a previous issue of *AIMSJ*, Volume 9, Number 2, 2006, we published a paper by Dr. Chang Won Lee, Jinju National University, entitled "Development of Web-Based Decision-Support System for Business Process Re-Engineering in a Health Care System." We published that manuscript by mistake. The author had submitted it for publication in the *Journal of Strategic E-Commerce*, and we did publish it there in Volume 4, Number 2, 2006. We apologize for the error and we would like to emphasize that the double publication was in no way the fault or responsibility of the author.

MODELING THE IMPACT OF NEW TECHNOLOGIES ON PACE OF PLAY IN GOLF: SEGWAY GT, RANGE FINDERS, RFID GOLF BALLS, AND LONGER HITTING DRIVERS

Jimmy D. Speers, Southeastern Oklahoma State University
Andrew A. Tiger, Southeastern Oklahoma State University

ABSTRACT

A model-based decision support system (DSS) is used to study the impact of new technologies on pace of play on golf courses. The DSS is based on a Microsoft Excel 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 on golf course play, specifically throughput (rounds played) and cycle time (round length). The use of a new mode of transport, the Segway GT, is compared to traditional two player carts. Results indicate that pace of play is improved and that golf course managers have cost/implementation strategic options that could offer advantages in a competitive market. Other technologies that are addressed include the use of radio frequency identification (RFID) to identify lost golf balls, global positioning systems (GPS) and other range finders to identify target distance, and longer hitting clubs.

INTRODUCTION

Golf courses and country clubs are second only to gambling in the amount of revenue produced in the amusement, gambling and recreation industries. In 2002 there were 12,189 golf courses that produced $17.4 billion (US Economic Census, 2002). In 2001 there were 518.1 million rounds of golf played. Since then the number has declined by 4.5 percent, even though 2004 saw an increase of .7 percent. In the late 90's, 1800 new courses were built at a rate of over 300 per year. That number has declined to just 150 new courses in 2004 (Kuffman, 2005). With the number of courses increasing and the number of rounds played decreasing, the imbalance in supply and demand has many courses struggling to attract customers. One of the major factors in getting people on the golf course is the amount of time it requires to complete a round of golf (cycle time). If cycle time can be reduced, the number of rounds played during a day (throughput) can be increased.

In a recent interview Lee Trevino addressed the issue of cycle time, he said, "We have a tremendous amount of high-end daily-fee courses in Dallas that are in trouble. They aren't getting the play. The harder you build the course, the more money it costs to maintain it. The economy goes south, people aren't playing, and you still have to meet this big nut to maintain it. To make it hard you put in all these mounds and deep bunkers and creeks and railroad ties, and you have to maintain them. I would never build a modern course. I'm strictly traditional. Build a golf course like it's supposed to be played. I tell people I've never seen them put chairs on a tennis course to make it tougher. *….If you put high handicappers on courses that take 5.5 hours to player, you're going to lose them. And time is money when it comes to golf.* You can't get as many rounds in on a tough course." (Lowell, 2004) New technologies offer the potential of reducing the cycle time. This paper uses math-based modeling to examine the impact of new technologies on the pace of play.

Math-based models have been used to analyze stochastic systems such as manufacturing plants or distribution networks. Recent research demonstrates that math-based models are also being used to model pace of play on golf courses (Tiger and Salzer, 2004; Tiger, et al, 2003). A simulation model that accurately quantifies queuing on a course, developed by Tiger, et al (2003) is the basis for this research. In Tiger et al's (2003) paper, a modeling concept was created that offered a simple, yet powerful method for modeling course congestion, specifically, waiting for the group immediately in front to move *out of the way*. The concept is call gate methodology.

Gates are modeling constructs used at different points of a course. The gates indicate at what point on the fairway the players behind would be able to safely hit. The location and frequency of the gates vary based on golfer characteristics (short or long hitters); hole length and design. Typically, a par 4 hole typically has one fairway gate and a par 5 hole has two fairway gates. No fairway gate is used on par 3 holes because the players behind must wait until all players leave the green to safely hit.

Many queuing statistics are available as model output: feature-specific (tee box, fairway, green, and to next hole) and type (par three, par four, and par five) are the primary outputs.

TECHNOLOGIES

The primary technology of interest in this paper was the use of one-person carts, similar to the Segway GT, and their impact on pace of play. The Segway Golf Transporter (GT) is a Segway that has been fitted with a golf bag carrier, extended life range batteries, enhanced traction tires, and a special software-control key ("Business Outlook," 2006). The Segway uses a technology called dynamic stabilization, enabling it to work seamlessly with the body's movements. The system uses gyroscopes and tilt sensors to monitor the center of gravity at approximately 100 times a second. When the rider leans forward, the Segway moves forward, when the rider leans back, the Segway moves backward. Riding a Segway is very simple; almost anyone can ride one (Alexander, 2006).

They are used in cities and resorts all over the world to give guided tours. A picture of the Segway GT is shown in Figure 1.

Figure 1

Other technologies that could affect pace of play are RFID golf balls, range finders, and longer (but not necessarily straighter) golf clubs. Looking for lost balls is one factor that can increase the time to play a round of golf. Advances in materials and production processes have produced drivers that allow an average golfer to hit the ball farther than they could when most courses were designed. With the greater distance, the angle that represents the player's accuracy covers a wider area. More balls are hit into the rough or into a lateral hazard, increasing the number of lost balls. In the data collected for this study, the average rate decreased by over 50% when a player lost a ball. This reduction negatively impacts round length (cycle time). This negative impact on cycle time can be alleviated with the use of a ball imbedded with an RFID chip and a handheld device to locate it. Radar Golf Inc. produces a ball, with an RFID chip imbedded in its core, that they claim performs equal to or better than balls from Titleist, Callaway, Nike and Maxfli (LaPedus, 2005). The system includes a handheld finder with a range of 30-100 feet, depending on terrain. When switched on it stays on for 5 minutes, the maximum amount of time allowed to look for a lost ball. Extra balls are carried in a shielded bag so that the handheld finder will only locate the ball in play. With the use of the handheld finder that "beeps" when pointed towards the ball, the golfer can find a lost ball more quickly. The handheld finder also provides a visual LCD signal strength display.

Another technology that offers the possibility of increasing pace of play is rangefinders. Knowing the exact distance from the tee box to a bunker or the distance to the green can allow the player to make a confident swing. Players usually must look for a sprinkler head, ground plate, or stake. The time to find the yardage can be reduced using a range finder. A range finder can give the correct yardage in a few seconds. Global Positioning Satellite (GPS) technology and laser rangefinders are the best available products.

Global positioning systems provide an accurate measurement from the player's current location to the green. GPS handheld devices can be carried by the golfer to find distances form his/her location to any waypoint previously set. Waypoints are set for tee boxes, bunkers, water hazards, greens, or any desired feature on the course. Many resorts and high-end courses use cart mounted GPS systems. The PGA TOUR does not permit the use of these devices during competition. The U. S. Golf Association allows the use of distance-measuring devices by local rule. The Tight Lies Tour, a Texas-based mini-tour, does allow the use of rangefinders. They decreased the time of play by 15 minutes per round in 2005 (Tschida, 2006).

Another alternative for range finding is the handheld laser range finder. The laser rangefinders look like small video cameras and are used like binoculars. These rangefinders send out a laser beam that bounces off the target. The unit measures the amount of time for the beam to bounce back and calculates the distance. The process takes less than a second. The laser rangefinder works only with line of site, but is more accurate than the GPS system (Gleason, 2005).

DATA COLLECTION

Prior research did not identify rates specific to transport mode. No information existed for determining different rates for walkers, two person carts, and one-person carts. Additionally, prior research assumed that all rates followed a normal distribution. For this research, new data was collected to (1) generate transport specific rates and (2) determine different rate shapes and parameters. Data was collected for two different transportation methods - two players in a cart and with one player in a cart. One player in a cart was assumed equivalent to a Segway GT. No research has been done in this area but the Segway GT will travel at 12.5 m.p.h. and the course where the data was collected for this study has its carts set at the 12 m.p.h. setting. The electric golf carts have faster settings, 20 m.p.h., but most courses do not use this setting because it is too fast for uneven terrain. A data collection sheet similar to Table 1 was used to record data as follows for a specific course: first, gates were established for each par 4 and par 5 hole. Some familiarity with the course must exist to establish reasonable gate locations. A global positioning system (GPS) was used to locate the gates on the course as waypoints. The GPS recorded the route of the players and the time. The times, locations, and speeds are viewed with software that shows when the waypoint is reached. The times are used to calculate the rate on the fairway in yards per minute. Also the time on the tee boxes and greens and the time to travel to the next hole are recorded. The start and stop times when searching for a lost ball were also recorded.

Table 1: Data Collection Form

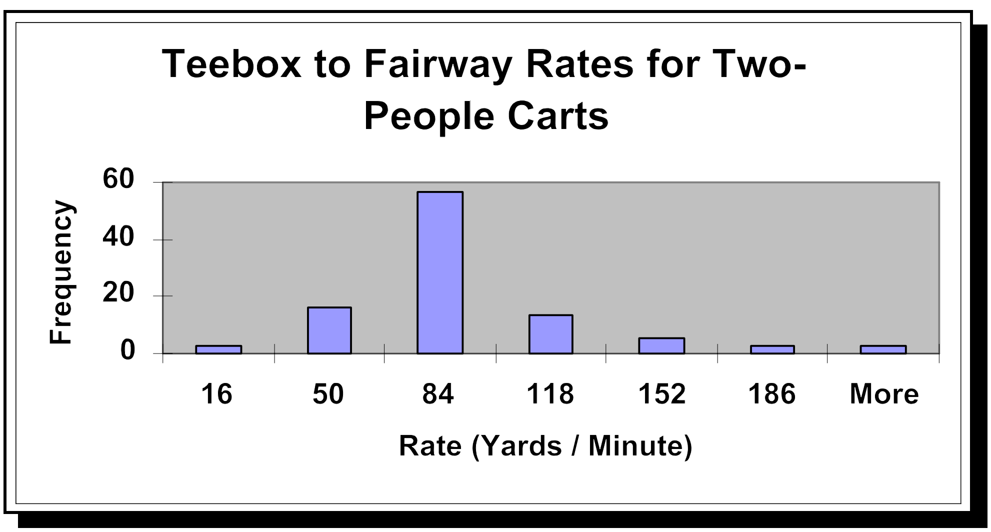
			Number	Tee box		Gate 1		Gate 2		Green		To Next
Hole	Par	Yards	in Cart	Enter	Leave	To Green	Time	To Green	Time	Enter	Leave	Hole (Yards)
1	4	341	2			100						75
2	3	164	2									75
3	4	327	2			125						250
4	5	463	2			200		50				50
5	4	295	2			50						250
6	4	333	2			50						50
7	4	346	2			125						50
8	3	150	2									200
9	4	315	2			100						300
10	4	294	2			50						250
11	3	129	2									50
12	4	337	2			100						100
13	4	375	2			150						50
14	4	362	2			100						200
15	5	483	2			200		50				250
16	3	136	2									75
17	5	481	2			200		50				75
18	4	339	2			100						

To illustrate, hole number 1 is a par 4 hole. The time entering and leaving the tee box is recorded. It was determined that the gate on this hole should be 100 yards from the green. When the gate is reached, the time is recorded in the box immediately following the "100" (see Table 1). The times entering and leaving the green are then recorded. On hole number 2, which is a par 3 hole, only the time entering and leaving the tee box and green are recorded. There is no need to use a gate on a par 3 hole because players on the tee box must wait until the players ahead leave the green before they can hit safely. Hole number 4 is a par 5 hole. There are two gates on this hole, 200 yards and 50 yards from the green. These times are recorded in the same manner as the gate on hole number one.

Table 2 summarizes the collected data results and Figure 2 provides the histogram for two person cart rates from the tee box to fairway. Figure 2's positive skewness existed for all rate histograms and a lognormal distribution was found to be a better fit than a normal distribution. Tee box and green times followed a normal distribution, which were the same results as the prior research.

Table 2			
Location	Unit of Measure	m	Shape
Tee box	minutes/golfer	0.77	normal
Tee box to fairway gate (two person cart)	yards/minute	74	lognormal
Tee box to fairway (one person cart)	yards/minute	87	lognormal
Fairway gate to Green (two person cart)	yards/minute	54	lognormal
Fairway gate to Green (one person cart)	yards/minute	70	lognormal
Green	minutes/golfer	1.07	normal
Green to next hole tee box	yards/minute	200	lognormal

Figure 2



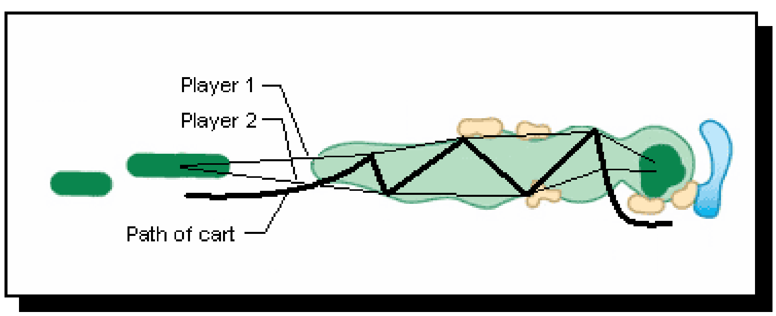
SIMULATION EXPERIMENT

An experiment was run comparing two players in a cart with one person in a cart for different tee time intervals (6, 8, 10, 12 and 14 minutes). Smaller intervals put more golfers on the course, increasing rounds played (throughput) and increasing round length (cycle time). Each mode/tee time interval was simulated for 100 busy days. A busy day is defined as a day that enough player demand exists to fill all tee time intervals. On most courses, this occurs during weekends and holidays. The main factor is the weather; however, other factors exist that might increase the number of busy days: the quality of the course, the size of the market area, the number of other courses in the area, etc. Courses in the southern United States could have over 100 busy days annually due to good weather; however, northern U.S. courses may have less than 50 annually.

EXPERIMENT RESULTS AND ANALYSIS

The use of the Segway GT reduced round length and increased rounds played for all tee time intervals studied. The reason for this is that with only one player on the vehicle, a more direct route is taken. When two players are in a cart, they travel to the next ball, or the ball that is the greatest distance form the green. This can cause a zigzag route to be taken. In Figure 3, if player 1 plays down the left side of the fairway, and player 2 plays down the right side of the fairway, the cart must travel form one side of the fairway to the other in order to get to the next ball to be played.

Figure 3



For the golf course used in this study, the optimum tee time interval would be 12 minutes. When tee time intervals are reduced to 10 minutes, no improvement in rounds played exists, but round length continues to increase, as shown in Figures 4 and 5. Service is compromised without the benefit of additional revenue. If the players are given a quicker round of golf, they are more likely to return, thus creating more business on less busy days, or adding to the number of busy days for the course.

Figure 4

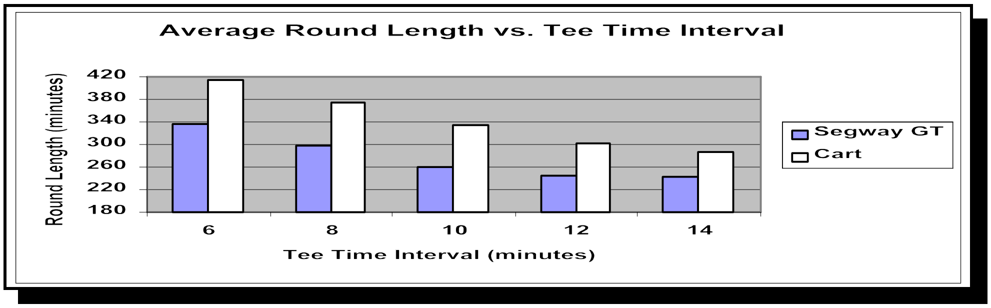
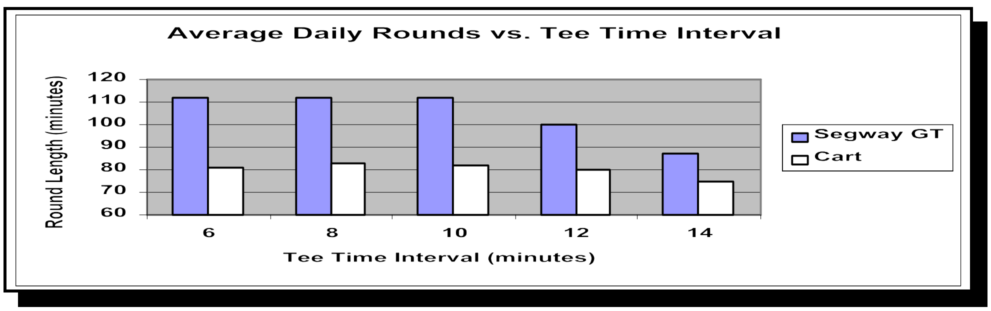
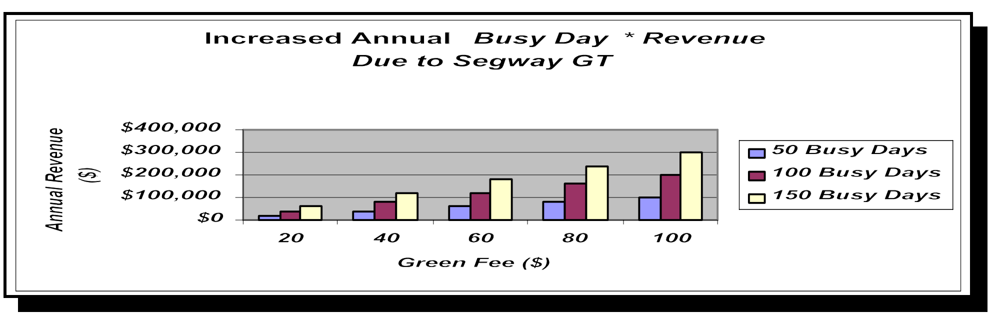


Figure 5



Additional revenue is illustrated in Figure 6 as a function of busy days and green fees (the cost to play a round of golf). Using this information as a starting point, course managers can determine whether introducing Segway GT would be a profitable decision.

