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AGILITY IN LARGE VOLUME, SMALL LOT MANUFACTURING

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ABSTRACT

Changing market demands for improved services and product variations require flexibility in the production system by its personnel, production methods, changeover tooling and scheduling. Thus, many high volume production systems must assume the dual identity of both being lean and agile. One company in particular in the furniture industry has been very successful in meeting the challenges of both approaches through embracing and implementing the concepts of on-line, real-time communication, continuous improvement, and constant vigilance of customer needs. The company daily encounters a multitude of interactions with dozens of retailers, suppliers of the hundreds of fabrics and other components, and the numerous activities involved in production changeovers to meet delivery promises. In spite of severe space, scheduling and material handling constraints, the company closely monitors its supply chain, production and customer expectations within a fairly complex environment. The most significant factor in maintaining and increasing agility has been the reduction in production lot sizes. This has simultaneously led to the more effective use of labor, material, equipment and space. A simulation developed represents an existing production system. It generates expected outputs under conditions of operation variability, queue lengths (buffers) and batch changeover (set-up) times over a range of 3 uniform and feasible batch sizes. Thus, the real-time status and location of components and subassemblies consigned to a specific production batch is essential for maintaining and improving quality and utilization of personnel, space, material and other resources.

INTRODUCTION

We have learned much about mass production and lean production systems from automobile manufacturing. Indeed the concepts of JIT, waste reduction and space utilization have had a profound effect on many industries such as electronics, clothing and furniture. As Christian and Zimmers (1999) indicated, managers of lean facilities are primarily concerned with eliminating waste; minimizing inventories to keep tight control over quality and production resources. Agile managers appear more concerned with meeting customer demands through product variations and delivery performance. However, agility does not have to compromise lean operations. Nor does being lean compromise a company's ability to respond to market demands for variety and expanded customer services.

Simulation is the most robust and realistic way of evaluating the performance of a system of multiple queues. Its primary use is to test changes in a system before they are implemented. Combined serial and parallel queue disciplines are difficult if not impossible to be treated by analytical methods. According to Hall (1999), testing of different probability distributions and various parameter changes found in many production systems cannot be accommodated except by simulation.

Discrete object-oriented computer simulation has been used to identify and help solve problems in an ever increasing number of applications. The on-going research on hundreds of assembly lines at General Motors by Alden et al. (2006) has led to many simulation models and observations that have saved millions of dollars. Simulation saves considerable time and money by viewing the dynamics of a system and providing insight into and a better understanding of those dynamics. Kline et al. (1972) cites the use of simulation as an operations research tool in analyzing a hardwood processing system that produced cabinets and similar products. The simulation helped illustrate the feasibility of alternative solutions by observing the animated flow of products through the processes. Simulation can also offer genuine excitement by pre-testing ideas and introducing realistic ''what-if'' changes in the parameters. As Keller et al. (1991) and Spedding and Sun (1999) concluded, simulation can also be useful in enhancing a cost accounting system by evaluating manpower, space and equipment requirements.

Enormous amounts of money continue to be spent by companies and industries to improve small-lot production. McRainey (1977) observed, as have others, that manufacturers are constantly being challenged by the demands of the distribution systems for quick response and just-in-time (JIT) requirements of customers. Manufacturers and certainly their marketing personnel, seek small-lot production with processes changed over quickly from one product to another to better serve customers. However, as Katayama and Bennett (1999) conclude per the classical economic models, i.e. EOQ/EMQ, an emphasis on agility must simultaneously focus on changeover costs when producing in smaller lots. Whitehead (2000) restates an underlying principle from the JIT concept that agile, small-lot systems can exist in concert with lean manufacturing systems. Both focus on reducing waste through lower inventory investment, space savings, better material handling, and reduced changeover and processing times. Thus small-lot sizes are fundamental to flexible JIT systems and enhance superior customer service.

The simulation study from Baykoc and Erol (1998), Inman and Bulfin (1999), and Ozcan et al. (2010) examined the performance of a multi-item, multi-line, multi-stage JIT system and demonstrated how the systems react under different circumstances. The variability of processing time and arrival demands of subsequent operations were studied. Sianesi (1998) demonstrated that the flexibility inherent in JIT production applied to ''mixed-model'' systems reduces WIP inventories in make-to-order environments.