Figure 6



CONCLUSION

Anecdotal evidence tells us that these technologies can increase the pace of play: in this study we demonstrated that a math-based model has enabled us to quantify the benefits. Benefits can vary from course to course due to the location of hazards and bunkers, distance traveled between holes, cart path routes, terrain, and green size. This study has shown that improvement always occurs when using the Segway GT on any golf course. Managers of golf courses are always looking for ways to improve pace of play. Reducing the time required to play a round of golf will attract more golfers to a course. It will also allow more players to play on any given busy day. These technologies offer managers options that can have a significant impact on revenues. The Segway GT allows golfers to travel through the course in a more direct route. The use of RFID golf balls will reduce the amount of time searching for lost balls, many of which are caused by golf clubs that allow the average players to hit farther but not more accurately. Range finders will reduce the amount of time to determine the yardage to the green or to a hazard. When the correct yardage is known, a player can select the correct club and be less likely to hit into a hazard. Having the ball in the fairway, instead of the hazard, will also speed up play. Implementing any or all of these technologies will improve pace of play and increase revenues.

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COMMENT GENERATION WITH THREE ELECTRONIC BRAINWRITING TECHNIQUES

Milam Aiken, University of Mississippi
Carl Rebman, University of San Diego
Mahesh Vanjani, Texas Southern University

ABSTRACT

Group support system meeting processes and outcomes are affected by the specific idea generation technique utilized. While most studies of electronic meetings have incorporated poolwriting, other, perhaps superior, brainwriting methods exist. For example, several studies have demonstrated that groups are more satisfied with gallery writing, although there is no significant difference between the two in the number of unique, quality comments generated. A new technique called forced gallery writing could combine the advantages of each. In the first comparison of the three brainwriting methods, results showed that forced gallery writing increased the perceived participation of group members while maintaining meeting satisfaction.

INTRODUCTION

Studies of group support systems (GSS) have shown that people in electronic meetings often participate more, save more time, and are more satisfied than people in traditional, verbal meetings (Jessup, et al., 1990; McLeod, 1992). Many variables can affect the processes and outcomes of meetings, however, including group size, individual typing speed, meeting topic, and the idea generation technique used (Benbasat & Lim, 1993). For example, one study of two brainwriting techniques (group idea generation through typed comments) showed that subjects using one produced better quality solutions, but subjects using the other produced more unique alternatives (Easton, et al., 1990). Yet, many researchers may be unaware of the differences among idea generation techniques, and studies often fail to mention which was used (Pervan, 1998).

This paper compares three brainwriting techniques: electronic poolwriting, electronic gallery writing, and forced electronic gallery writing, or simply, forced gallery writing. First, we describe each technique, and then we review earlier comparison studies. Following a description of the experiment, we present the results and discuss their implications.

THREE BRAINWRITING TECHNIQUES

Although several brainwriting techniques exist, we focus on only three for a comparison. Poolwriting and gallery writing are perhaps the most commonly used, and we introduce a third that could combine the advantages of the two while minimizing their disadvantages.

Poolwriting

Using the brainwriting pool or individual poolwriting technique, each group member (VanGundy, 1992):

- *Writes down an idea about how to solve the problem posed to the group on a sheet of paper,*
- *Places the sheet in the center of the table,*
- *Retrieves the sheet already on the table (exchanging papers),*
- *Thinks about the ideas on the new sheet and uses them to stimulate a new idea,*
- *Writes down a new idea on the sheet,*
- *Repeats the procedures beginning in step 2 above for the remainder of the meeting.*

Electronic individual poolwriting or electronic poolwriting (EPW) replaces the papers with files. A group of N people at computer terminals exchange typed comments on N+1 files. With the electronic and manual versions, ideas are recorded, and the individuals can submit ideas in parallel. While the manual version is somewhat anonymous (individuals may look at what others are writing if they are in close proximity), the electronic version provides greater anonymity (again, if individuals are in close proximity, they may look at each others' computer screens).

The advantage of EPW is that a large number of comments can be written over the course of the meeting because each participant is required to write a comment in his or her file before exchanging it with the spare file. The disadvantage is that group members are unable to see all of the comments over the course of meeting, although they may see a complete, printed transcript afterwards (Herniter & Gargeya, 1995). Another disadvantage is that, at any one time, each group member sees a completely different subset of comments in his or her file. If someone starts laughing or talks about a comment, nobody else in the group knows what the person is looking at, leading to some frustration.

Gallery Writing

Using gallery writing, each group member:

- *Writes a comment or comments on (large sheets of paper attached to the wall/the blackboard/flip charts on stands/ etc.) in a room,*
- *Steps back or walks over to another area of the room,*
- *Reads comments written by other group members,*
- *Writes a new comment or comments in the same location,*
- *Repeats the steps above for the duration of the meeting.*

Electronic gallery writing (EGW) substitutes one disk file for the many sheets of paper or blackboard. In the manual version, it is very easy to see what others are writing; thus, there is little anonymity. The electronic version, however, affords much greater anonymity (unless group members can see what others are typing at their individual computer terminals). Using EGW, participants can type and read the same set of comments in parallel (unlike EPW). In our implementation of EGW, after typing a comment, the user presses the "INSERT" key to add the idea to the public comment window at the top of the screen. The user's comment will then appear along with new comments written since the last submission. To read new public comments without submitting a new one, the user simply presses "HOME." As with EPW, EGW automatically records all comments onto a disk file.

Forced Electronic Gallery Writing

A new variant of EGW called forced electronic gallery writing or forced gallery writing (FGW) was developed in an attempt to combine the advantage of EGW (subjects have access to all comments at the same time) with the advantage of EPW (group members are forced to submit a comment before they can view other, new public comments). Some participants in EGW meetings may be "free "riders" and won't contribute ideas; they simply press the "HOME" key repeatedly to read others' comments. By disabling the "HOME" key, FGW users must submit a comment in order to see new, public comments. Adding this feature could increase the number of comments and reduce free riding.

Although more comments could be generated with FGW than with EGW, the technique has two disadvantages:

- ***More off-topic comments.*** *As is the case with groups using EPW, many comments may be added that are short and nonsensical (e.g., "abc" or "7d8x") or a few spaces, simply to get new comments to read. Our implementation of FGW does not* *allow any comments less than three characters in an attempt to restrict such behavior.*

- ***Fewer comments can be viewed.*** *Using EGW, participants can see all comments at the end by pressing "HOME." Using FGW, however, a participant might not see C-(N-1) or C-N+1 comments (where C is the total number of public comments and N is number of group members) if, at the end of the meeting, all of the remainder of the group submits a comment and the individual doesn't.*

COMPARISON STUDIES

Several studies comparing EPW and EGW have been conducted (e.g., Aiken, et al., 1996), and results are summarized below:

- Meeting participants want to be able to view all comments written by group members at any given time.
- Meeting participants want to be able to view all comments written by group members over the course of the meeting.
- Group members write more comments using EPW than when using EGW.
- Group members write roughly the same number of unique, relevant comments using EPW and EGW. That is, many comments written with EPW are redundant or off-topic.
- Group members have the same evaluation apprehension using EPW and EGW. Both techniques give participants a high degree of anonymity, and thus, they are less likely to be afraid of others criticizing the comments they write (apprehensive of others' negative evaluation of their ideas).
- Group members experience less production blocking, in general, when using EGW than when using EPW. It is easier for participants to share information using EGW, and thus, fewer comments produced during the meeting are blocked or restricted during the discussion. The greatest cause of production blocking in EPW meetings is the fact that participants cannot view many comments during the discussion because of the random swapping of files.
- Group members are more satisfied with the meeting process when using EGW than when using EPW.
- Group members prefer using EGW than EPW for electronic meetings.
- Group members, in general, experience more group cohesion when using EGW than when using EPW. That is, they feel more "a part of the group."

- Group members believe EGW is easier to use, even though the user interface is exactly the same.
- Group members experience roughly the same stimulation and synergy using both EGW and EPW.
- Group members perceive the quality of comments to be higher when using EGW than when using EPW.

Other studies have shown that the distribution of comments in EPW groups varies with group size, typing speed, and meeting duration. Each participant sees more of the public comments over the course of the meeting in long meetings with a small group of people who type fast. Individuals cannot see 100% of the comments, and in a simulation of a group of 20 typing on average one comment per person every 120 seconds in a 10-minute meeting, it was shown that only 10% of the comments can be expected to be viewed by each member (Aiken, et al., 2002). In actual EPW meetings involving eight groups of six for 10 minutes, this comment distribution rate has been shown to vary between 21% and 72%, with an average of 49% (Aiken & Vanjani, 2003).

Because all information is shared using EGW, group members may spend more time reading others' comments (not writing new comments) than when using electronic poolwriting. In one study (Aiken & Vanjani, 1996), group members using EGW spent on average only 39.9% of the total meeting time typing new comments while subjects using EPW spent 52.6% of the time typing new comments. Participants using EPW have fewer comments on their screens (especially in very short meetings) and are forced to write something to get a new screen of comments. Therefore, they spend more time composing new ideas than reading others' opinions. An important function of a GSS is to give a group ready access to information generated by participants (Briggs, et al., 1998). Only EGW gives group members complete and immediate access to group information; EPW does not.

Only one study has focused on FGW, however, and it was compared to EGW only (Aiken & Alonzo, 2001). In the study, 10 groups of six subjects used each technique for a 10-minute meeting. Subjects had very little evaluation apprehension and perceived little production blocking, believed all group members participated, and were satisfied with the meetings. However, subjects wanted the ability to read comments without writing a new comment, indicating a preference for EGW. FGW subjects wrote about 68% more total comments and generated more relevant and irrelevant comments (significantly more for each type). The uniqueness of the comments was not examined, however. That is, although more relevant comments might have been generated using FGW, some might have been redundant.

A COMPARISON EXPERIMENT

The three brainwriting techniques were compared in an experiment in order to understand their relative advantages and disadvantages in more detail.

Hypotheses

Based upon prior GSS comparison studies, the following hypotheses were developed for a study of EGW, FGW, and EPW:

H_1. *There is no difference in subjects' evaluation apprehension among the meeting techniques.*
H_2. *There is no difference in subjects' perceptions of production blocking among the meeting techniques.*
H_3. *There is no difference in subjects' perceived participation among the meeting techniques.*
H_4. *There is no difference in subjects' process satisfaction among the meeting techniques.*
H_5. *There is no difference in the number of comments among the meeting techniques.*
H_6. *Subjects want to be able to read public comments without submitting a new comment.*

Subjects

Undergraduate MIS students volunteered to participate in the experiment for extra credit in their courses, and the 63 subjects were randomly assigned to nine groups of seven each. Three groups were assigned to each of three treatments.

Procedure

The groups used EGW, FGW, and EPW for 10 minutes each to discuss solutions to the parking problem on campus, methods to increase tourism in the city, and ways to improve campus security. All three topics and the experimental design have been used in prior studies and by other researchers (e.g., Dennis & Valacich, 1993; Gallupe, et al., 1992), and experience with groups using these topics indicates that 10 minutes generally is adequate for most participants to express their opinions fully. The three techniques and three topics formed nine combinations, and three groups were assigned to each of the three technique/topic groupings:

EGW: parking, EPW: tourism, FGW: security
EGW: tourism, EPW: security, FGW: parking
EGW: security, EPW: parking, FGW: tourism

Software

The only difference among the three programs was the means of viewing public comments. Using EGW, all comments written by the group were available at all times, and new comments typed by the group could be viewed after a participant submitted a new comment (pressing the "INSERT" key). New public comments also could be viewed without submitting a new comment (pressing the "HOME" key), if the group member did not have an idea to submit at the moment. Using FGW, group members were not able to read new public comments without submitting a new comment (the "HOME" key was disabled). Finally, using EPW, another subset of public comments could not be viewed unless the participant submitted a new comment (again using the "INSERT" key). All public comments could not be viewed simultaneously and over the course of the meeting using EPW. Otherwise, the human-computer interface for the three programs was identical.

In addition, the programs tracked the comments written by each individual, and stored the results in a separate file with the member number, group number, and the time written. However, comments were anonymous to group members. After using each brainwriting technique, the subjects completed the relevant portion of the questionnaire shown in the Appendix.

Table 1: Questionnaire Summary Ratings (All Groups)

	Mean	Std Dev
EGW (n=21)		
e1	1.841	1.370
e2	6.476	0.895
e3	5.667	1.503
e4	6.048	1.113
FGW (n=21)		
f1	6.047	1.113
f2	1.651	1.138
f3	6.333	1.107
f4	6.349	0.864
EPW (n=21)		
p1	1.746	1.534
p2	5.603	1.819
p3	5.921	1.418
p4	5.270	1.877
q (n=63)	5.683	1.664

All questionnaire variable means are statistically significantly different from the median = 4 at $\alpha = 0.01$.
See the Appendix for definition of the variables.

Table 2: Analysis of Variance (All Groups and Meeting Techniques)		
	F	p
Evaluation Apprehension	208.46	<.001
Production Blocking	231.18	<.001
Participation	3.89	0.022
Meeting Satisfaction	10.64	<.001

RESULTS

Table 1 shows means and standard deviations for the questionnaire variables for all groups. There was a significant difference (at $\alpha = 0.01$) between the mean and median for each question. Using each technique, subjects felt low evaluation apprehension, low production blocking, high participation, and high meeting satisfaction. In addition, subjects wanted the ability to read comments without writing new ones.

Table 2 shows an analysis of variance for all groups and meeting techniques. As indicated, there was a significant difference in evaluation apprehension, production blocking, participation, and meeting satisfaction among the three techniques. Thus, hypotheses H_1, H_2, H_3, and H_4 are rejected, and H_6 is not rejected. In combination with Table 1, we can conclude:

Evaluation apprehension: *EPW = EGW < FGW*
Production blocking: *EPW < FGW < EGW*
Perceived participation: *EGW < EPW < FGW*
Meeting satisfaction: *EPW < EGW = FGW*

Table 3: Questionnaire Summary Ratings by Group Type						
	Group Type					
	1		2		3	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
EGW						
e1	1.619	1.284	2.286	1.488	1.619	1.284
e2	6.619	0.669	6.048	1.203	6.762	0.539
e3	5.381	1.687	5.286	1.586	6.333	0.966
e4	5.810	1.167	5.762	1.221	6.571	0.746

Table 3: Questionnaire Summary Ratings by Group Type						
	Group Type					
	1		2		3	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
FGW						
f1	1.524	1.167	1.857	1.062	1.571	1.207
f2	5.905	1.300	6.619	0.498	6.576	1.250
f3	6.143	1.108	6.429	0.746	6.476	0.680
f4	5.619	1.359	6.238	1.136	6.286	1.488
EPW						
p1	1.810	1.750	1.619	1.284	1.810	1.601
p2	5.429	1.748	5.524	1.806	5.857	1.957
p3	5.286	1.617	6.095	1.375	6.381	1.024
p4	4.905	1.814	5.143	1.880	5.762	1.786
q	6.095	1.179	5.667	1.880	5.286	1.821

Group Types:
EGW/Parking, FGW/Security, EPW/Tourism
EGW/Security, FGW/Tourism, EPW/Parking
EGW/Tourism, FGW/Parking, EPW/Security

All questionnaire variable means are statistically significantly different from the median = 4 at $\alpha = 0.05$.

Table 3 shows the results for each of three meeting technique/topic combinations. Overall and for each group type, subjects perceived low evaluation apprehension, low production blocking, high participation among group members, and high meeting satisfaction. In addition, subjects wanted the ability to read comments without submitting a new comment. All of these results are in agreement with those shown in Table 1. Table 4 shows that there was very little difference between the ratings for the three groups within each group type.

Table 4: Questionnaire Analysis of Variance Within Group Types						
Groups	**1**		**2**		**3**	
	F	**p**	**F**	**p**	**F**	**p**
e1	1.480	0.253	0.760	0.484	0.520	0.602
e2	0.720	0.498	0.120	0.888	2.440	0.116
e3	0.300	0.748	0.160	0.857	4.670	0.230
e4	1.090	0.356	0.990	0.391	0.000	1.000
f1	0.430	0.658	0.120	0.892	1.200	0.324
f2	0.510	0.610	0.180	0.840	0.460	0.638
f3	**0.110**	**<.001**	0.240	0.792	**5.550**	**0.013**
f4	1.390	0.274	0.240	0.790	1.410	0.270
p1	0.410	0.670	0.790	0.468	1.830	0.189
p2	0.880	0.433	0.510	0.607	0.140	0.873
p3	0.150	0.862	**3.030**	**0.073**	1.150	0.338
p4	0.380	0.689	2.280	1.310	0.620	0.551
q	0.220	0.804	0.670	0.526	0.670	0.526

Group Types:
EGW/Parking, FGW/Security, EPW/Tourism
EGW/Security, FGW/Tourism, EPW/Parking
EGW/Tourism, FGW/Parking, EPW/Security

Statistically significant values at $\alpha = 0.10$ are shown in bold.

Table 5 shows that evaluations for each of the meeting techniques were significantly different, in some cases, with different topics, and Table 6 shows a comparison of each of the three meeting techniques using each of the three topics (e.g., EGW vs. FGW with the "parking" problem). In about half of the comparisons, there was no significant difference. In other cases, however, one technique was rated higher than another in one meeting, but lower than another in a different meeting.

Table 5: Analysis of Variance Among Group Types

EGW	F	p
e1	1.69	0.192
e2	**4.12**	**0.021**
e3	**3.36**	**0.041**
e4	**3.81**	**0.028**
FGW		
f1	0.52	0.598
f2	**2.57**	**0.085**
f3	0.91	0.408
f4	1.63	0.205
EPW		
e1	0.10	0.901
e2	0.31	0.731
e3	**3.66**	**0.032**
e4	1.17	0.316

Statistically significant values at $\alpha = 0.10$ are shown in bold.

Table 6: Questionnaire Comparisons between Meeting Techniques with the Same Topic						
	Parking		**Tourism**		**Security**	
Comparison	**T**	**Pr > |t|**	**T**	**Pr > |t|**	**T**	**Pr > |t|**
EGW-FEG						
e1-f1	0.00	1.000	-1.56	0.134	-0.10	0.921
e2-f2	**2.95**	**0.008**	-0.30	0.764	**-3.02**	**0.007**
e3-f3	-1.29	0.211	**1.96**	**0.065**	**-2.64**	**0.016**
e4-f4	1.31	0.205	-0.33	0.745	**-3.08**	**0.006**
FGW-EPW						
f1-p1	0.12	0.908	-0.60	0.557	0.36	0.720
f2-p2	0.47	0.643	0.10	0.921	**-3.16**	**0.005**
f3-p3	**-2.69**	**0.014**	-0.87	0.397	**-2.66**	**0.015**
f4-p4	-1.34	0.196	-0.27	0.791	**-4.12**	**0.001**
EGW-EPW						
e1-p1	-0.15	0.886	-1.06	0.303	-0.74	0.470
e2-p2	**1.89**	**0.074**	-0.40	0.690	0.83	0.419
e3-p3	1.07	0.296	**2.69**	**0.014**	-0.35	0.733
e4-p4	**2.00**	**0.059**	0.00	1.000	1.13	0.273
Statistically significant values at $\alpha = 0.10$ are shown in bold.						

Table 7 shows a comparison of each meeting technique by experimental subject, across topics. EGW was rated lower than FGW in participation, perhaps because FGW forced subjects to submit more comments. FGW was rated higher than EPW in production blocking, participation, and satisfaction, perhaps because of the difficulty in viewing all comments with the latter. Finally, EGW was rated higher than EPW in production blocking and satisfaction.

Table 7: Comparisons Between Meeting Techniques with Same Subject
(Difference of Means T Tests)

Comparison	T	Pr > |t|
e1-f1	1.54	0.129
e2-f2	0.94	0.350
e3-f3	**-4.32**	**<.001**
e4-f4	0.00	1.000
f1-p1	-0.54	0.588
f2-p2	**3.48**	**0.001**
f3-p3	**3.26**	**0.002**
f4-p4	**3.33**	**0.002**
e1-p1	0.47	0.639
e2-p2	**4.03**	**<.001**
e3-p3	-1.54	0.128
e4-p4	**3.19**	**0.002**

Statistically significant values at $\alpha = 0.005$ are shown in bold.

Table 8 shows means and standard deviations of the comments written with each technique overall and with each group type, and Tables 9 and 10 show comparisons of the comment counts between techniques and among group types. Table 9 shows that, overall, there was no significant difference in the number of comments generated with each meeting technique. Therefore, we cannot reject H_5.

Table 8: Comment Summary

	Group Type							
	All		1		2		3	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
EGW	1.587	1.410	1.048	0.865	1.190	0.873	2.524	1.806
FGW	1.794	1.220	1.333	1.111	2.143	1.236	1.905	1.203
EPW	1.825	1.374	2.048	1.746	1.952	1.203	1.476	1.078

Table 9: Difference-of-Means T Test of Comments

Comparison	P-Value
All groups	
EGW – EPW	>0.10
EGW – FGW	>0.10
FGW – EPW	>0.10
Group Type 1	
EGW – EPW	**<0.01**
EGW – FGW	>0.10
FGW – EPW	**<0.05**
Group Type 2	
EGW – EPW	**<0.05**
EGW – FGW	**<0.01**
FGW – EPW	>0.10
Group Type 3	
EGW – EPW	**<0.01**
EGW – FGW	**<0.05**
FGW – EPW	>0.10
Statistically significant values at α = 0.10 are shown in bold.	

Table 10: GLM Comparison of Comments among Group Types		
	F	**p**
EGW	**8.75**	**<.001**
FGW	**2.56**	**>.05**
EPW	1.04	>.10
Statistically significant values at $\alpha = 0.10$ are shown in bold.		

DISCUSSION

While there was significant disagreement among results when analyzed by group, group type, and subject, overall, there was a significant difference among EGW, FGW, and EPW in all measures, with the exception of the number of comments generated. Subjects using all three techniques, however, had low evaluation apprehension and production blocking and had high meeting satisfaction. In addition, the perceived participation of group members was high with all three techniques.

The new technique introduced only recently (FGW) was designed to maximize the advantages of EGW and EPW while minimizing their disadvantages. With the exception of production blocking (EGW was rated higher), FGW gave subjects the least evaluation apprehension, highest perceived group member participation, and highest (tied with EGW) meeting satisfaction. Because subjects were forced to type new comments to see new ones, perceived participation was high. With greater participation, subjects using FGW might have felt that their comments would not stand out, decreasing evaluation apprehension. Despite the fact that subjects did not want to be forced to submit comments, apparently, this did not detract from their overall meeting satisfaction significantly. The subjects rate EGW as the easiest to use, however, because it did not force them to type new comments.

While there was no overall significant difference in the number of comments as expected (prior studies had shown EPW generated significantly more than EGW), subjects generated more comments with FGW than with EGW, but they typed fewer comments with FGW than with EPW. Thus, the technique appears to offer a middle ground between the two. However, the uniqueness and quality of these comments was not examined. That is, although more comments might have been generated using FGW than with EGW, some could have been off-topic or redundant. This analysis is left to future study.

A disadvantage still remains with FGW. Subjects stated that they did not want to be forced to submit a comment to read new comments, as FGW and EPW require. Yet, by forcing group members to submit comments, free riding is reduced, participation increases, and more comments are written. These results, taken together with earlier studies, suggest that FGW could be superior to EGW in some cases, and both are better than EPW.

CONCLUSION

Although ratings for all three techniques were favorable, the experiment presented here shows that a new group brainwriting technique called Forced Gallery Writing is better than Electronic Gallery Writing, under certain circumstances, and both generally are better than Electronic Poolwriting. As FGW is a hybrid between EPW and EGW, subjects using the technique generated slightly more comments than those using EGW, increasing participation and decreasing free riding, but they generated slightly fewer comments than subjects using EPW. There was no significant difference among the three techniques, however, in the numbers of comments generated.

In the experiment, subjects using FGW experienced the least evaluation apprehension and greatest perceived participation while tying EGW in meeting satisfaction. Thus, it appears that the technique can be used to increase participation and generate more comments without significantly harming group members' moods.

Limitations of the study include a restricted set of topics, one group size and meeting duration, and college students as subjects. EPW might be superior if a group needs to discuss a more complex problem; while small groups in short meetings might prefer EGW. Finally, MIS students are comfortable with computers and can type well. Groups with other member characteristics could have different perceptions of the brainwriting techniques.

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APPENDIX

Post-Experiment Questionnaire

Please circle your responses below:

Electronic Gallery Writing
Using this meeting technique,

(E1) I was afraid that others in my group would criticize my comments.
1 2 3 4 5 6 7
Disagree Neutral Agree

(E2) It was easy to submit and read comments.
1 2 3 4 5 6 7
Disagree Neutral Agree

(E3) I believe all members of my group wrote comments.
1 2 3 4 5 6 7
Disagree Neutral Agree

(E4) I was satisfied with this meeting process.
1 2 3 4 5 6 7
Disagree Neutral Agree

Forced Gallery Writing
Using this meeting technique,

(F1) I was afraid that others in my group would criticize my comments.
1 2 3 4 5 6 7
Disagree Neutral Agree

(F2) It was easy to submit and read comments.
1 2 3 4 5 6 7
Disagree Neutral Agree

(F3) I believe all members of my group wrote comments.
1 2 3 4 5 6 7
Disagree Neutral Agree

(F4) I was satisfied with this meeting process.
1 2 3 4 5 6 7
Disagree Neutral Agree

Electronic Poolwriting
Using this meeting technique,

(P1) I was afraid that others in my group would criticize my comments.
1 2 3 4 5 6 7
Disagree Neutral Agree

(P2) It was easy to submit and read comments.
1 2 3 4 5 6 7
Disagree Neutral Agree

(P3) I believe all members of my group wrote comments.
1 2 3 4 5 6 7
Disagree Neutral Agree

(P4) I was satisfied with this meeting process.
1 2 3 4 5 6 7
Disagree Neutral Agree

(Q) I would like to be able to read comments without writing a new comment.
1 2 3 4 5 6 7
Disagree Neutral Agree

AN ENTROPY-BASED APPROACH FOR MEASURING PROJECT UNCERTAINTY

Arben Asllani, University of Tennessee-Chattanooga
Lawrence Ettkin, University of Tennessee-Chattanooga

ABSTRACT

Because of dynamic, complex and competitive environments, many information technology (IT) projects are plagued by significant cost overruns and unexpected schedule slips. Research suggests that a major reason for project failures is management's inability to address uncertainty during the development of a new management information system. Dealing with project uncertainty consists of three main segments: identifying sources of project development uncertainty, quantifying project uncertainty, and using such uncertainty measure for improving decision making process with respect to projects. While the first segment has been a major concern for researchers and practitioners, very little progress in the way of theoretical development has been achieved in the areas of uncertainty quantification and its use in project management.

This paper explores various aspects of project uncertainties and offers three entropy-based uncertainty measures: aggregate uncertainty, weighted aggregate uncertainty, and deviation uncertainty. Aggregate uncertainty incorporates a list of unknown risk factors into a single entropy-based measure. Weighted aggregate uncertainty considers the relative importance of unknown uncertainty factors. Deviation uncertainty is a relative uncertainty measure which indicates the degree of deviation of a given project from an ideal project in which all factors are certain. An actual project is used to demonstrate our measures. The paper also discusses managerial implications of such measure.

INTRODUCTION

In our global competitive economy, information technology has become a primary resource for competitive advantage. In particular, the successful development of computer-based systems that support a firm's competitive strategy is critical to organizational success. Yet, for the last three decades, projects have suffered from high failure rates (Mayer 1998, Jiang et al., 2002). Turner (1982) indicates that between one third and one half of all information systems projects never reached the implementation stage. Other evidence is provided by an IBM study which suggests that 55 percent of projects exceeded their planned budget, 58 percent exceeded their planned schedule, and 88 percent had to be significantly redesigned (Gibbs, 1994). Recent studies by the Government Accountability Office and the National Institute of Standards and Technology show that 31.1% of all software projects will be cancelled before they ever get completed. Further results indicate that 52.7% of projects will cost over 189% of their original estimates (Rensin, 2005).

Research suggests that a major reason for projects failures is management's inability to address uncertainty during the development of new management information systems (Kydd, 1989, Mazzola & McCardle, 1996). Other sources suggest that information systems requirements uncertainty has a direct negative effect on project performance (Nidumolu, 1996) and development risk affects budgets, schedules, and system quality of projects (Jiang et al., 2002). Traditional techniques of project management have become inadequate to monitor project uncertainty (Lycett & Paul, 1999, Meyer at al. 2002). Practitioners and researchers have developed and utilized a variety of system development tools, such as prototyping, data modeling, structured and object-oriented design, and computer-assisted software engineering. Unfortunately, even with these efforts, the failure rates remain high. In a recent study, only 37 percent of major projects were completed on time and only 42 percent were completed on budget (Gordon, 1999).

Two major areas of uncertainty management consist of uncertainty identification and uncertainty quantification. Identifying uncertainty sources during the development of IT related projects has been a major concern for researchers and practitioners (Chapman & Ward, 1997). However, current research is focused on empirical studies that investigate the impact of uncertainty reduction on project success (Rai and Al-Hindi, 2000, Jiang et al. 2001). There is a lack of formal comprehensive and multifaceted uncertainty measures (Jiang et al., 2001) and very little progress in the way of theoretical development has been achieved in the area of uncertainty quantification (Jiang et al., 2002). The purpose of this paper is to provide three measures of uncertainty for IT related projects. The proposed measures represent different aspects of uncertainty and are based on *entropy*, a concept borrowed from information theory.

The paper is structured as follows: First, we provide a brief discussion of project risks and uncertainty. Although risk and uncertainty are two different concepts, we use the list of risk factors provided by the literature as a starting point in the approach to measure project uncertainty. Then, we explore the concept of entropy and its potential applications for measuring systems uncertainty. Later, we propose measures of aggregate uncertainty for projects and discuss possible areas of their implementation. The performance of these measures is demonstrated using an actual information system development project, facilitated by one of the authors. Finally, we present conclusions and discuss possible implementations of the proposed measures.

PROJECT UNCERTAINTY VS RISK

It is important to make a distinction between risk and uncertainty. In this paper, we define project risk as a condition that has an effect on the project outcome (PMBOK Guide, 2000, p127). For example, project size is a risk factor and smaller projects tend to be less risky than large and complex projects. The amount of existing expertise in a given project is another risk factor. Project that lack such an expertise are more risky that those projects that have such an expertise.

Uncertainty is defined as the absence of information (Downey & Slocum, 1975, Tushman & Nadler, 1978) about a given risk factor, which in turn leads to the inability to accurately predict the outcome of a given system (Nidumolu, 1995). Following the above examples, identifying the size of the project reduces the uncertainty, but not necessary the risk. If the project is identified as small then, based on our risk definition, the project is less risky. If the project is identified as large, then the project may be more risky. With regard to expertise, identifying the amount of existing expertise reduces the uncertainty, but again, not necessary the risk. If the project lacks expertise then the project is risky. If the expertise exists, then the project is less risky. In general, project managers expect the uncertainty to be higher at the beginning stages of a given project (when the number of unknown risk factors is large) and lower during the late stages of a project (when the number of unknown factors is reduced).

Moynihan (2000) describes three types of information system uncertainty: aggregate, latent, and profile. Aggregate uncertainty consists of an algebraic composition of a well defined list of risk factors, which are associated with a given project. Latent uncertainty is an implied statistical measure which can be drawn from a possibly infinite number of risk factors. Profile uncertainty is a non-algebraic definition that is focused a single risk factor and the amount that such a factor is not known by project managers. Moynihan's definitions of uncertainty are based on Law, Wang and Mobley's taxonomy (Law et al., 1998).

In this paper we focus only on the first, aggregate uncertainty. There are several literature sources which attempt to identify project uncertainty as an aggregation of several variables. Although a comprehensive and authoritative list of risk factors is provided by Schmidt et al. (2001), we have filtered and modified a list of factors which are suggested by Jiang & Klein (2001), Lederer at al. (1990), and Alter & Ginzberg (1978).

There are two main reasons why we decided to use the list of factors presented in Table 1. First, there is a close fit of the selected factors with the list of risk factors in the project, which will be later used to illustrate our proposed measures. Second, Jiang & Klein (2001) have established a rank order of importance for each factor, which will be later used to illustrate the weighted uncertainty measure. It is also important to emphasize that the purpose of this paper is not to identify all risk factors, but rather to use them as input for measuring uncertainty.

A brief definition of risk factors represented in Table 1 is provided. Project size refers to the number people involved in the project and application complexity is defined as the magnitude or the scope of the project. Technology acquisition concerns the amount of new hardware and software, as well as the number of vendors involved. Insufficient resources refer to both budget and labor assets allocated to the project. Methodology and expertise refer to the set of guidelines and skills required to design, develop and implement the project. The amount of user support is represented by a combination of level of user enthusiasm, user preparedness for the new system, and level of user feedback. User experience and historical data consists of a blend of tacit knowledge and historical project repositories relevant to the current project. Role definition and coordination is defined as the ability to clearly assign and monitor roles to the people involved in the project.

Conflict considers poor communication or hostility between user and designer team members. Finally, the ability to estimate the designer's expertise, to define the purpose of the project, and to provide consistent working standards and stable IS personnel, will directly impact the overall project uncertainty.

Table1. Information Systems project Uncertainty Factors

Uncertainty Factors	Jiang & Klein (2001)	Lederer at al.(1990)	Alter & Ginzberg (1978)
Information system project size	9		6
Application complexity	8		
Technology acquisition	7		1
Insufficient resources	6	5	3
Lack/presence of methodology and expertise	5	7	2
Lack/presence of user support	4	2	7
Lack/presence of user experience/historical data	3	3	5
Lack/presence of role definition and coordination	2	6	
Lack/presence of user/analyst conflicts	1	8	
Ability/inability to anticipate designer's expertise		9	
Lack/presence of IS project purpose			4
Lack/presence of review standards		4	
Changes in IS development personnel		1	

Numbers indicate the significance of each factor (1=less significant and 9=very significant).
Empty cells indicate absence of the respective factors in the respective study.

ENTROPY AND INFORMATION UNCERTAINTY

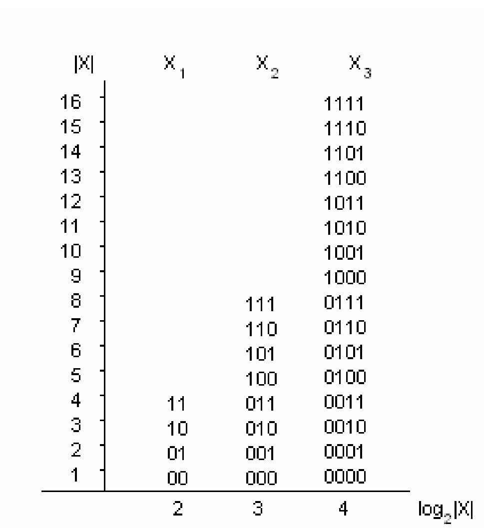
Shannon (1948) developed the concept of entropy as a tool to measure information uncertainty. According to Shannon, the uncertainty of a system decreases as we receive more information about the possible outcomes of the systems. Mathematically, entropy is defined as:

$$E(X) = \log |X| \qquad (1)$$

where X is the set of possible outcomes of a given system and $|X|$ indicates the number of possible outcomes from this set. For example, if a given system can possibly produce 16 outcomes, then applying a logarithm with base 2, one can say that the uncertainty of such a system is $log_2 16 = 4$, on the other hand if another system has 8 possible outcomes then its uncertainty will be reduced to 3 $(log_2 8 = 3)$. Shannon derived this formula by following a rigorous route and by setting down several desirable properties for uncertainty. Figure 1 provides an intuitive explanation for the entropy.