The system described in this study is more complex in that the subassemblies are produced on separate but parallel lines and linked to a specific mixed-product batch. Also the operations must be synchronized within a relatively narrow time interval. Delays of any component batches may cause all production to slow or stop. The time for a unit or batch in the system will depend on the maximum of the various operation and waiting times and not just on their sum. This leads to more complicated queue disciplines. It is a requirement to finish each of the dependent operations at the same time. There is little value by completing an operation or a batch early only to wait for other parallel operations to be completed. In fact, it may be disruptive and wasteful of costly resources of space, personnel and equipment.

Simulation models do require empirical data, yet reasonable estimates or sample data are helpful in identifying the empirical data needed. In the system studied, estimates were used to help develop the simulation model and generate results approximating an

existing production system. Stopwatch studies or video tape gathering of real-time data may discover other variables for which the simulation model does not accommodate. On the other hand, the model verifies the fundamental logic employed in managing the system and points towards areas where constant improvement, the company credo, can enhance profitability. Large lots may appear more economical but smaller lots or batch sizes leads to less waste of space, inventory investment and better customer service. Statistical analysis of empirical data may add refinement to the results but being able to manipulate the model and ask ''what-ifs'' appears to offer more of a contribution to understanding a complex system.

To represent an actual, interactively constrained production system by a discrete event, animated model is a challenge. The ability of a simulation to visually represent the flow, delays and projected throughput helps understand some of the requirements for maintaining, controlling, improving and managing a fairly complex JIT system. The simulation model designed makes a number of realistic assumptions in order for production to respond to the need for small-batch production. The simulation objective:

- To discover the effect on throughputs for selected standard batch quantities as a function of operation time variability, batch changeover times and WIP buffers.

The complexities, operations and challenges of furniture production provide opportunities to apply and extend the concepts inherent in MRP, JIT, TQC and other manufacturing support systems. Many find a special fascination about furniture extending from the design stage to manufacturing operations to marketing and distribution stages. Furniture manufacturing is an industry where the lead time and retail inventory are critical to sales. The Grubb Furniture Mfg. case study Keller et al. (1991) reminds us that if customers want a particular item that is not in stock at the retailer, they still want it now or as soon as possible. If the lead time from the manufacturer is 8 weeks or more, they may go elsewhere. Production in small batches can contribute significantly by offering less lead time and more product variations.

COMPANY BACKGROUND

The company studied is one of the largest producers of upholstered furniture. The major products include chairs, recliners, sofas, love seats and modular seating groups sold through domestic and foreign furniture retailers. The image of a large, agile furniture manufacturing facility is one of a hybrid flow-shop. Unlike mass production, flexibility is required to accommodate the dynamic workload imbalances created by the market place. Inherent in accommodating customer requirements, the company must offer different furniture styles in a large variety of fabrics all within a short lead-time. Skilled, cross-trained employees ameliorate some of the imbalances encountered but the coordination of engineering, marketing, suppliers and production suggests a very complex environment.

Customization is an important manufacturing strategy in furniture production. Quick response to changes has become essential in the global economy and competitive environment. To illustrate, knowledge of the Asian market suggests that the rooms in apartments and homes are generally smaller than in the U.S. Therefore, furniture needed to be modified, requiring considerable engineering effort to resize components and final assembly.

To support agility and leanness, a limited variety of customization is offered. In other words, there is a manageable limit to the combinations of the 900 fabrics and 50 styles. These limited varieties can work together with specific Bills of Material (BOM) from the MRP system to recapitulate sales orders and generate production batches with the proper allocation of materials.

To increase its responsiveness yet reduce costs incurred by more changeovers, the company transformed the factory into an agile manufacture facility but included many ideas from lean production facilities. In order to produce the variety of styles and fabrics with responsiveness and flexibility, manufacturing their units in small lot sizes has proven very effective. These small lot sizes together with high volume production require quick changeovers and constant re-balancing of the work load in the operating departments. Small lot sizes, flexible equipment and tooling plus skilled workers permit quick transitions from one batch to another thereby minimizing WIP. The smaller lot sizes also have shorter production cycles, which reduce delivery times. Pricing can also be very competitive leading to a larger market share.

For the large variety of styles and fabrics customers may order, their communication system provides timely, accurate and comprehensive information to management. This is an absolute requirement to assure intelligent decisions with respect to the supply chain, production management and customer relations. The on-line, real time communication system provides comprehensive schedule control plus immediate response to inquiries from customers, suppliers, operators and managers. The Automatic Data Collection (ADC) sub-system provides updated status and location of customer orders, production lots, components and subassemblies. On-line inventory status of raw material and purchased components is also available to develop and adhere to weekly schedules and changes.