Let us suppose that a given machine can only produce binary digits. If there are four possible outcomes for a given system (column X_1), then our machine would require only two digits to represent these states: state 1 as 00, state 2 as 01, state 3 as 10, and state 4 as 11. In other words, the amount of average surprise or uncertainty about the value of a given state is condensed to the two-digit values. Similarly, the uncertainty of a system with 8 possible states is 3, and with 16 possible states the uncertainty level is 4. In general, for a system with |X| possible states, the uncertainty level is estimated to be $log_2\ |X|$, when binary symbols are used to represent the information. If the system has only one possible outcome, then we have no uncertainty, which is also shown by the entropy formula since $log_2 1=0$. The base of the log function indicates the binary digits. When information is represented in decimal notations then logarithm with base 10 must be used. In a general case, the natural logarithms (base e) can be used.

Figure1. Digits Required to Represent Different Possible Machine States

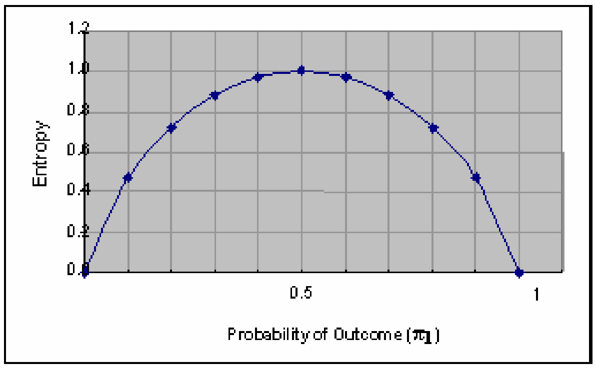


When the likelihood of possible outcomes is not equal, i.e. probability distribution is not uniform, entropy is expressed as:

$$E(X) = -\sum \pi(x) \log \pi(x) \qquad (2)$$

Figure 2 shows the relationship between entropy level and the probability if there are only two outcomes. The value of entropy based on (2) gradually increases when the probability of event one (π_1) approaches 0.5 (events are equally likely). Note that entropy is zero (no uncertainty) when $\pi_1 = 1$ ($\pi_2 = 0$) or $\pi_1 = 0$ ($\pi_2 = 1$). In addition, entropy becomes one when $\pi_1 = \pi_2 = 0.5$.

Figure2. Entropy based uncertainty (N = 2)



Shannon entropy can be implemented in many real-world situations involving uncertainty (Klir, 1990; Soofi 1994). In a more recent article, the concept of entropy was described as "probabilistic logical inference theory" (Solana-Ortega, 2001). Entropy-based measures have been successfully used to measure operational complexity (Sivadasan et al., 2002). As the complexity of a system increases there is an associated increase in the amount of information required to monitor and manage that system. In another study, Richards (1995) compares information system alternatives. Very often, project managers rely on subjective assessments, such as their instincts or the recommendation of vendors rather than on an objective analysis of their information needs and how they can be met by various system alternatives. The entropy concept is used to quantify these issues and provide a more objective measure for comparing systems.

PROPOSED UNCERTAINTY MEASURES

In order to implement the concept of entropy as an appropriate measure of various aspects of project uncertainty, we make two basic assumptions: First, we assume that uncertainty of a project is a function of the number of risk factors for which we do not have enough information. For example, we know that the project size is a potential risk factor, i.e. the larger the project the more risky the project tends to be with respect to potential investments, benefits, and so on. However, the uncertainty of the project is due to the fact that we do not know what the size of the project is going to be. In other words, the project is uncertain as long as we do not know its size, even if the project ends up to be a small one. Similarly, the uncertainty level is reduced if we receive information about the project size, even if that information indicates that the project is large. Second, we assume that a given risk factor is either known or unknown at a given project development stage. The project manager has established a threshold for each factor, and if the amount of received information does not meet the threshold, then the risk factor is still counted as an unknown factor.

Based on the two assumptions, we propose three different aggregate, entropy-based measures. In order to illustrate these measures, we use data from a project, where a manufacturing database system was designed and implemented in a particular Production Facility of a Global Manufacturer, which will be referred in this paper as PFGM. One of the authors of this paper was a member of a consulting team which oversaw the design and implementation process. PFGM is located in small city in Southeast Region of the US. It produces power tools, accessories, and home improvement products. Its products and services are marketed in more than 100 countries and the facility has established a reputation for product innovation, quality, end-user focus, design, and value. The purpose of the new project is to provide a platform to dynamically measure and control overall manufacturing performance of the facility. The project duration was approximately 18 months. We use this project as an illustration of risk factors and uncertainty analysis. The concepts are applicable to any set of risk factors at any given project.

Aggregate Uncertainty

This measure provides a direct link between the entropy concept and the number of unknown uncertainty factors of a project. Here, the set of possible outcomes of the system (X) corresponds to the set of risk factors which are still unknown by the decision maker. In general, as the project moves along its stages and the managers acquires additional information about each risk factor, the uncertainty level gradually reduces. The formula for this type of uncertainty is:

$$AU = \log_e N \text{ or } AU = \ln N \tag{3}$$

where, N represent the number of unknown risk factors of a given project.

The consulting team at PFGM was initially required to provide an estimate regarding the potential benefits of the future project. Such an evaluation was based on the information that consulting team had about several risk factors. Table 2 represents a list of factors which were identified using previous risk evaluation literature and the specific circumstances of the project. The question marks (?) indicate that the respective factor was not known at a given stage. For example, at the beginning of the first stage of the project there were a total of 11 factors for which the management team did not have adequate information.

Using formula (3) to measure aggregate uncertainty, we found an uncertainty level of 2.40. Consulting team felt that the level of project uncertainty with such large number of unknown factors was relatively high. In cooperation with the management team of PFGM, we decided to establish the following general guidelines as benchmarks for this project: low uncertainty projects usually indicate a measure between 1 and 1.50, medium uncertainty projects indicate a measure between 1.50 and 2.00, and high uncertainty projects indicate a value above 2.00. As a result, the consulting team decided to proceed with the design stage of the project and at the same time gather more information about the project.

Factors for PFGM project

Uncertainty Factors	Project Development Stages		
	Design	Prototype	Implement
Information system project size	?	?	
Application complexity			
Technology acquisition	?	?	?
Insufficient resources	?	?	?
Lack/presence of methodology and expertise	?		
Lack/presence of user support	?		
Lack/presence of user experience/historical data			
Lack/presence of role definition and coordination	?		
Lack/presence of user/analyst conflicts	?	?	?
Ability/inability to anticipate designer's expertise	?		
Lack/presence of IS project purpose	?	?	
Lack/presence of review standards	?	?	
Changes in IS development personnel	?		
Total number of unknown factors	11	6	3
Aggregate Uncertainty (formula 3)	2.40	1.79	1.10

As the project entered the second stage, the team was able to interview potential end users and study the project documentation. At this stage, the team had a better understanding of the roles and the expertise of people involved in the project. Also, it was decided that there would be no changes in the IS personnel for the duration of the project. We again emphasize that acquiring information about a given project does not necessary mean that the information is positive. For example, factor number 5 was considered as a known, even when the actual information we received was a lack of a system development methodology at PFGM. As shown in Table 2, the level of uncertainty at the end of stage one was 1.79. Since this value is less than our previously established threshold 2.00, we consider the certainty level for PFGM at this stage to be comfortable enough to give the final "go" for evaluation of IT investments in this project.

As shown in Table 2, the level of uncertainty was significantly reduced and the only factors still unknown at the beginning of the final stage were: type of technology, funds to purchase it, and level of communication between end users and database designers during the final stage of implementation. At this level, the uncertainty level had dropped to 1.10.

It is important to note that the proposed aggregate uncertainty measure is a more appropriate measure than, let say, the number of risk factors itself. As mentioned earlier, the uncertainty is not defined by the number of unknown risk factors. Rather it is defined by the amount of information that the decision maker has about such factors. In such a case, we demonstrated that logarithmic function is a better representation than the linear function. In addition, as we will demonstrate in the following section, the proposed, measure can be easily modified to present not only the number of unknown factors, but also their respective importance in the form of weights.

Weighted Aggregate Uncertainty

The first measure of aggregate uncertainty assumes that all unknown risk factors are equally important for the project. However, as both scholars and practitioners suggest, some factors have a greater impact on project performance than others. As a result, receiving information about an important factor will lead to greater reduction in the project uncertainty as compared to the case we the information is received about a less important factor. For example, Jiang and Klein (2001) consider project size as a very significant and the amount of user support as somewhat significant (see Table 1). As a result, with respect to project uncertainty, identifying the project size is more important than identifying the presence or lack of user support. The larger the weight of an unknown risk factor, the higher the level of uncertainty.

We propose the following formula for the weighted aggregate uncertainty:

$$WAU = -\sum w_i x \ln w_i \qquad (4)$$

where, w_i = weight assigned to unknown risk factor *i*. This coefficient is calculated as follows:

$$w_i = (M-r_i+1)/\sum i \text{ for all } i= 1 \text{ to } M \qquad (5)$$

where, M is total (known + unknown) number of risk factors listed for the project, r_i rank of importance of factor i ($r_1 = 1, r_2 = 2, \ldots$). Let us illustrate how the weighted aggregate uncertainty can be calculated for the design stage of the PFGM project where total number of factors $M = 13$.

As shown in Table 3, the importance of each risk factor is transformed into a coefficient (w_i), which represents the relative weight of the factor. Then, logarithm with base ***e*** of each weight is calculated. As noted earlier, the logarithm of numbers between 0 and 1 is negative, that is why a minus sign precedes formula 4. As shown, the entropy level of 2.22 is smaller than simple aggregate uncertainty 2.40 calculated in Table 2 for the same stage of project development. This indicates that formula 4 tends to focus on more important factors and slightly eliminates (according to their lighter weight) less important factors. More importantly, our analysis shows that weighted aggregate uncertainty measure is sensitive to the weights, i.e. the uncertainty value will be reduced when a more important factor is dropped from the list of unknown factors, as compared to the case when a less important factor is dropped from such a list.

Table3. Weighted Aggregate Uncertainty for the Design Stage

Risk Factors* (ri)	Description	Importance**	Weight of unknown factor in stage 1	Factor's weight	$ln\ w_i$	$w_i x ln w_i$
1	Information system project size	13	13	13/72=0.18	-1.71	-0.31
2	Application complexity	12				
3	Technology acquisition	11	11	0.15	-1.88	-0.29
4	Insufficient resources	10	10	0.14	-1.97	-0.27
5	Lack/presence of methodology and expertise	9	9	0.12	-2.08	-0.26
6	Lack/presence of user support	8	8	0.11	-2.20	-0.24
7	Lack/presence of user experience/historical data	7				
8	Lack/presence of role definition and coordination	6	6	0.08	-2.48	-0.21
9	Lack/presence of user/analyst conflicts	5	5	0.07	-2.66	-0.18
10	Ability/inability to anticipate designer's expertise	4	4	0.06	-2.89	-0.16
11	Lack/presence of IS project purpose	3	3	0.04	-3.18	-0.13
12	Lack/presence of review standards	2	2	0.03	-3.58	-0.10
13	Changes in IS development personnel	1	1	0.01	-4.27	-0.06
		$\sum_{i=1}^{M} i$	=72	Weighted Entropy		=2.22

* From Tables 1 and 2
** 13 is very important and 1 is least important

Deviation Uncertainty

The first two proposed measures indicate the level of uncertainty for a given project during different stages of system development life cycle. However, they do not provide an absolute value of uncertainty level. Referring back to Table 2, we calculated that the uncertainty level at the beginning of the project was 2.40. Does this value mean that the project is very uncertain, somewhat uncertain, or not uncertain compared to other projects? In order to answer this question, we offer a third measure of uncertainty. It shows how much the uncertainty of a given project deviates from an "ideal" case. Alter and Glinzberg (1978) define the ideal situation as a "system (which is) …produced by a single implementer for a single user, who anticipates using the system for a very definite purpose which can be specified in advance with great precision. Including the person who will maintain it, all other parties affected by the system understand and accept in advance its impact. All parties have prior experience with this type of system, the system receives adequate support, and its technical design is feasible and cost effective." The formula for this type of uncertainty is:

$$DU = \ln D / \ln n \qquad (6)$$

Where, $D = \sum d_i$ represent total distance from an optimal level for all factors.

d_i = distance from the "ideal" level of unknown factor i $(i=1, 2, \ldots n.)$

n = number of factors under consideration.

Deviation uncertainty measure was used by the PFGM consulting team to evaluate the overall project uncertainty at the beginning of the project. Based on formula (5), we formulated several questions as shown in Table 4. The development team members were asked to answer those questions using a Likert scale (1-strongly agree and 5-strongly disagree). The average response is also shown in Table 4. Applying (6) will generate an uncertainty level 1.66, as such we concluded that the project we were about to undertake represent a low to medium level of uncertainty. Such result was used consequently in the process of project scheduling and resource planning.

Table 4. Deviational Uncertainty for PFGM project

Factors derived from an ideal situation	Average Response
System is produced by a small group of implementers	2.57
System is used by a small group of users	3.86
System has a very definite purpose	3.14
System does not impact other parties	4.71

Table 4. Deviational Uncertainty for PFGM project	
Factors derived from an ideal situation	Average Response
There is prior experience with this type of system	3.86
System receives adequate support	3.43
Technical design is feasible and cost effective	3.71
	Natural Logarithm
Total deviation (D) = 25.28	3.23
Total number of risk factors = 7	1.95
Deviational Entropy = $\frac{\ln D}{\ln n}$	1.66

CONCLUSIONS

Uncertainty management remains a major concern for the successful implementation of projects. While existing literature identifies major project risk factors, this paper uses those factors as a starting point to offer three entropy-based measures of project uncertainty. These measurements are based on the theory of information, uncertainty, and project development risks.

Aggregate uncertainty consists of a logarithmic function that incorporates a given list of unknown risk factors. The measure of aggregate uncertainty assumes that all unknown risk factors are equally important for the project. In the case when the importance of factors varies, we propose a second measure: weighted aggregate uncertainty. The third measure, deviational uncertainty, provides an absolute value of uncertainty level and shows how much the uncertainty of a given project deviates from an "ideal" case. Using a real world example, we demonstrate the methodology and sensitivity of the proposed formulas.

The paper demonstrates that information entropy provides an objective measure of project uncertainty. Those measures consider many risk factors, the importance of these factors, and the deviation of these factors from an "ideal" value. The entropy-based measures can be used to successfully and accurately measure uncertainty of an organizational project in general and information technology project in particular.

Providing a numerical value for the uncertainty in projects has several advantages. In general, measures of project uncertainty can be integrated with theoretical frameworks to produce future models for increasing the likelihood of successful IT implementations. More specifically, the likelihood of a successful project implementation is positively related to the degree of certainty with which the implementation can be planned. Using a quantity-based independent variable at the early stages of the project, IT manager will be able to predict the final outcomes of the project more accurately. A better prediction of project costs, schedule, and potential benefits leads to more realistic expectations about project outcomes and lower failure rates.

Also, uncertainty measures can serve as thresholds for developing approval procedures during the system development life cycle, as indicated in the case of PFGM. Initial stages of an information system generally represent situations of higher uncertainty. As the project moves along its phases, project managers develop a better understanding of the project and the project outcomes become more predictable. At any stage, a manager can compare the uncertainty reduction regarding the project outcomes during the coming stage with the additional cost of moving to that stage. One can compare the expected value of adopting new IT to the fixed cost of the adoption and decide whether the adoption is worthwhile.

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THE IMPACT OF FAIRNESS ON USER'S SATISFACTION WITH THE IS DEPARTMENT

Obyung Kwun, Southern University at New Orleans
Khaled A. Alshare, Emporia State University

ABSTRACT

This study utilized the justice theory to study the effect of fairness of information systems development process on user satisfaction with the IS department. To validate the research model, partial least square (PLS) analysis was used to analyze the data that were collected from 123 middle-level managers who have participated in the IS development. The findings showed that interactional justice and distributive justice, but not procedural justice, had positive impacts on user satisfaction with IS department. Additionally, interactional justice had the strongest impact on user satisfaction with the IS department.

INTRODUCTION

Information Systems (IS) development has been seen as a decision-making process where social processes play an important role in determining the outcome and the reactions to that outcome (Guimaraes & Igbaria, 1997; Ives & Olson, 1984; Yoon et al., 1995). Previous studies (Garrity & Sanders, 1998; Markus & Keil, 1994; Franklin et al., 1992) suggest that most systems will fail if psychological and organizational issues are not properly addressed during the development, implementation, and use of the system. With this socio-technical perspective, user satisfaction with IS has been one of the most frequently used measures for IS success (Khalifa & Liu, 2004; DeLone & McLean, 1992).

Numerous studies have focused on factors that influence IS success. User involvement has been a major factor that contributed to IS success (Doll & Torkzadeh, 1991; Igbaria & Guimaraes, 1994, Kohli & Gupta, 2002; Lehaney, et. al., 1999; Schwalbe, 2006; The Standish Group, 2002; Tait & Vessey, 1988). Some studies (e.g., Hunton, 1996; Hunton & Price, 1997; Kwun & Alshare, 2005), based on justice theory, have successfully demonstrated the importance of the user's overall perception of fairness in improving the satisfaction with IS, but they have not considered user satisfaction with the IS department, which may be one of the important factors in IS success. According to justice theory research, fairness of decision-making influences satisfaction with organizations and its authorities as well as the outcomes (Folger & Konovsky, 1989). Fairness of the decision-making facilitated the positive attitudes necessary for cooperative relations in decision-making teams (Korsgaard et al., 1995)

Though previous IS development research has noted the impact of user attitudes toward personnel in the IS department (i.e., systems developer) on system success (Hartwick & Barki, 1994; Hirchheim & Newman, 1991), user satisfaction with the IS department (systems developer) has not been explicitly tested in the IS literature. The relationship between the IS department and the user is central to the success of IS development (Beath & Orlikowski, 1994; Mallalieu et al., 1999). This is especially important when IS development is a continuous process during an organization's life. This study attempts to investigate the effect of fairness of IS development process on user satisfaction with the IS department.

LITERATURE REVIEW

Designing information systems is a complex and demanding process. It is an evolutionary process that involves constant learning, as new or changing needs are identified. Participation by users in the process of analysis, design evaluation, and implementation is useful since it increases the knowledge and skill of users. Land and Hirschheim (1983) reported benefits of user participation in IS development process. Participation provides users opportunities to protect their interests, and facilitates user's compliance with the outputs of decision-making during system development. Participation of users acts as a motivator that makes them accept the new system without much resistance to change. Finally, participation permits various skills and knowledge of users to be incorporated in the process of developing the system.

A close relationship between the developer and users is a prerequisite for building effective systems (Beath & Orlikowski, 1994). The ability of the system developer to use his or her people skills to minimize conflicts with the end users directly affects the user's satisfaction with the IS (Guimaraes & Igbaria, 1997). Despite the difference between the user and the system developer, effective communication between them facilitates conflict identification and its subsequent resolution, which improves user satisfaction (Mckeen et al., 1994). As indicated by Ajzen & Fishbein (1980), a positive attitude toward the IS department may increase the user's intention to cooperate with the department.

Researchers have utilized the three dimensions of the justice theory (procedural, interactional, and distributive justice) in examining the relationship between fairness of the IS development process and IS success (Kwun & Alshare, 2005; Joshi, 1989; Joshi, 1990; Hunton, 1996; Hunton & Price, 1997). Procedural justice refers to the fairness of the formal procedures through which outcomes are achieved (Greenberg, 1987). Interactional justice deals with the interpersonal treatment people receive from the decision maker and the adequacy with which formal decision making procedures are explained (Tyler & Bies, 1989). Distributive justice refers to the perceived fairness of the resulting distribution of outcomes of decision making. The fairness of outcomes is evaluated based on some distributive rules that include equity (the ratio of outcomes received to the inputs provided), equality (equal receipt by all parties), and needs (receipt of resources according to the extent to which they are required by the recipients). However, equity, in general, is the dominant rule in fairness judgments (Cohen, 1987).

The three dimensions of the justice theory have been adequately representing individual perception of fairness. As measures of perception of fairness for the decision making process and decision outcomes, these dimensions of justice have been shown to influence attitudes (e.g., satisfaction) and behavior (e.g., turnover) (Greenberg, 1990). For example, perception of fairness improves level of organizational citizenship behaviors which promote effective functioning of the organization (Moore & Love, 2005). Justice research also has recognized that perception of fairness has impact on organizational outcomes such as satisfactions with employing organization, and its decision-making authorities as well as satisfaction with outcome itself (Barling & Phillips, 1992; Folger & Konovsky, 1989; Korsgaard, et al., 1995). In IS development context, procedural justice has been used to explain the effects of user participation on satisfaction with IS (Hunton & Price, 1997). Joshi (1989, 1990) recognized the importance of fairness in systems development and created an instrument to measure fairness in IS based on both distributive and procedural justice. Additionally, Kwun and Alshare (2005) studied the effects of the justice dimensions on user's satisfaction with IS. They found that interactional justice and distributive justice, but not procedural justice, had significant positive impacts on users' satisfaction with IS. However, the impact of fairness on organizational outcomes such as satisfaction with IS department has been ignored. Thus, this study attempts to find the effect of three dimensions of justice on user satisfaction with the IS department. Based on the above discussion of the three dimensions of justice, the following hypotheses were proposed:

H1: Procedural justice has a positive effect on the user satisfaction with the IS Department.

H2: Interactional justice has a positive effect on the user satisfaction with the IS Department.

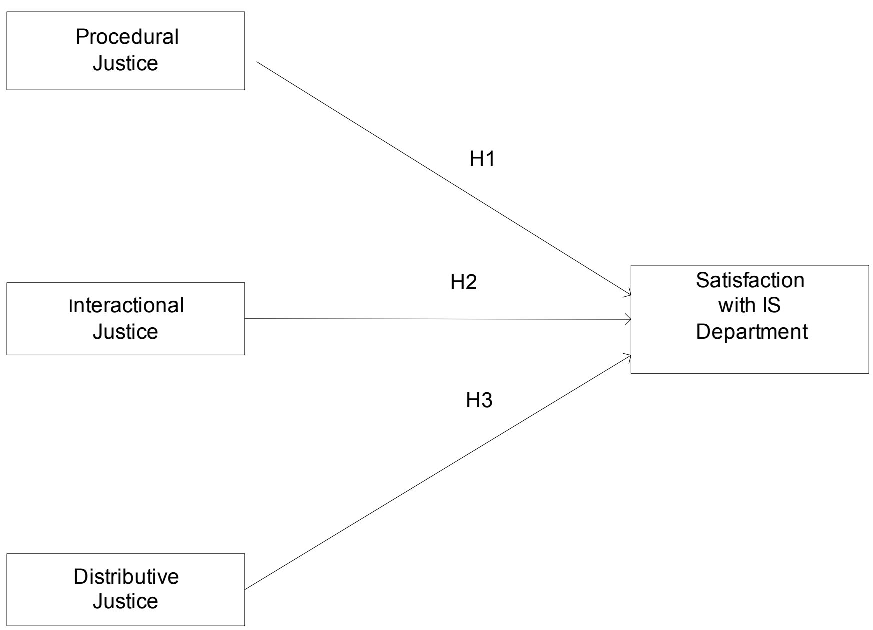
H3: Distributive justice has a positive effect on the user satisfaction with the IS Department.

RESEARCH METHODS AND DATA COLLECTION

Research Model

The relationship between user perception of fairness and their reactions is directly derived from justice theory. Therefore, the user perception of fairness of the IS development process was expected to influence satisfaction with the IS department (i.e., systems developer). As shown in Figure 1, the main constructs in the research model include: (1) procedural justice, (2) interactional justice, (3) distributive justice, and (4) satisfaction with the IS department (i.e., systems developer).

Figure 1: Proposed Research Model



Measures

Procedural Justice: The items to measure procedural justice were developed based on the elements of procedural justice suggested by Leventhal (1980) (e.g., consistency, bias suppression, accuracy, and correctability) and Thibaut and Walker (1975) (e.g., control over process and control over outcome decision). These items were designed to measure the degree to which the formal procedures used in the IS development process were fair. An example would be "Procedures were designed to collect accurate information necessary for the system development." A five-point Likert scale was used for the response, ranging from strongly disagree (1) to strongly agree (5).

Interactional Justice: The items for this dimension of interactional justice focused on the interpersonal behavior of the IS developers. Based on the previous studies on interactional justice (Bies, 1987; Bies & Moag, 1986; Tyler & Bies, 1989), the items reflected the degree to which the IS developer treated users with trustfulness, kindness, justification, and respect. An example would be “The IS developer treats you with kindness and consideration.” The response scale was a five-point Likert scale, ranging from strongly disagree (1) to strongly agree (5).

Distributive Justice: Distributive justice was measured in terms of the degree to which respondents believe that they are fairly rewarded when they consider their input. The items for the study were developed based on the items used in a study done by Joshi (1990). However, the other elements of distributive justice (equality and needs) were also considered. An example would be “Information resources are fairly allocated based on the user’s needs.” The response scale was a five-point Likert scale, ranging from strongly disagree (1) to strongly agree (5).

Satisfaction with IS Department: These items were developed to measure the user’s satisfaction with the IS department. The items measure the user’s satisfaction with the system developer’s skills and abilities such as people, model, system, computer, organizational, and societal skills. An example would be “How would you rate the IS department’s ability to meet the requirements of all the users?” The response scale was a five-point Likert scale, ranging from very dissatisfied (1) to very satisfied (5).

Statistical Procedures

Partial Least Squares (PLS) analysis was used to test the proposed research model. PLS is a multiple regression-based technique for testing a research model with multiple-item constructs and direct and indirect paths. It has been considered appropriate for exploratory study and testing predictive models. PLS is especially useful in situations where sample size is small; missing data is common; and there are high correlations between the predictor variables. In addition, PLS does not require assumptions about distributional characteristics of the raw data.

PLS, as a structural equation modeling, recognizes two parts of model testing: measurement and structural models (e.g., Barclay et al., 1995; Fornell & Larcker, 1981). In order to test a research model, the measurement model has to be evaluated first, and then the structural model has to be tested. The assessment of both models was conducted using PLS-GUI 2.0, which is LVPLS 1.8 with a graphical user interface.

The Measurement Model

There can be two types of relationships between constructs and their measures (items): formative and reflective (Fornell & Larcker, 1981). Formative items are considered to be causes of the construct. Reflective items are considered to be effects of the construct. In PLS, the relationship between constructs and items used to measure them must be specified. In order to specify the relationship, theoretical knowledge must be applied as much as possible (Lohmoller, 1981). Lohmoller also suggests that exogenous constructs (independent variables) should be modeled with formative items, and endogenous constructs (dependent variables) should be modeled with reflective items when theoretical knowledge about the construct does not exist. For our model, as shown in

Table 1, the items measuring all of exogenous constructs were considered formative as indicated in justice theory, whereas the items measuring the endogenous construct were considered reflective, since there is no theory that clearly describes the relationship between items and constructs they measure.

Table 1: The Measurement Model		
Constructs	**Model**	**Relationship**
Procedural Justice	Exogenous	Formative
Interactive Justice	Exogenous	Formative
Distributive Justice	Exogenous	Formative
Satisfaction with IS Department	Endogenous	Reflective

The Structural Model

The test of the structural model consists of estimating the path coefficients between constructs in the research model, which indicates the strength of the relationships and the R^2 value of the dependant variable, which shows the amount of variance explained by the model. Although other techniques such as jackknifing and bootstrapping have been used to test the significance of the path coefficients, t-test of ordinary least square (OLS) regression was used as recommended by Chatelin et al. (2002). Using the construct values generated by PLS analysis, a multi-regression analysis was performed. The hypotheses were tested by assessing the significance of the relationship between the constructs.

Samples and Data Collection

The data were collected using a commercial research website (www.zoomerang.com). After the questionnaire was posted, the web page address for the questionnaires was sent to a list of randomly selected 2500 middle-level managers. Middle-level managers have been used in IS development research as subjects, since they are the best representatives of the user community and are more likely to participate in the IS development process. Researches in user participation within the justice framework also involved middle-level managers as subjects (Joshi, 1990). Since informal word-of-mouth communication, rather than direct experience, has proven to influence user attitude and behavior (Gallettta et al., 1995), it has been assumed that the middle mangers' perceptions of justice in IS also influences the individual user perception of justice (Joshi, 1989).

DATA ANALYSIS

Two Hundred twelve managers completed the survey, which represented 8.4 percent response rate. Seventy-eight of the 201 usable responses indicated that they had never participated in the system development process; therefore, they were excluded from the analysis.

Profiles of the Sample

As shown in Table 2, the sample group consisted of 36.6 percent (45) females and 63.4 percent (78) males, with average age of 44.1 years. Over 98 percent of the respondents were familiar with computer technology. This may be because most middle-level managers have to use computer-based information systems to perform their daily work and are aware of their investments in computer technology. These managers represent different industries: 16.5 percent were from manufacturing, 35 percent were from Service, 8.1 percent were from merchandising, and 35.8 percent were from other industries that include government, health care, and education. In terms of the number of employees and revenue, the majority of the managers were from relatively large organizations. Also, the majority of the managers had been in the managerial position in the organization for more than four years. Their job titles varied, but the typical titles included manager, supervisor, and director.

Table 2: Frequency Distributions of Key Variables (N=123)

Variable	Responses	Percent
Gender:		
Male	78	63.4
Female	45	36.6
Computer knowledge:		
Very high	43	34.15
High	48	39
Average	30	23.6
Low	2	1.6
Very low	0	0
Tenure:		
< 1 year	5	4.1
1-3	33	26.8
4-9	55	44.7

Table 2: Frequency Distributions of Key Variables (N=123)		
Variable	Responses	Percent
10-15	16	13
> 16	14	11.4
Industry:		
Manufacturing	21	16.3
Services	45	35.8
Merchandising	11	8.1
Other	46	35.8
Company Size:		
< 500 F. emp.	23	17.9
500-2000	30	24.4
2001-10000	28	22.8
>10000	42	34.1
Revenue:		
< 200 mi.	28	20.3
200-500	26	18.7
> 500	69	54.5

RESULTS

The results of the study are divided into two sections. The first section discusses reliability and validity of the research model. The second section provides answers for hypotheses H1-H3; that is the effects of justice dimensions on user satisfaction with the IS department.

Assessing the Measurement Model

The measurement model addressed the relationship between the constructs and the items used to measure them. The test of the measurement model involved estimation of the convergent and discriminant validity of the measurement instrument. Convergent validity, which examined the extent to which alternative measures of the same construct were related to each other, and the discriminant validity, which considered the degree to which measures of a construct were not related to measures of other constructs, were used to validate the research instrument.

As shown in Table 3, the reliability (Cronbach's Alpha) of items on all constructs ranged from 0.79 to 0.92. These values were greater than 0.7, the acceptable value that was suggested by

Nunnally (1978); thus, the reliability measure was satisfactory. With respect to individual items, all items for formative constructs (independent variables) showed positive weight except PJ3 and IJ1. Also, all items in the reflective construct (the dependent variable) had loading of 0.60 or above, which was recommended as acceptable values by Hair et. al., (2006). With respect to the AVE criterion, the reflective construct (SD) had 0.61 which was greater than 0.5 as suggested as acceptable value by Fornell & Larcker (1981). In order to achieve discriminant validity, no item should be loaded higher on another construct than it is on the construct it intends to measure. All items loaded highest on their target constructs

Table 3 : Reliability Analysis (Cronbach's Alpha and AVE)

Construct	Cronbach's alpha	Aveg. Variance Extracted
PJ (5 items)	0.79	.043
IJ (5 items)	0.87	0.50
DJ (6 items)	0.87	0.54
SD (9 items)	0.92	0.61

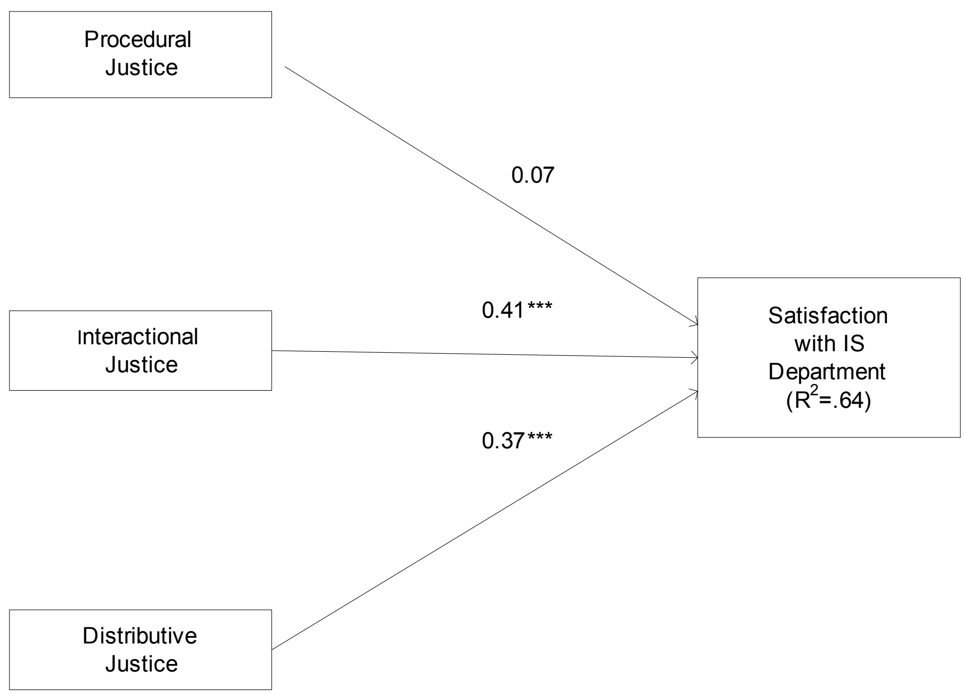
In order to improve the validity of the results, the formative items with negative weight were removed when the structural model was tested. As a result, PJ3 and IJ1were dropped to estimate the structural model. Overall, the analysis of convergent and discriminant validities, along with the examination of the individual items imply that the measurement model considered satisfactory. The list of items for each construct is reported in Appendix A.

Estimating the Structural Model

The significance and the strength of the relationships among the constructs are shown in Figure 2. Although procedural justice had a positive effect on satisfaction with the IS department, the coefficient was small (0.07) and the relationships was not significant (H1 was not supported). This may be due the lack of end-users' interests in knowing details about the formal procedure for a particular project, since such projects usually have a short development life cycle. Additionally, the IS development project team involved an adhocracy where members consisted of people with different specialties organized into a short-lived team without strong central management and well established formal procedures (Mintzberg, 1979). Because of the lack of formal procedures in IS development, managers might have had difficulties forming perceptions of the procedures. Moreover, since middle-level managers, regardless of their participations of the systems development process, usually involved in informal meetings with the IS development teams, they were aware of such procedures, if there was any, and they had already developed attitudes toward such procedures.

Interactional justice had significant positive impacts on satisfaction with the IS department. Thus, the hypothesis H2 was supported. Additionally, it had a stronger positive impact on satisfactions with the IS department with path coefficients of 0.41 than the other justice dimensions. Finally, distributive justice had significant and positive impacts on satisfactions with the IS department. Therefore, the hypothesis H3 was supported. The path coefficient was 0.37. As shown in Figure 2, the three variables together (procedural justice, interactional justice, and distributive justice) explained 64 percent (R^2) of variance of satisfactions with the IS department.