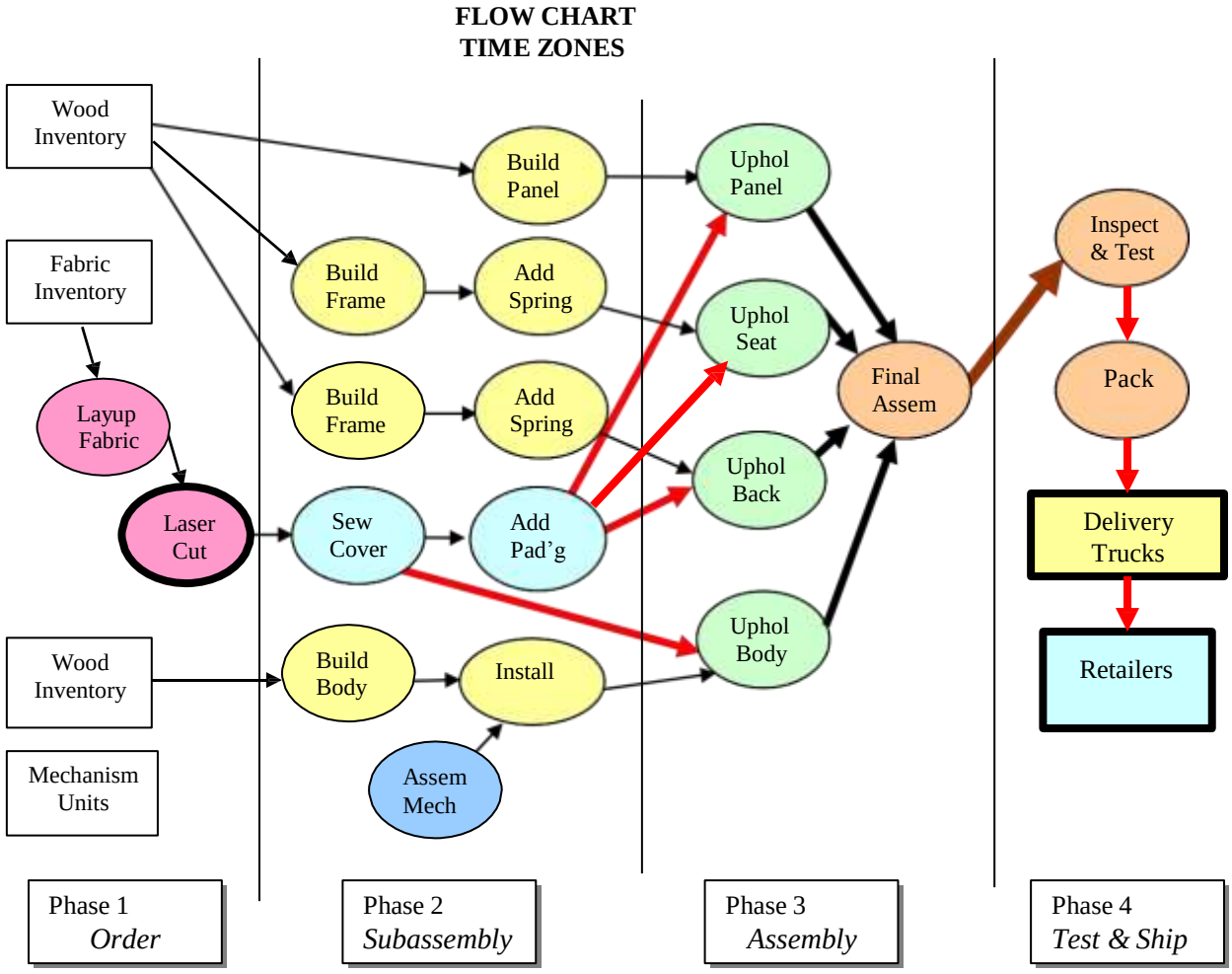
THE PRODUCTION SYSTEM

The manufacture of upholstered furniture is similar to automobile manufacturing. For example, a chair's wood frame is analogous to an automobile platform or frame. Chair frames can be imagined starting down a line and then the sub-assembled seats, backs and panels added at subsequent workstations. Similar to automobile production, the variety of styles (basic frames), fabrics, colors and special options, generate a huge number of possible combinations of end-item units. The product variations, number of fabrics, raw materials, components, plus the scheduling options and shipment commitments, plus the production methods and the needs for flexibility and synchronization makes make-to-order furniture manufacturing a very complex and demanding scheduling and production activity.