Figure 2: Research Model Analysis Results



* Indicates that the path is significant at the p<.05 level
** Indicates that the path is significant at the p<.01 level
*** Indicates that the path is significant at the p<.001 level.

CONCLUSIONS AND IMPLICATIONS

This study utilized justice theory in investigating the impact of user perceptions of fairness of the IS development process on their satisfactions with the IS department. The results indicated that interactional justice and distributive justice had positive effects on satisfaction with the IS department. However, Interactional justice, compared to distributive justice, had a stronger effect on the user's satisfactions. Additionally, results revealed that procedural justice did not have a significant impact on users' satisfactions with the IS department.

Implications for Practitioners

This study has many implications for practitioners. System development is not only a technical process, but it is also a social and interpersonal process. This implies that system development must address social and interpersonal aspects of the system development to improve users' satisfactions with the IS department. One way to improve these satisfactions will be improving perceptions of fairness in the system development process. In order to improve perceptions of fairness, IS developers must adopt formal procedures that promote accuracy, provide opportunity to appeal, illustrate consistency, give opportunity for clarification, show concern for users, and guarantee fair allocation of resources and benefits of the resulting system. Also, since IS development requires user participations, the IS developer's interpersonal treatment and communication skills become equally, if not more important than other skills (e.g., technical skills). Interactional justice deals with issues beyond formal procedures. In order to improve fairness of interpersonal treatment during IS development, IS developers must consider users' opinions, avoid personal bias, provide timely feedback, treat users with kindness and consideration, show concern about users' rights, and be truthful.

The results of this study confirmed that interpersonal skills are among the most important factors that affect satisfactions. One way to improve perceptions of these interpersonal treatments could be by applying impression management (Bies, 1987), which is a way to influence people's subjective judgment about social and political interaction (Bolino & Turnley, 1999; Rao, et al, 1995). Therefore, impression management skill of IS developers may play a major role in influencing users' perceptions of fairness.

It is worth of mentioning that the majority of users generally do not have a chance to participate in IS development process. Their perceptions of fairness may heavily rely on the distribution of outcomes, although they may be aware of procedural and interactional fairness through their representatives in IS development process. Also, their satisfaction with the IS may affect their perceptions of procedural and interactional fairness. Thus, to improve user satisfaction with the IS department, information resources should be properly distributed by considering factors such as equity, equality, and needs.

Implications for Researchers:

While the study provided strong support for relationships between the constructs and user satisfaction with IS department, there were still several limitations in generalizing the results. First, there may be biases attributable to common-method variance. Since people tend to claim credit for positive events and avoid blame for failures, the results of the study may be exaggerated for data collected through the ex post facto self-report on both independent and dependent measures (Hawk & Aldag, 1990). This study relied on self-reports from users on both perceptions of fairness & satisfaction. Thus, relationships among the constructs might be inflated. Second, a sample of middle-level managers was used in this study. These middle-level managers, such as supervisors or directors of departments were most likely to represent users who participated in the system development and understand departmental issues. However, they may have different interests from those of general users. Therefore, future research might use pre- and post-data collection so the results would not be based on self-reported data, and involve direct users of systems as the target population. Another future research might be to include other factors that may produce new relationships among the constructs, since the factors that affect perceptions of fairness could vary across different settings. Another plausible direction for future research might be adding factors that take in account individual differences, since justice is subjective in nature.

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Appendix A: The list of Items		
Construct	Item	Description
Procedural Justice	PJ1	The IS development process is designed to collect accurate information necessary for making decisions.
	PJ2	The IS development process is designed to provide opportunities to appeal or challenge the decision made.
	PJ3	The IS development process is designed to generate standards so that decisions can be made with consistency.
	PJ4	The IS development process is designed to hear the concerns of all those affected by the decision. …………..
	PJ5	The IS development process is designed to provide useful feedback regarding the decision and its implementation.
	PJ6	The IS development process is designed to allow for requests for clarification or additional information about the decision.
Interactional Justice	IJ1	The IS department considered your view point
	IJ2	The IS department was able to avoid any personal bias.
	IJ3	The IS department provided you with timely feedback about the decision and its implications.
	IJ4	The IS department treated you with kindness and consideration.
	IJ5	The IS department showed concern for your rights as a user.
	IJ6	The IS department took steps to deal with users in a truthful manner.
Distributive Justice	DJ1	Information resources (e.g., hardware, software, the database, and IS staffs who provide support service) are allocated fairly based on user's time and effort during the development process.
	DJ2	Information resources are allocated fairly based on user's need.
	DJ3	Information resources are allocated fairly to all users.
	DJ4	The benefits from the system are allocated fairly based on user's efforts during the development process.
	DJ5	The benefits from the system are allocated fairly based on user's need.
	DJ6	The benefits from the system are allocated fairly to all users regardless of their effort during the development process and their need

Appendix A: The list of Items		
Construct	Item	Description
Satisfaction with IS Department	SD1	How would you rate the IS department’s ability to meet the requirements of all the users?
	SD2	How would you rate the IS department’s ability to meet the information needs of your area of responsibility?
	SD3	How would you rate the IS department’s communication and interpersonal skills?
	SD4	How would you rate the IS department’s ability to specify components, scopes, and functions of the system?
Satisfaction with IS Department	SD5	How would you rate the IS department’s knowledge of hardware/software, programming language?
	SD6	How would you rate the IS department’s ability to finish IS development within budget?
	SD7	How would you rate the IS department’s ability to finish IS development within time?
	SD8	How would you rate the IS department’s knowledge of your functional area and its organizational condition?
	SD9	How would you rate the IS department’s ability to articulate and defend its position on important issues about information technology’s impact on society?

OPTIMIZING METAL CUTTING COST BY INTEGRATION OF COST OF QUALITY USING TAGUCHI'S LOSS FUNCTION

Sharad K. Maheshwari, Hampton University

ABSTRACT

The metal cutting is one of the most basic and common operations in manufacturing industries. The quality of final product depends largely upon the control of metal cutting operations performed on its components. There are many characteristics of the machined components which directly contribute to the product quality. These characteristics may include dimensional accuracy, surface finish, roundness, etc. Most of the characteristics of a work-piece are the function of machine-tool and cutting-tool condition, cutting parameters, material of the tool and work-piece, and worker training. The production planners generally don't have control over the material of the work-piece and condition of machine-tool. The worker training problems are addressed separately based upon the availability, time, learning curve issues, etc. However, the cutting parameters are totally controlled by the production planner. Therefore, the selection of the cutting parameters becomes a critical issue to control the quality. The selection of the cutting parameters is mainly dependent on the economics of metal cutting operations. However, traditionally these economic models do not include the quality related cost. Even though, some recent attempts have been made to include quality issues in the tool economics models cutting parameters but the relationship between the surface roughness and cutting parameters has not been explored extensively. This paper is an attempt to develop a model to include surface roughness into the tool-economics model to select cutting parameters using Taguchi's loss function approach.

INTRODUCTION

The metal cutting operations are fundamental to most discrete part manufacturing industry. The quality of the products which use parts produced via metal cutting operations largely depends upon quality of metal cutting operations. The quality issues had not received much attention in the manufacturing operations until 1960-1970s. However, increased competitiveness and globalization of economy has created a revolutionary change in the quality practices and management. The concept of quality has also been changing to include every aspect of an organization. These quality driven changes also had impact on metal cutting industry. The production planers have find ways to improve quality of each metal-cutting operation. Therefore, it is becoming essential to consider quality related factors in every aspect of the metal-cutting operation. The most fundamental aspect of the metal-cutting operations is the selection of cutting parameters, i.e., cutting speed, feed rate, and depth of cut. The selection of these three main machining parameters is dependent on the cost of the metal cutting operation. The traditional cost models for metal cutting operations mainly included cost of machining, setup and tool. In general, these model models are based on optimization of processing cost (tool cost, machine-use cost, regrinding cost, tool change cost) or tool life subjected to technological constraints such as limits on cutting parameters, machine torque, spindle force, etc. Optimization of a given cost model provides the most economic values of these parameters to operate the machine. But these approaches of metal cutting economics (for examples, Lambert & Walvekar, 1978; Davis, Wysk & Agee, 1978; Maheshwari, 1984; Schall & Chandra, 1990) are simply based on the time and tool factors and do not allow considerations for some other important factors which are directly related to the machining operation.

Two important components ignored in the traditional metal cutting cost models are dimensional accuracy and quality of the surface finish. Mostly, it is assumed that there is no significant change either in the dimensional accuracy or in the surface roughness as a metal cutting operation proceeds before a tool change is necessary. This make the life of cutting tool (time before tool must be changed) as a main driving force in the traditional economic models of metal cutting operations. The variations in the tool life are also extensively studied (Ramalingam & Watson, 1977; 1978) and are generally showed to vary with the basic cutting parameters. However until recently, the relationship between tool life and quality characteristics has not received much attention from researcher. Some recent literature (Robles & Roy, 2004; Wu & Chyu, 2004; Hui, Leung & Linn, 2001; Choi & Park, 2000; Cheng & Saeed, 1995; Hui & Leung, 1994) indicates that quality considerations are becoming more important in the economics of metal cutting. These quality considerations in the selection of cutting parameters along with intelligent monitoring systems can possibly deliver much higher quality at lower cost.

The poor quality of workpiece is largely influenced by the condition of cutting-tool which is a function of cutting parameters (Mittal & Mehta, 1988; Maheshwari, Mishra & Mehta7, 1991.) A challenge to the planner is what parameters to select to improve the product quality at minimum overall cost. Both the workpiece and the cutting tools are routinely inspected. Computerized tool and workpiece inspections could be used to enhance monitoring process (Kendall & Bayoumi, 1988.) Based on the condition of the tool or the quality of the parts at a given time, an operator can decide to change the cutting tool. As indicated earlier, the condition of tool depends upon the cutting parameters. Thus, the selection of cutting parameters--cutting speed, feed rate and depth of cut, in a metal cutting operation becomes very critical. However, these models do not include the cost of resulting quality such as dimensional accuracy, surface finish, etc. The literature (Wu & Chyu, 2004; Hui, Leung & Linn, 2001; Cheng & Saeed, 1995; Hui & Leung, 1994) has shown the cost incurred due to deviation in quality of the workpiece during the cutting process is an important component of the tool economics. Taguchi's loss function (Taguchi, 1988) is used to model the cost of the dimensional quality deviations.

The Taguchi model includes a cost of deviation from preset quality level. It models quality cost as a quadratic loss function. That is, any deviation from the quality results in loss to the society which increases somewhat exponentially as the deviation from the preset quality limit increases. This approach has been applied to a wide variety of fields like from manufacturing to service industry with success; for example computer fraud detection (Schölkopf & Smola, 2002) real estate service (Kethley, Waller & Festervand, 2002) or quality of hog (Roberts, 1994.) In this study, two separate quality dimensions of metal cutting are included. These two dimensions are size (tolerances) and surface quality (roughness). A model for tool economics with the application of Taguchi's quadratic loss function to dimension accuracy and surface roughness is developed below.

MOTIVATION

The new tool economics model found in the literature normally are limited to only one quality characteristics; dimensional accuracy. However, the quality of the workpiece is defined by several characteristics including surface finish. We believe that the surface finish should be the part of the tool economics model along with dimensional accuracy and other traditional factors. The surface roughness can contribute to the significant losses in certain components such as automobile pistons, cylinders and bearing. Therefore, ignoring the surface finish cost during the machining operations could result in greater losses during the actual usage of the product. However, these losses can be reduced if quality cost due to surface roughness is included in the tool economics model. The cutting parameters can be selected such that the losses due to the surface roughness are reduced.

MODEL FORMATION

The tool economics model is expanded to include the losses due the surface roughness. Taguchi loss function is used to incorporate surface roughness losses. The other traditional cost factors are also included. The closed form mathematical can be formulated with certain practical assumptions. The model assumptions are listed below:

1. Only flank wear influences the dimensional accuracy and surface finish and other factors have no significant impact on the surface finish and dimensional accuracy.
2. Tool life is function of the flank wear only.
3. The quality loss can be defined using Taguchi functions.
4. The catastrophic failure of the tool is ignored.
5. Tool- life can be restored completely after regrinding.
6. The mean rate of tool wear and standard deviation of tool wear is known.

Notations

The following notations are used in the model formulation:

V	Cutting speed.
d	Depth of cut.
f	Feed rate.
r	Rate of tool wear.
H	Cumulative height of flank wear.
h	Height of tool wear at a give time, t.
t	Time instance during a machining operation.
T	Total time.
L	Tool life.
x_1	Random variable, dimensional accuracy.
x_2	Random variable, surface roughness.
m	Desired value of a dimension of a component.
$l(y)$	Loss due to the deviation from the desired value.
y	Average dimension produced by the machining processes.
σ_1	Standard deviation of dimensional accuracy.
σ_2	Standard deviation of surface roughness.
m	Desired value of a dimension.
R_a	Average roughness.
K	Tool life equation constant.
K_{lossi}	Constant associated with Taguchi loss function.
n_j	Exponent associated with tool life.
a, b, c	Constants, cost factors.

TAYLOR'S TOOL LIFE MODEL

The tool-economics models largely depends upon the Taylor's tool life equation. This equation relates the tool life (L) with the cutting speed and described as below:

$$VL^{n'} = \text{Constant}$$

The above equation can be rewritten as:

$$L = K\,V^{n}$$

The equation shows that the tool life is a function of the cutting speed only. The constant K depends upon material of tool and workpiece. This above equation has been modified to reflect the impact of other machining parameters feed rate and depth of cut. The modified Taylor's tool life equation is:

$$L = K V^{n1} f^{n2} d^{n3}$$

The literature shows other factors, such as machine torque, may also influence tool life. However, in this paper will restrict modeling to the three important cutting parameters, speed, feed and depth of cut.

As per our assumption (6), the tool life is a function of flank wear only. The above equation can be related to the height of flank wear. In most of the cutting operations, the flank wear has far more significant impact on the tool life than any other kind of wear. Hence, our assumption is very realistic and can be used without loss of any generality. The above equation can be modified as:

$$L \propto H$$
$$L = K_1 * H$$

It is also well known in the metal cutting literature that the tool-wear rate is somewhat constant during the most of the useful life of a tool. Therefore, the cumulative flank wear can be related to the rate of tool wear as:

$$h = rt$$

Above equation is valid only during the constant wear rate zone. The initial increasing wear rate zone is ignored, as that period is normally very small compared to the constant wear rate zone. The same is true for the last zone as tool deteriorates fast and is removed from the operations for regrinding or exchange.

TRADITIONAL TOOL ECONOMICS MODEL

The traditional tool-economics models largely depend upon the Taylor tool life. These models include the setup cost, machining cost and tool cost. A per unit cutting cost model can be written as:

$$\text{Cutting cost} = \text{machining cost} + \text{tool cost} + \text{set up cost}$$
$$= a/V + bV^{(-n1-1)} + c,$$

If use modified Taylor's equation:

$$= \quad a/V \quad + bV^{(-n1 - 1)} \; f^{-n2} \, d^{-n3} \; + \; c.$$

QUALITY COST MODEL

Dimensional Accuracy

A machined part is considered acceptable as long as it's dimensions are within the tolerance limits. However, Taguchi's loss function approach assumes there are losses for any deviation from the desired value. The desired value is normally the design dimension of the component. However due to the manufacturing limitations, some deviations from the designed value is acceptable. The acceptable deviation limits are called tolerances. According to the loss function approach, even the deviation within the tolerance limits results in the losses to the larger society. These losses are represented as:

$$l(y) = K_{loss} (y-m)^2$$

Due to tool wear at the flank, the cutting conditions are changing continuously. The depth of cut is reduced by the amount of the tool wear at the flank. Hence, the dimensional accuracy is changing along with the tool wear. Furthermore, it is also well documented in the literature that the tool wear is a stochastic phenomenon. Therefore, there is some randomness in the amount of tool wear along with a deterministic wear component. The random component of the tool-wear will also result in the dimensional deviations hence will result towards the loss. Total deviation from the actual dimension at any given time can be written as:

$$\text{(Deterministic component + random component of dimensional changes)} \quad = \quad (rt + x_1)$$

Using Taguchi's loss function, at any given time "t", the losses due to this change can be formulated as:

$$l(y) \quad = \quad K_{loss1} (rt+x_1 - m)^2;$$

Assume that mean of the desired variation is zero.

$$m \quad = \quad 0;$$

Hence;

Total loss due to the dimensional accuracy at time ‘t’ = $K_{loss1}(rt + x_1)^2$
Expected loss due to the dimensional accuracy at time ‘t’ = $E[K_{loss1} (rt + x_1)^2]$
= $E[K_{loss1} (r^2t^2 + x_1^2 + 2rt\, x_1)]$
= $K_{loss1} (r^2t^2 + \sigma_1^2 + 2rt\, m)$

m = 0;

Expected loss due to the dimensional accuracy at time ‘t’ = $K_{loss1} [r^2t^2 + \sigma_1^2]$
Total loss due to the dimensional accuracy over time T = $\int^T K_{loss1} (r^2t^2 + \sigma_1^2)\, dt$
= $K_{loss1} (r^2T^3/3 + \sigma_1^2 T)$
Mean loss over time T = $K_{loss1} (r^2T^2/3 + \sigma_1^2)$

Using:

rT = H

Mean losses due to the dimensional accuracy = $K_{loss1} [\sigma_1^2 + (1/3) H^2]$

Surface Finish

The surface finish is measured in terms of the roughness value of the surface. Lower the value of surface roughness better it is for the quality. Hence, any deviation in the roughness value on the negative side does not result in any loss. The literature on the machining operations shows that the tool wear and surface finish are closely related. The relationship between flank wear and roughness value can be formulated as:

$$R_a \propto h^{s.}$$
$$R_a = K_2\, h^{s.}$$

However, all of the variations in the surface cannot be explained alone by the tool wear height. Assuming that all other variations in the roughness are due to random causes, the total roughness can be written as:

$$R_a = (x_2 + K_2\, h^s)$$

Assuming that the mean desired value of roughness is zero, meaning by completely smooth surface. The losses due to the surface roughness can be modeled using Taguchi’s loss function in a similar way as the formulation of the dimensional accuracy losses. The losses can be formulated as:

Losses due to surface roughness at a given time ‘t’ = $K_{loss2}(x_2 + K_2\, h^s$ - mean desired value)2
= $K_{loss2}(x_2 + K_2\, (rt)^s)^2$
[mean desired value of roughness = 0]

Expected losses due to roughness at a given time 't' $= E[K_{loss2}(x_2 + K_2\,(rt)^s)^2]$

$= K_{loss2}\,E[x_2^2] + K_{loss2}\,(K_2)^2\,(rt)^{2s}] + K_{loss2}\,E[K_2\,(rt)^s\,x_2]$

$= K_{loss2}\,\sigma_2^2 + K_{loss2}\,(K_2)^2\,(rt)^{2s} + K_{loss2}\,[K_2\,(rt)^s * \text{mean}\,]$

(Assuming mean of x_2 is zero).

$= K_{loss2}\,\sigma_2^2 + K_{loss2}\,(K_2)^2\,(rt)^{2s}$

Total losses due to roughness in Time T $= \int^T \{K_{loss2}\,\sigma_2^2 + K_{loss2}\,(K_2)^2\,(rt)^{2s}\}dt$

$= K_{loss2}\,\sigma_2^2\,T + (1/(2s+1))K_{loss2}\,(K_2)^2\,(rT)^{2s+1}$

Mean losses due to the roughness $= K_{loss2}\,\sigma_2^2 + (1/(2s+1))K_{loss2}\,(K_2)^2\,(rT)^{2s}$

Using:

$rT = H$

Mean losses due to the surface roughness $= K_{loss2}\,\sigma_2^2 + (1/(2s+1))K_{loss2}\,(K_2)^2\,(H)^{2s}$

Mean total losses due to quality $= K_{loss1}\,[\sigma_1^2 + (1/3)\,H^2\,] + K_{loss2}\,[\sigma_2^2 + (1/(2s+1))(K_2)^2\,(H)^{2s}$

Per unit loss due to variation $=$ (mean losses/unit time)/V

$= \{K_{loss1}\,[\sigma_1^2 + (1/3)\,H^2\,] + K_{loss2}\,[\sigma_2^2 + (1/(2s+1))(K_2)^2\,(H)^{2s}\}/V.$

Total Cost Function:

Traditional machining cost + losses due to quality $= a/V + bV^{(-n1\,-\,1)}\;f^{-n2}\,d^{-n3};\; + \;c + \{K_{loss1}\,[\sigma_1^2 + (1/3)\,H^2\,] + K_{loss2}\,[\sigma_2^2 + (1/(2s+1))(K_2)^2\,(H)^{2s}\}/V.$

CONCLUSIONS

The paper shows a new formulation of tool-economics using Taguchi function, which includes the quality losses due to dimensional accuracy and surface roughness. The cutting parameters selected using this model will optimize tool cost along with cost incurred due dimensional deviations and surface roughness. It must be noted that by inclusion of Taguchi loss-function in the tool economic model, the cost considerations are not limited just to the accounting considerations of direct labor and material costs but it includes perceived cost in the form of loss incurred upon society due to any variation. This creates a need to calculate of the societal loss constants like K_{loss1} and K_{loss2}. Further work is needed to estimate such loss constants.

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MODELING THE ACADEMIC PUBLICATION PIPELINE

Steven E. Moss, Georgia Southern University
Xiaolong Zhang, Georgia Southern University
Mike Barth, Georgia Southern University

ABSTRACT

In recent years, many academic institutions have implemented more stringent academic qualification standards by increasing research requirements for faculty. This paper analyzes the impact of changing research requirements in terms of faculty research output. We model the academic research pipeline including review and revision processes as a queue network and study the stationary behavior of the research pipeline. Both a theoretical model of the publication process and a simulation showing numerous combinations of submission strategies and publication requirements are presented. Within this framework, research requirements can be analyzed via probability constraints on the output process, and the research effort that satisfies this constraint is derived. We also study the transitional behavior of the publication queue to understand the convergence towards the stationary solution. Our analyses shows that submission requirements substantially exceed publication requirements if a faculty member is to maintain a required number of publications over any given time interval.

INTRODUCTION

The purpose of this research is to evaluate the pipeline for publications as a queueing model and to evaluate the probability of success for producing a given number of peer-reviewed journal articles over a fixed time interval. Publications are an important aspect of tenure, promotion, and salary decisions for business faculty. The Association to Advance Colleges and Schools of Business International (AACSB), the premier accrediting body for business schools, requires that colleges of business clearly delineate research and publication standards for faculty, including quality standards.

The AACSB standards place a particularly strong emphasis on peer-reviewed journal articles. Although the accreditation instructions specify a long list of intellectual contributions other than journal articles, the example summary table included in the accreditation standard 10 related to faculty intellectual contributions uses only two categories of intellectual contributions: (1) peer-reviewed journal articles, and (2) other intellectual contributions. Because of this (perhaps) overreliance on peer-reviewed journal articles as the standard of measuring the research productivity of faculty, peer-reviewed journal articles are perceived to be the gold standard for business faculty.

The process of taking a research idea from concept to publication includes several stages and can encompass considerable delays independent of the time it takes to process through peer review (Clark et. al., 2000). Although an informal review may improve the potential for a positive publication decision (Brown, 2005), the additional delay may reduce the available time a new academic has to establish a publications record in anticipation of tenure and promotion review.

The standards for intellectual contributions differ from college to college but still generally apply a numerical standard (e.g., three peer-reviewed publications within five academic years) and often a quality standard (e.g., one A-level peer-reviewed journal article per year). The standards have been increasing over time in both quantity and quality of peer-reviewed journal articles (Starbuck, 2005). At the same time, the delay between submission and response by journals has doubled in some disciplines over the last several decades (Azar, 2006). Once a paper is finalized in a suitable form and format for a target publication, the submission process begins, and that process can entail considerable delay in and of itself. A study done by Mason, Steagall and Fabritius cited in Clark et. al. (2000) reported that the average delay between submission and printing to be 35 weeks, and they reported instances where there were delays of over a year. Ellison (2002b) reports that the number of revisions and the length of time to process an article in the top economics journals has increased and that the average waiting time for an acceptance has increased to 20-30 months.

The publications pipeline for business faculty at state and regional universities can be significantly different than for their top-level business school colleagues. Publications in the lesser known journals can still entail a long delay, and the quality level of these journals is harder to measure. Acceptance rates and average review times are reported in Cabell's Directories of Publishing Opportunities, and administrators regularly use those published numbers to evaluate the quality of journals. Many academics also use Cabell's published figures to determine where to submit articles. However, the information in these directories is self-reported by each journal, and there is no standardized methodology for reporting acceptance rates. A self-reported acceptance rate of 40 percent in one journal may actually be more restrictive than a 20 percent acceptance rate reported in another. Given these caveats, a sample drawn from the 2006-07 editions of Cabell's Directories for Accounting, Economics and Finance, Management, and Marketing showed that all four disciplines had a mean acceptance rate of 25 percent, with the most common self-reported value to be 21-30 percent.

The acceptance rate for publications and the average delay between submission and acceptance are critical considerations for business faculty working towards promotion and tenure. Newly minted faculty members are not as cognizant of the delays built into the process and may easily underestimate the amount of work that is required to achieve those standards. Also, as pointed out in Frey (2003), the pressure to publish can often lead faculty members to respond slavishly to the whims of outside reviewers rather than to pursue their own academic and intellectual standards.

The publication process can be thought of as a queueing system, with a submission rate of X (the number of publications that a faculty member must submit per year) and a service rate of Y (the rate at which the submissions move through the pipeline). This research explores the effect of changes in the required number of journal articles over a fixed time interval and the submission rate of the author on the probability of successful completion of tenure and promotion requirements for business school faculty. In the next section of this paper we will present a theoretical queueing model for the academic publication process, modeled as a steady-state process. The following section will present a simulation approach of the publication process assuming varying research requirements and research strategies. We will conclude with a discussion of the findings and the potential impact on faculty working towards tenure and promotion as well as tenured faculty members working to maintain their academic qualifications.

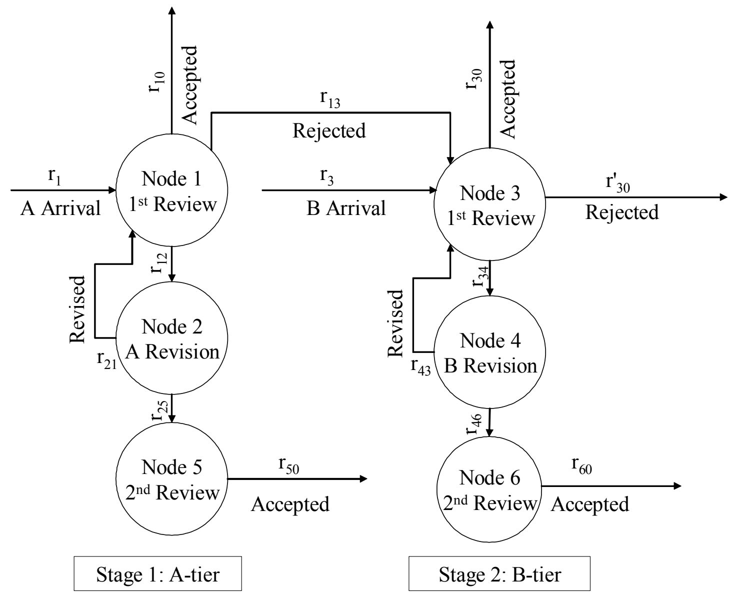
THE ACADEMIC RESEARCH PIPELINE AS QUEUEING NETWORK

For simplicity, we assume that a researcher can follow one of two submission strategies: (1) submission directly to a B-level journal or (2) submission directly to an A-level journal and then follow up with a submission to a B-level journal if the paper is rejected by the A-level journal. The first strategy is the shorter route because the article goes through the review process only once, but it will also have a smaller probability of acceptance for the same reason. Some researchers (e.g., Azar, 2006; Starbuck, 2005) have blamed the increasing number of "frivolous submissions" (i.e., submissions of lower-quality articles to the top journals in the field) on the slowdown in the overall peer review system. In our model, we are also assuming that authors follow an ethical approach and submit their research to the appropriate level of journal, rather than take the shotgun approach.

In our model, authors submit articles to either an A-tier or a B-tier journal, with the A-tier representing the top journals in a particular field. This two-tier publication system is described using a two-stage queueing network with feedback. The first stage of the network represents submitting an article to an A-tier journal for review, which may be accepted, rejected, or revised for re-submission. An accepted A-tier paper exits the publication system. A rejected A-tier article is re-submitted to a B-tier journal. A revised paper can be resubmitted as a new manuscript or undergo a second review. For simplicity, we lump multiple reviews and revisions that often occur in top-tier journals into one round as a second review. We make a simplifying assumption that all papers are accepted after a second review, reflecting the fact that the vast majority of papers that undergo multiple revisions are eventually accepted. The second stage of our queueing network represents the B-tier journals. In addition to the arrival from rejected A-tier papers, a B-tier journal also has its own independent stream of direct submissions. The B-tier reviewing process is similar to the A-tier one except that the rejected papers are assumed to exit the publication system. The arrival of articles at each tier of journal is assumed to be Poisson distributed. A reworked paper that failed to be accepted in either an A or B-tier journal is treated as a new submission in the queueing system.

Our simplified publication system represents a Jackson network with feedback (Jackson, 1957, 1963). The following schema, see figure 1, depicts the 2-stage publication queueing network modeled in this paper.

Figure 1: Schema for Publishing Queue Network



Nodes 1 and 3 represent the A and B journal first review process respectively. Nodes 2 and 4 represent their corresponding revision queues. Nodes 5 and 6 represent the second review process of each tier. By convention, node 0 represents the outside of the publication system. The independent arrival rate for each node is represented by γ_i, while the routing probabilities between two nodes, representing key journal review statistics, are denoted by γ_{ij}, and their interpretation is shown in table 1.

Table 1: Arrival Rates and Routing Probabilities	
Var.	Definition
γ_1:	A-tier journal submission rate
γ_3:	B-tier journal submission rate
γ_{10}:	Acceptance rate of A-tier journal
γ_{30}:	Acceptance rate of B-tier journal
γ_{13}:	Rejection rate of A-tier journal

Table 1: Arrival Rates and Routing Probabilities	
Var.	Definition
γ_{21}:	Percentage of revised A-tier articles resubmitted as new article to another A-tier journal
γ_{25}:	Percentage of revised articles gone through a second review
γ'_{30}:	Rejection rate of B-tier journal
γ_{34}:	Percentage of B-tier journals asked for a revision
γ_{43}:	Percentage of revised B-tier articles resubmitted as new articles to another B-tier journal
γ_{25}:	Percentage of revised B-tier articles gone through a second review

Certain combinations of routing probabilities must add up to one. These combinations are shown by the four equations in table 2.

Table 2: Equations Constrained to 1
$\gamma_{10} + \gamma_{12} + \gamma_{13} = 1$
$\gamma_{21} + \gamma_{25} = 1$
$\gamma_{30} + \gamma'_{30} + \gamma_{34} = 1$
$\gamma_{43} + \gamma_{46} = 1$

Because feedback is involved, the stationary distributions of the research output streams represented by γ_{10}, γ_{30}, γ_{50}, and γ_{60} depends on the total net mean flow rate into each node. Let λ_i be the total net mean flow rate into node *i* including the independent arrival from the outside and the feed back from other nodes. When the queue network converges to stationary equilibrium, the total expected inflow of articles must equal to the total expected outflow for each node. This balance of flow implies that the following equation must hold (Gross and Harris, 1985).

$$\lambda_i = \gamma_i + \sum_{j=1}^{6} \gamma_{ji} \lambda_j$$

Expanding the flow of balance equations for each of the six nodes in our publication network yields the six linear equations, shown in table 3.

Table 3: Linear Equations for Flow of Balance, Nodes One through Six
$\lambda_1 = \gamma_1 + \gamma_{21} \lambda_2$
$\lambda_2 = \gamma_{12} \lambda_1$
$\lambda_3 = \gamma_3 + \gamma_{13} \lambda_1 + \gamma_{43} \lambda_4$
$\lambda_4 = \gamma_{34} \lambda_3$
$\lambda_5 = \gamma_{25} \lambda_2$
$\lambda_6 = \gamma_{46} \lambda 4$

The first equation simply states that the total net inflow into node 1 is the sum of the independent arrival and the feedback flow from node 2. The second equation indicates that the arrival to node 2 is a fraction of the outflow of node 1 according to our network structure. Other equations can be interpreted similarly. The overall mean arrival flow rates for each node can then be easily solved from the linear system of equations shown in table 3, which are given by the following six equations shown in table 4.

Table 4: Overall Mean Arrival Flow Rate for Nodes One through Six
$\lambda_1 = \gamma_1/(1- \gamma_{12} \gamma_{21})$
$\lambda_2 = \gamma_{12}\lambda_1$
$\lambda_3 = (\gamma_3 + \gamma_{13} \lambda_1)/(1- \gamma_{34} \gamma_{43})$
$\lambda_4 = \gamma_{34}\lambda_3$
$\lambda_5 = \gamma_{25}\lambda_2$
$\lambda_6 = \gamma_{46}\lambda_4$

Given the overall arrival flow rates, the accepted article output streams associated with the A-tier and B-tier journals are independent Poisson processes with rates shown in table 5 (Melamed, 1979; Burke, 1956; Disney et. al., 1980).

Table 5: Accepted Article Output Streams		
	A-tier	B-tier
Accepted in 1st review	$\gamma_{10} \lambda_1$	$\gamma_{30} \lambda_3$
Accepted in 2nd review	$\gamma_{50} \lambda_5$	$\gamma_{60} \lambda_6$
Where,		
γ_{50} and γ_{60} = 100% by assumption		

Let $X_A(t)$ be the number of A-tier journal articles accepted in a year, $X_B(t)$ be the number of B-tier journal articles accepted in year *t*. Variables X_A and X_B are Poisson distributed due to the fact that they are sums of independent Poisson distributions. Therefore the sum of X_A and X_B is also Poisson distributed with mean rates shown below.

$$\text{Rate} = \gamma_{10}\,\lambda_1 + \gamma_{30}\,\lambda_3 + \lambda_5 + \lambda_6.$$

Let *n* be the number of articles needed in a *m*-year period to attain or maintain an Academic Qualification (AQ), be it tenure, promotion, or any other standard. Therefore probability of publishing the *n* articles can be calculated from the following equation.

$$P(AQ) = P\left(\sum^{m}_{t=1} X_A(t) + \sum^{m}_{t=1} X_B(t) \geq n \right)$$

where $\sum X_A(t) + \sum X_B(t)$ is Poisson distributed with mean rate of $m(\gamma_{10}\,\lambda_1 + \gamma_{30}\,\lambda_3 + \lambda_5 + \lambda_6)$.

Researchers can decide on a level of research effort measured by submission rates of γ_1 to A-level journals and γ_3 to B-level journals in order to achieve a desired level of probability in securing *n* journal articles and thus meeting their AQ status requirement. For example, if a researcher were to submit one ($\gamma_1 = 1$) A-tier paper and three ($\gamma_3 = 3$) B-tier papers a year and the statistics on journal acceptance, revision, and rejection rates were assumed to be as shown in table 6.

Table 6: Revision and Rejection Rates given 1 A-tier and 2 B-tier Articles submitted per year

	A-tier	B-tier
Acceptance	$\gamma_{10} = 0.05$	$\gamma_{30} = 0.1$
Rejection	$\gamma_{13} = 0.65$	$\gamma'_{30} = 0.5$
Revision rate	$\gamma_{12} = 0.3$	$\gamma_{34} = 0.4$
Resubmit as new	$\gamma_{21} = 0.2$	$\gamma_{43} = 0.1$
Resubmit for 2nd review	$\gamma_{25} = 0.8$	$\gamma_{46} = 0.9$

Substituting these input parameters into formulas for calculating the overall arrival rates at each node, shown in table 4, we can obtain the node arrival rate estimates shown in table 7.