As shown in the flow chart below, production begins with the laser cutting of the fabrics. Layers of fabrics are inserted into the laser cutter and cut into stacks of individual pieces. The pieces are subsequently sewn together for the chair arms, seats, back and body. The cutting operation signals the start of assembling a corresponding batch of wood frames and other subassemblies. The communication system alerts all the departments and monitors all the released batches. The follow-on departments then perform and coordinate their operations so that their output is synchronized at each stage. A small WIP inventory of some components exists at some operations as a function of the lot size, changeover times and batch orientation of the system in contrast to the continuous flow of a moving assembly line.

The critical determinant for the success of lean/agile production is the lot size initiated by the programmed CNC laser cutter. It is the key to agile production and all the ancillary benefits of small lot production. Its changeover time between batches is a fraction of the manual methods

using physical patterns. The batch or lot size can be as small as 1, "the ideal lot size". In place of cutting 50 or more sets at a time, the lot size was reduced to 15. Further reduction in lot size would increase the costs of material handling and changeovers. The laser cutting operation thus controls the lot size for all subsequent operations throughout the plant.



The cut pieces are passed to sewing stations for sewing and the sewn components distributed to the upholstering work centers. All the sewn components of each unit arrive at their next operation in that same layer sequence when cut. Therefore, all workstations perform their tasks on the same sequential unit. The obvious objective is that specific fabric subassemblies of a chair arrive together at final assembly. The cutting operation thus commits all production operations to process the individual units in the same sequence as in the layers at cutting.

The skilled workers are able to accommodate product variety inherent in mixed model batch production. They are directly involved in methods improvement, material handling, equipment maintenance, quality improvement and the teamwork necessary to maintain high levels of production. Flexible material handling equipment is used to keep the units moving through the plant. An Automatic Data Collection system provides schedule status and location for all units whether they are at or between workstations. The "allocated space" or modified "Kanban square" technique assures continuous flow of the batches between operations. Limited

space forces immediate decisions and action to keep items moving thereby maintaining control and avoiding bottlenecks and delays.

SCHEDULING

A production schedule is constrained by several major objectives. The scheduling goes through several iterations beginning with grouping the orders by Style and Promise Date. Then the orders are then grouped by delivery route in attempting to achieve Full delivery truckloads. This preliminary schedule is adjusted with other orders to help fill a truckload and/or fill a production batch.

1. Promise Dates (Maintaining Customer Relations)
2. Daily Output Requirements (Specified Production Rate)
3. Specified Batch Size (Predetermined Fixed Quantity)
4. Dedicated Delivery Routes (Economic Full Truckloads)
5. Fabric and Component Inventory Availability

Devising an optimum schedule for more than 125 batches containing over 2000 individual units is a daunting task. With the aid of multi-sort routines, some logical criteria and a lot of personal experience, the schedule is generated for the next week. There would be some adjustments necessary as the schedule is executed. The visibility of current operations plus daily feedback can influence last minute changes or modification of the daily assignments.

A cost effective production schedule is therefore contingent on:

- Consolidating the units ordered into style groups
- Configuring orders in accordance with shipping routes
- Synchronizing all activities with the cutting operation
- Maintaining complete on-line visibility of the factory floor

THE MANUFACTURING INFORMATION SYSTEM

Small production batches can be rescheduled more easily than larger batches. This can provide better customer service and better control of quality. Changing over from one style to another is done with little disruption- given the availability of materials as displayed by the information system. Because changeover times are very short at all stages of production is rarely impeded. In the hands of skilled workers, well-designed production aids and fixtures are easily changed over from one style or product to another.

The Manufacturing Information System (MIS) provides a real time view of the factory floor, the products moving through it, the operations completed and potential bottlenecks. It is based on a comprehensive bar code and data collection system (ADC). The transactions from the floor and elsewhere build, update, link and maintain a database for tracking and monitoring, procurement, suppliers, production and shipping.The system provides real-time status with respect to the inventories of Materials, Work-In-Process, and Finished Goods.

It tracks and displays the status of batches with respect to the schedule and location of each batch or individual orders as they move through the plant. Thus if a question is asked about an order, customer, individual item, etc. the system can respond within minutes with status information. In addition to production tracking, accurate and valid transactions are essential for

operating the individual and team wage incentive program. This program rewards employees directly for both quality and quantity output.

Operators are able to quickly and easily changeover a production system or subsystem to a new product or variation of an existing product. The company has invested significantly in improved fixtures and other tooling. Without better methods and tooling, frequent changeovers leads to large WIP, lost time and lower operator productivity.

The impact of small lot sizes on the production system is illustrated by the following realistic data: Output of 400 units per 8-hour day is equivalent to about one unit per minute. Using a lot size of 15 units, approximately 25 lots would be processed per day per operation. If each successive lot represented a different style, the 25 lots would cause the operator(s) to changeover every 16 minutes at several stations. If changeover tooling is poorly designed or in poor condition, the operator could suffer lost time and money during changeovers.

Entering an electronic transaction from the factory floor using a bar-coded tag and scanner allows the operator to concentrate on quality and process improvements instead of data collection and recording. It enables operators to enter accurate data directly into the database and get immediate feedback of their performance and other relevant data. It also places responsibility for the accuracy and validity of the data with the operator.

Easy access to manufacturing data is essential for the company's operations. Data collected in real-time ensures data accuracy. Accurate and current data aids communication among the supervisors, operators and other functions such as quality, accounting, sales, engineering, maintenance, etc.

For any given order, the status and location is known instantly and accurately. Valid shipping dates can be verified. Questions regarding orders in process can be answered on a terminal in a matter of seconds. The speed of information is important and real-time information allows everyone to make better decisions. On-line data provides confidence about the accuracy and validity of the information and eliminates guesswork. It provides the visibility to identify opportunities for maintaining the synchronization on the production floor.

QUALITY CONTROL

The most essential factor in implementing an agile production system is a reduction in lot size i.e., number of layers of fabric in a lot. Cutting a lot of 50 at a time would appear to be far more economical than cutting 12 or 15. However, if there is a problem in processing the large lot, all 50 units may be affected. Stopping production on this lot would severely impact other lots, interrupt flow, increase WIP and perhaps close down all production for a time. With only 15 in the lot, it is much easier to work around the problem with far less interruption and stress.

Although they are on an incentive, the operators understand the role of teamwork and quality control and the impact it has on internal and external operations. They also understand that they are responsible for quality, not inspectors. They are given the tools to monitor the quality control process and are relieved of the clerical tasks via the ADC transactions. Accuracy and validity of the data transacted provide instantaneous updating of status and location of all items, instantaneous signals of trouble, instant visual displays of production verification data, e.g., fabric swatches, visual presentation of reports and graphics e.g. Pareto diagrams.

The speed of information is what is important because real-time information provides everyone to make better decisions. It provides confidence about the accuracy and validity of the information and eliminates guesswork. The faster that data is collected; the faster it can be acted upon, that helps identify the impact of quality problems and other problems on the production

schedule. When a problem of workmanship does arise, it is the responsibility of the immediate supervisor to resolve the issue, perform the coaching and submit the findings.

The small lot size and space restrictions allow and require close control of quality. If a problem does occur, the low inventory requires a quick resolution. Of the few problems experienced in production, "tailoring" or upholstering workmanship will always remain the primary area of concern. Damage during handling and assembly errors account for the few remaining quality problems reported through a Quality Information System.

THE SIMULATION

The purpose of the simulation was to develop a model to pretest changes in a production system being considered by management. Several years ago they reduced the batch size, which varied from 20 to 50 units per batch, to a standard quantity of 18 units per batch. Given that smaller batches offer greater flexibility to respond to style changes, schedule changes, improved quality control and customer service, does further reduction in batch size significantly affect output, production costs and other factors including impacting the skilled labor force?

The model developed attempts to emulate this complex system. Predicting throughput for a single linear flow system with 3 or more manually controlled sequential workstations, with or without product changeovers, with or without WIP buffering, with or without random delays is not as difficult as in combined serial/parallel systems. Effective use of queuing and statistical models may preclude the need for simulation in these simpler cases, although the advantages of simulation in providing insight are lost. When there is interaction between the workstations in the case of 2 or more parallel subassembly lines, the model is more complex. Synchronization at points of coordination is required because of space, quality or time constraints. A simulation, using realistic estimates and assumptions, can contribute insight into several operating areas including communication, monitoring and supervision needs.