Table 7: Arrival Rates	
Node	Arrival rate
λ_1	1.06
λ_3	3.85
λ_5	0.26
λ_6	1.38

Therefore, the annual research output would be Poisson distributed with a mean rate of 2.08. Derived as follows,

$$\text{Mean rate} = (\gamma_{10}\,\lambda_1 + \gamma_{30}\,\lambda_3 + \lambda_5 + \lambda_6)$$
$$2.08 = .05*1.06 + .1*3.85 + .26 + 1.38$$

If five published papers in five years are required to maintain academically qualified status, and the faculty member wishes to be 98% confident of achieving academically qualified status, our model shows that one A-tier and three B-tier submissions per year would be required.

Using the revision and rejection rates given in Table 6 as a baseline scenario, we calculate in Table 8 the overall mean research output rate and the probability of AQ when we vary the annual submission rates for the A-tier and B-tier journals.

The shaded cells in the probability table represent research efforts that produce better than 75% level of certainty in achieving AQ. Results in Table 8 suggest two strategies on allocating research efforts. First, if one wants to submit journals to only one tier (looking at the first row or the first column), one is better off in the long term to target the A-tier journals. The same number of A-tier papers achieves a higher average output rate than the B-tier papers, albeit over a longer period of time, since they have two shots at acceptance. Some academic researchers (e.g., Clark et. al., 2000; Ellison, 2002a, 2002b) have blamed this shotgun approach for the perceived backlog in the current review pipeline at the top tier journals.

The model shows that following the strategy of first submitting to an A-tier journal, with the rejected paper subsequently submitted to a B-tier journal, may result in a paper taking twice as long to work through the pipeline. However, this strategy may increase the overall acceptance rate for the author. This particular model looks at a steady state, and therefore it doesn't matter whether a paper takes one year or two years to go through the process because once it is in steady state, papers enter the pipeline and exit the pipeline at the same rate. Therefore, the adage of writing good papers and aiming high seems to be supported by our model.

Table 8 : Sensitivity Analysis of Research Effort—Baseline

Annual Mean Rate of Research Output

	A-Tier Journal Submission Rate					
B-Tier Journal Submission Rate	0	1	2	3	4	5
0	0.00	0.64	1.28	1.92	2.56	3.20
1	0.48	1.12	1.76	2.40	3.04	3.68
2	0.96	1.60	2.24	2.88	3.52	4.16
3	1.44	2.08	2.72	3.36	4.00	4.64
4	1.92	2.56	3.20	3.84	4.48	5.12
5	2.40	3.04	3.68	4.32	4.96	5.60

Probability of AQ

	A-Tier Journal Submission Rate					
B-Tier Journal Submission Rate	0	1	2	3	4	5
0	0.00	0.22	0.76	0.96	1.00	1.00
1	0.10	0.66	0.94	0.99	1.00	1.00
2	0.52	0.90	0.99	1.00	1.00	1.00
3	0.84	0.98	1.00	1.00	1.00	1.00
4	0.96	1.00	1.00	1.00	1.00	1.00
5	0.99	1.00	1.00	1.00	1.00	1.00

To achieve a 75% chance of AQ with this focused strategy, one needs to submit 2 A-tier papers or 3 B-tier papers a year, a research effort two or three times higher than the required AQ output rate (one paper a year). Second, one can mix up the research effort and submit to both A-tier and B-tier journals. Again, A-tier articles are favored. For a fixed number of total mean submissions, for example four papers in a year, more A-tier articles increase the output rate and the probability of AQ.

We constructed two different scenarios to compare with the baseline case reported in Table 8. Table 9 presents the same results when the AQ requirement is doubled to ten papers in five years and Table 10 summarizes the case in which the acceptance rates for the A-tier and B-tier papers are doubled from the baseline level.

Table 9: Sensitivity Analysis of Research Effort—Higher AQ Standards						
Annual Mean Rate of Research Output						
	A-Tier Journal Submission Rate					
B-Tier Journal Submission Rate	0	1	2	3	4	5
0	0.00	0.64	1.28	1.92	2.56	3.20
1	0.48	1.12	1.76	2.40	3.04	3.68
2	0.96	1.60	2.24	2.88	3.52	4.16
3	1.44	2.08	2.72	3.36	4.00	4.64
4	1.92	2.56	3.20	3.84	4.48	5.12
5	2.40	3.04	3.68	4.32	4.96	5.60
Probability of AQ						
	A-Tier Journal Submission Rate					
B-Tier Journal Submission Rate	0	1	2	3	4	5
0	0.00	0.00	0.11	0.49	0.82	0.96
1	0.00	0.06	0.39	0.76	0.94	0.99
2	0.02	0.28	0.68	0.91	0.98	1.00
3	0.19	0.59	0.87	0.97	0.99	1.00
4	0.49	0.82	0.96	0.99	1.00	1.00
5	0.76	0.94	0.99	1.00	1.00	1.00

Changing the AQ standard has a significant impact on the research effort required to achieve AQ status with a desired level of certainty. Table 9 shows that if a 75% level of certainty of maintaining AQ is desired, then one needs to submit at least five papers in total if A-tier submissions are less than 3. If one submits three A-tier papers or more, one needs submit one less in total. Table 10 suggests that targeting journals with higher acceptance rates has much less effect on research effort than change AQ standards.

The stationary analysis seems to indicate that changing AQ standards can have a drastic impact on faculty's research effort in the long run. As an alternative, submitting to journals with higher acceptance rate will not likely offset this additional workload. The inherent uncertainty in the publishing process requires research efforts measured in number of annual submissions several times that of required by AQ standards in order to maintain a desired level of certainty for AQ. Academic administrators need to be aware of the resource implications when making changes to the existing AQ standards.

Table 10: Sensitivity Analysis of Research Effort—Higher Acceptance Rate						
Annual Mean Rate of Research Output						
	A-Tier Journal Submission Rate					
B-Tier Journal Submission Rate	0	1	2	3	4	5
0	0.00	0.73	1.47	2.20	2.94	3.67
1	0.58	1.32	2.05	2.79	3.52	4.25
2	1.17	1.90	2.63	3.37	4.10	4.84
3	1.75	2.48	3.22	3.95	4.69	5.42
4	2.33	3.07	3.80	4.54	5.27	6.00
5	2.92	3.65	4.38	5.12	5.85	6.59
Probability of AQ						
	A-Tier Journal Submission Rate					
B-Tier Journal Submission Rate	0	1	2	3	4	5
0	0.00	0.31	0.86	0.99	1.00	1.00
1	0.17	0.79	0.98	1.00	1.00	1.00
2	0.69	0.96	1.00	1.00	1.00	1.00
3	0.94	0.99	1.00	1.00	1.00	1.00
4	0.99	1.00	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	1.00	1.00	1.00

SIMULATING THE ACADEMIC RESEARCH PIPELINE

The model produced in the prior section is a steady state model, but the steady state may take years to achieve. Research (e.g., Clark et. al., 2000; Ellison, 2002b) shows that the review time for article submissions has been increasing over the past twenty years and is often measured in terms of years rather than months. The longer the turnaround time between submission and acceptance, the longer the time needed to reach steady state, all else held constant. However, in addition to the increasing time delay, the acceptance rate for the top journals in the major fields of business academics are decreasing (Swanson, 2004), making it even harder to meet the publications standards for tenure, promotion and merit pay increases imposed by colleges of business. Interestingly, as it becomes more difficult for newer doctoral faculty to publish in these academic journals, they are being evaluated by senior faculty and administrators who came up through a system with looser standards. The reality faced by newly hired faculty may differ from the perceptions of their older, more established colleagues, who may underestimate the existent limitations of today's research pipeline. The length of the review process and the rate of acceptance are therefore relevant concerns for faculty who are still in the process of reaching that steady state level of research productivity.

To assess various combinations of publication requirements and journal submission strategies a simulation model of the publication process is developed. In the simulation there are two decision variables, length of time between each new submission and the required number of publications over any given five years. Each submitted article in the simulation flows through a process. The first step is an A-tier journal review. For this review we use a Binomial distribution with a 5% acceptance probability. The journal review time is assumed to be Poisson distributed with a mean service time of 6 months. If the journal article is accepted it moves on to printing. The printing process is assumed to be Poisson distributed with a mean service time of 6 months from journal article acceptance, with a minimum time of 2 months. If the submitted article is not accepted we assume there is a 30% probability that the submission will receive a please revise and re-submit from the A-tier journal (Binomial 30%). The second review time is assumed to be Poisson distributed with a mean of 4 months. The combination yields an overall acceptance rate of 33.5% for A-tier journals.

In terms of this research these are more conservative estimates of acceptance rates and turnaround times than prior findings from Moyer and Crockett (1976) or Coe and Weinstock (1984) , but may be overly optimistic for some of today's A-level journals. The acceptance rate at the A-level journals is also affected by the number of frivolous submissions by authors hoping to slip an article through. If authors are submitting a large number of lower-quality articles so as to clog up the pipeline, the acceptance rates would be lower and the turnaround times would be longer. While there has been some limited research on the average acceptance rates and average turnaround times, there is relatively little on the variability of these values from one journal to the next. These parameters could also differ significantly from discipline to discipline (Swanson, 2004), so the choice of appropriate acceptance rate and turnaround time parameters is based partly on empirical evidence and partly on judgment.. Once the article is re-submitted we assume it is accepted after a second review time that is assumed to be Poisson distributed with a mean service time of 4 months. The accepted journal article then moves into the printing queue.

Articles not accepted in the A-tier journals are subsequently submitted to a B-tier journal. The B-tier simulation is identical to the A-tier process with the following changes to acceptance probabilities and service times. In the B-tier we assume there is a 10% probability of acceptance in the first review with a mean service time of 4 months. Rejected articles are assumed to have a revise and re-submit probability of 40%. This combination yields an overall acceptance rate of 46% for

B-tier journals. The overall mean acceptance rate in the simulation for journal articles after submission to both A and B-tier journals with revise and re-submissions is 64%.

The month of printing is recorded for each accepted journal article. At the end of years five through eight a determination is made if the required number of journal articles has been printed over the prior five years. The process is simulated 1000 times and the percentage of time the required number of journal articles is achieved at the end of years five through eight is the simulation output.

The required number of journal articles over a specific period of time will, of course, depend largely on the goal of the researcher. The long-term rule of thumb for AACSB purposes has been two articles in the prior five years. Some schools have increased that level to three over the past five years, and generally speaking, the achievement of tenure would require even more. With respect to merit pay, some schools are quite competitive and faculty may be required to achieve multiple "hits" each year to maintain their equilibrium. The important point is that the requirements differ from school to school, and often include both a quantity requirements and a quality requirement. Therefore, the results shown here are meant more to illustrate how the probabilities of achieving success, differ based on the publications strategy.

SIMULATION RESULTS

Tables 11 through 14 show the probabilities that a required number of journal articles, one through five, will have been published for the prior 5 years given journal submission intervals ranging from six to eighteen months. The results are shown for the time periods ending year five through eight. For tenured faculty with an ongoing publication stream the later tables when the simulation has reached a steady state are more applicable. For new faculty with nothing in the pipeline facing tenure and promotion reviews the earlier tables may be more of interest.

Table 11: Probability of achieving required number of journal articles at the end of year 5

Submission Interval	Required journal articles				
(months)	1	2	3	4	5
6	1.00	0.99	0.93	0.78	0.50
7	1.00	0.97	0.87	0.59	0.30
8	1.00	0.95	0.77	0.49	0.17
9	1.00	0.91	0.71	0.33	0.08
10	0.98	0.88	0.59	0.24	0.04
11	0.98	0.82	0.52	0.13	0.01

Table 11: Probability of achieving required number of journal articles at the end of year 5					
Submission Interval	Required journal articles				
(months)	1	2	3	4	5
12	0.98	0.81	0.42	0.09	-
13	0.97	0.76	0.34	0.06	-
14	0.96	0.74	0.28	0.01	-
15	0.94	0.65	0.23	-	-
16	0.93	0.61	0.21	-	-
17	0.91	0.56	0.13	-	-
18	0.91	0.53	0.11	-	-

Table 12: Probability of achieving required number of journal articles at the end of year 6					
Submission Interval	Required journal articles				
(months)	1	2	3	4	5
6	1.00	1.00	0.98	0.92	0.77
7	1.00	0.99	0.96	0.84	0.59
8	1.00	0.98	0.92	0.75	0.45
9	1.00	0.98	0.86	0.65	0.28
10	1.00	0.96	0.80	0.50	0.18
11	0.99	0.93	0.73	0.38	0.11
12	0.99	0.91	0.65	0.32	0.07
13	0.98	0.87	0.56	0.21	0.03
14	0.98	0.84	0.52	0.17	0.00
15	0.98	0.82	0.45	0.12	-
16	0.97	0.79	0.39	0.08	-
17	0.97	0.76	0.28	0.03	-
18	0.96	0.70	0.26	0.01	-

Table 13 : Probability of achieving required number of journal articles at the end of year 7					
Submission Interval	Required journal articles				
(months)	1	2	3	4	5
6	1.00	1.00	0.99	0.96	0.88
7	1.00	1.00	0.97	0.88	0.70
8	1.00	0.99	0.95	0.84	0.60
9	1.00	0.98	0.90	0.70	0.41
10	1.00	0.97	0.85	0.61	0.30
11	1.00	0.95	0.78	0.49	0.18
12	0.99	0.94	0.75	0.36	0.13
13	0.99	0.90	0.63	0.29	0.07
14	0.98	0.90	0.62	0.26	0.04
15	0.98	0.84	0.53	0.18	0.03
16	0.98	0.82	0.46	0.14	0.02
17	0.96	0.81	0.40	0.08	-
18	0.96	0.78	0.40	0.11	-

For a tenured faculty member attempting to have a 90% chance of publishing 3 journal articles over any given five year period the results show they would need to submit an article every 9 months or submit 6.67 articles each five year period. If the publication requirement is reduced to 2 journal articles over five-years the required interval between submissions is approximately 13 months or submitting 4.6 articles each five-year period. Increasing the requirement to 4 journal articles increases the submission rate to one article every 7 months or 8.6 articles each 5-year period. Not shown is the required submission interval to be 90% sure of having 1 journal article in any given five year period. The submission interval is 24 months.

For new faculty with no papers in the pipeline the results show a higher required submission rate if the faculty member is to have the required number of articles in print by a the end of year 5 or 6. To have four articles in print would require submitting journal articles at rates in excess of 2 per year.

Table 14: Probability of achieving required number of journal articles at the end of year 8					
Submission Interval	Required journal articles				
(months)	1	2	3	4	5
6	1.00	1.00	0.99	0.96	0.88
7	1.00	1.00	0.97	0.89	0.71
8	1.00	0.98	0.95	0.82	0.60
9	1.00	0.99	0.90	0.73	0.42
10	1.00	0.97	0.86	0.63	0.31
11	1.00	0.95	0.77	0.47	0.19
12	0.99	0.93	0.74	0.42	0.13
13	0.98	0.90	0.68	0.30	0.07
14	0.98	0.89	0.64	0.26	0.07
15	0.98	0.84	0.55	0.19	0.02
16	0.97	0.84	0.52	0.15	-
17	0.96	0.80	0.44	0.12	-
18	0.96	0.75	0.38	0.06	-

The simulation does not capture the possibility of varying an individual submission strategy based on prior successes or failures. The results are obviously sensitive to the assumed acceptance rates and review times. We feel the results are applicable when discussing a group of faculty and what will be required on average. More importantly the results clearly show the relationship between journal submissions and required articles is not one to one. The difference between required submissions and required journal articles is attributable to variation in review and printing times and acceptance rates below 100%. It should be noted that even if an author has a 100% acceptance rate, the variation in review and printing times will increase the required submission rate above the required publication rate if the author wishes to be confident that in any given 5 year period selected they will have the required number of publications.

CONCLUSIONS

The publishing pipeline is an important area of research for a number of reasons. First and foremost, faculty research expectations are an important aspect of the university teaching profession.

This pipeline process has major implications for a faculty member's ability to attain tenure, promotion or pay raises. The increasing length of time in the review process and the increased stringency of the reviews are raising the standards independent of any increases imposed by university administrators. Simply put, achieving five publications in five years is harder to achieve today than it was ten years ago, and will be yet harder to achieve five years from now.

Our queueing network model stripped away some of the complexities associated with the academic publishing process. Our assumption of a two-tier system is not restrictive, however, because additional tiers can be appended to the B-tier and decomposed in a way similar to how we decomposed A-tier and B-tier. In our model, we only allow for one-round of revision. Multiple revisions can be easily incorporated by lumping them. Our results still apply if durations of multiple revisions are Poisson.

One limitation of our model is the assumption of self-serving queue. As a direction of future research, our model can be extended to consider the finite service capacity of a journal. This will allow us to analyze the impact of review time and the size of editorial staff on the stationary distribution of publications. Another limitation is our assumptions about acceptance rates and turnaround times. Published research shows that the acceptance rates and the turnaround times are changing over time and it is becoming more arduous to achieve success, especially in the top-level journals. Although acceptance rates are reported in Cabell's and are included in some of the journals, these acceptance rates are not necessarily comparable because they are not standardized. The information in Cabell's on both acceptance rates and turnaround times are self-reported by the various journals, and there is no real audit mechanism in place to check these numbers. An interesting line of research might be a study that verifies these values on a standardized basis, but we leave that to other researchers. Our simplifying assumptions about the acceptance rates and the length of the review cycle are agreeably subject to debate.

The surprising aspect of the publishing pipeline delay problem is not that it exists, but that so little research has gone into it. That is not to say that there is not published research in this field, but rather that there is relatively less than one would expect, given the importance of a research record on a faculty members success. This paper takes a step in that direction.

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