Before conducting an extensive and detailed data gathering effort for the simulation, preliminary estimates of operation, changeover and move times are helpful to understand what data are needed and, more importantly, what data are not needed to represent the system. Some assumptions made for this initial simulation to represent the system are as follows:

> A system startup distortion is mitigated by discarding the first 100 of each 2000 cycle runs. For balancing, the same mean and variance parameters were assumed for all operations. Simulated times for the batches are generated using normal distribution parameters. Batch changeover times were applied equally to all subassembly operations. Queuing buffers between all workstations were held constant at 0, 1 or 2 batches. Partial batches are not permitted.

The simulation computes the average time per unit from processing batches of 18, 15 and 12 units per batch under different constraints of buffers, operation variability and changeover times:

Again, the purpose of the simulation model is to determine the impact on throughput when the following parameters are changed.

Batch size	3 levels; 18, 15 and 12 units per batch.
Buffers permitted (WIP)	3 levels; 2, 1 and 0 batches per workstation.
Batch time variability	2 levels of standard deviation.
Batch changeover times	4 levels.

The simulation generates the expected throughput for each of the 72 (3 x 3 x 2 x 4) combinations of the above. The simulation design would grow exponentially in complexity as more features are included such as different changeover times per workstation, etc. The objective was to test throughput sensitivity using 3 feasible batch sizes when the number of buffers, operation variability and changeover times are varied.

RESULTS

The primary variable to be tested is the batch size. Each of 3 batch sizes is tested using the simulation model to generate the average time per batch under conditions of batch time variability, maximum buffers permitted and changeover times at each of 14 operations. The results are expressed as long-run, average daily outputs in units, i.e. chairs, as calculated from the simulations of batch times and compiled in Table 1. This comprehensive matrix permits the effect on output to be examined for any combination of the selected parameter values chosen.

Table 1

	Buffers and units per batch	Batch SD	Batch SD	Simulated output per day for selected buffers							
				Batch sizes, batch SDs and changeover (setup) times							
		0.5 min.	2.0 min.	Output in units per day Changeover (min./batch/oper.)				Output in units per day Changeover			
		Avg. min. per unit*		0.0	0.5	1.0	2.0	0.0	0.5	1.0	2.0
	2 Buffers										
1	18	1.214		395	387	378	362				
2			1.253					383	375	367	352
3	15	1.242		386	376	367	349				
4			1.266					379	369	360	343
5	12	1.280		375	363	352	332				
6			1.297					370	359	348	328
	1 Buffer										
7	18	1.235		389	380	372	357				
8			1.270					378	370	362	348
9	15	1.263		380	370	361	344				
10			1.291					372	362	354	337
11	12	1.301		369	357	347	327				
12			1.328					361	350	340	321
	No Buffer										
13	18	2.263		212	210	207	202				
14			2.283					210	208	205	200
15	15	2.295		209	209	203	198				
16			2.313					208	205	202	196
17	12	2.343		205	201	198	191				
18			2.359					203	200	197	190
	1	2	3	4	5	6	7	8	9	10	11

For example, cell (1,4) ¼ average units/day with 2 buffers/station ¼ 395 units per day (best); for example, cell (18,11) ¼ average units/day with 0 buffers/station ¼ 190 units per day (worst). Average min/unit generated from 2000+ cycles (batches) of the simulation model.

The best long-run daily throughput is achieved where the changeover time is assumed to be 0, 2 buffers (batches) are allowed at each workstation and the operation variability is the least. From the average time per unit generated after 2000 runs and shown in column 4, the throughput expected for an 8 h day is 395 units for batches of 18 units. For the worst practical case scenario, the throughput averages 321 units per day from large variability of batch times, single buffered workstations having long, 2 min batch changeover times and the smaller batch size of 12 units. The difference in throughput from the lowest output (321) to the highest (395) is approximately 23% (0 buffer scenarios were dismissed as impractical).

Table 1 details are as follows: column 1 identifies the 3 batch sizes, 18, 15 and 12 units and grouped under 2, 1 or 0 buffers or WIP batches, an average time per batch is derived from a simulation run of 2000 or more batches and having a batch SD of 0.5 min at each operation in the system. Column 2 is the average time per unit from dividing the average batch time by its batch size (18, 15 or 12). Column 3 is the same but with a batch SD of 2.0 min. Column 4, the average, long-run output per day, results from dividing the average minutes per unit from column 2 into a 480 min day. Columns 5–7 yield average outputs per day after deducting the time lost from changeovers from batch to batch. Exhibit A shows impact of batch size on time per unit for 2 levels of task variability. Exhibit B reflects the impact of batch size, variability and number of buffers on output per day.

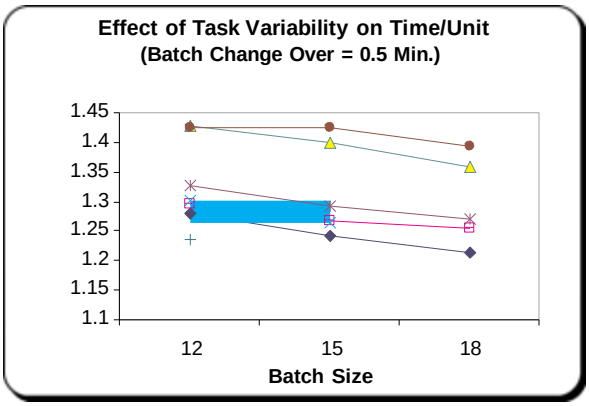


Exhibit A

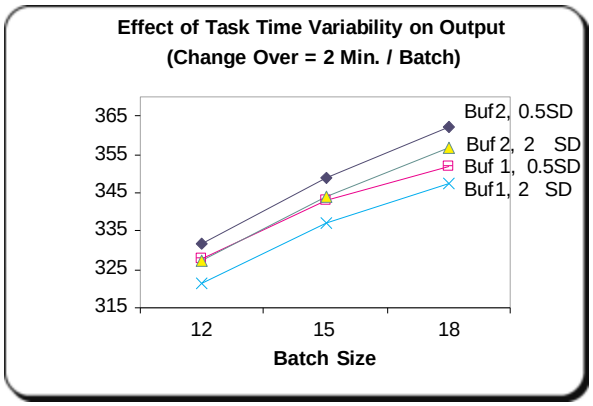


Exhibit B

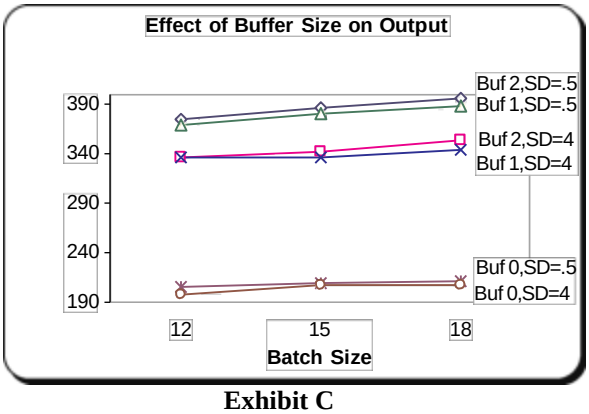


Exhibit C

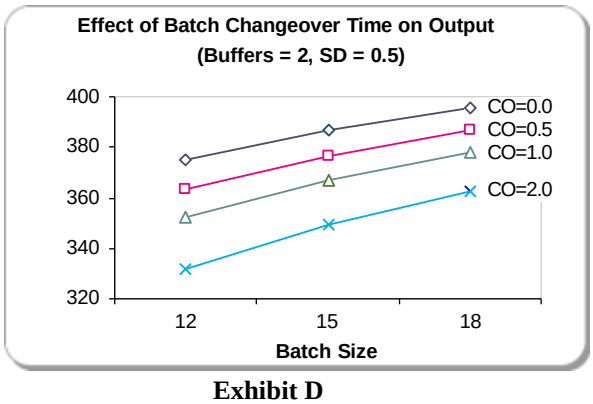


Exhibit D

As expected, the average time per unit at each operation increases as the batch size is reduced. This is due to the increase in relative variability of the smaller batches and prorating the changeover time over fewer units. Larger batches reduce the effect of variability of individual units (from statistics, the batch SD is equal to the unit SD multiplied by the square root of the batch size). If the variability of individual units can be decreased, the batch variability and interoperation delays would decrease and throughput is increased. This is difficult to accomplish in the real environment given the manual skills involved, the variety of products and the short cycle time.

Reducing the units in the batches from 18 to 12 yields a 5% reduction in average output [e.g. (395-375)/395]. As stated earlier, however, smaller batches require less floor space, provide more flexibility and shorter delivery times.

The case of 0 buffers is depicted in Exhibit C. Data from Table 1 indicate that the throughput would be reduced by approximately 54–48% if moving batches directly between workstation is attempted. Direct pass, i.e. no WIP buffer batches, between manually controlled operations, is impractical, costly and inefficient. Workstations are either starving for work or overwhelmed, causing delays. At least one batch should be available to decouple the operations and prevent delays and lost output.

In the system modeled, buffers of 2 batches yield only about 1.7% more output than single buffers. However, the ‘‘extra’’ WIP batches may avoid queuing delays. The single buffer system would need less floor space and allow greater control by increased attention given to the location and status of the batches.

If the variability, expressed as batch SDs, could be reduced from 2 to 0.5 min per batch, throughput could increase from 367 to 378 units or approximately a 3% increase for the present batch size of 18. For smaller batches, the improvement is about 2%, i.e. 360–367 units per day for batches of 15 and 12, respectively. This may not appear significant but in the long run, reduced variability can contribute significantly to profitability by reducing delays and thus the average time per unit.

Exhibit D depicts the rather obvious result that output per day increases as operation changeover time is decreased. The synchronization constraint in the simulation determines that the subassembly batch components arriving last control the cycle time and cause delays for the other subassembly lines. Given the same variability, if the changeover time can be reduced from 2 to 0 min per batch, output can increase about 10%, i.e. 347-387 units per day. For a batch size of 12, output would increase about 8%, i.e. from 327 to 357 units per day.

SUMMARY

The graphs and data demonstrate that further reduction in batch size would reduce production output. Reducing the queue size from 2 to 1 buffer (batch) would have a very small impact on output. However, synchronized output from an interactive set of manually controlled assembly line operations demands a buffered system. Less operation time variability and less changeover time between batches would increase output as would be expected. Without cost data such as cost of space, alternative material handing methods and estimated cost benefits of shorter delivery cycles, an economic model on the

order of EMQ (economic manufacturing quantity) would not contribute to understanding the real system.

The synchronization required between parallel subassembly lines can be extreme in the sense that if one subassembly line became a bottleneck at any of its operations, all the other assembly lines would be affected. If this requirement is relaxed such that synchronization is necessary only at the last of the subassembly operations, as in the simulation model presented, throughput will increase. However, synchronization at each interim stage offers better control of quality and suggests opportunities for product improvements and improved production methods. It can help avoid delays and can anticipate problems.

In the production system described, the tradeoffs are between small-lot flexibility to better serve customers plus closer control of quality and production methods versus economies-of-scale such as cutting larger batch quantities and less lost time from fewer changeovers and less material handling. Smaller batch sizes and resulting larger variability would make the system much more sensitive to disruptions. With smaller batches also, troubles may be detected earlier and fewer batches would be impacted until problems are resolved.

The production system described is comparable to other JIT (just-in-time) systems used so successfully in the automotive and other industries. There are instances in JIT systems that the best lot quantity is found by trial and error and dependent on what the system could tolerate in terms of changeover delays, processing times, buffers and material handling. A simulation model that accurately represents a real system and is quick and easy to use can avoid expensive and distracting experimentation on the production floor. Simulation helps understand the real system and allow users to explore alternatives. The simulation in this case helped understand the impact of batch size and variability on system performance. It also demonstrated the importance of buffers to protect system performance.

The batch size is the key to an integrated, flexible, synchronized parallel customer-oriented assembly system. Small batches can better accommodate changes in schedules, changes in methods, changes in materials handling and changes in product configuration. A cost-effective production schedule is contingent on consolidating customer orders into batches that also recognize the distribution system. Small batches can reduce delivery time, thereby improving sales. Retailers and customers have become less tolerant of long delivery times, delays or postponements. In furniture production, synchronizing all activities with the cutting operation, maintaining complete on-line visibility of the factory floor plus giving immediate attention to problems has become a requirement. Long-term and short-term system balancing requires constant review of the facilities, methods, technologies, and education in JIT and quality management principles and techniques. A real-time visual monitoring system may be helpful to digest the comprehensive data generated in real time.

Through diligence, experience, education and an attitude of constant improvement, the company produces more products of better quality with better on-time delivery and at lower costs. The company now has both an agile operation through its flexibility to respond to the market and a lean operation by focusing on minimizing waste of materials, space, labor, rework and WIP.

Converting to an agile yet lean operation took several years of patient and cooperative effort. Most furniture production is labor-intensive requiring skilled workers who can easily adapt to several different tasks. However, a significant amount of training was required for all personnel toward accepting changes that seem so logical in hindsight.

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THE IMPACT OF SWITCHING COST ON PRODUCT DESIGN STRATEGY

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ABSTRACT

In the setting of two competitors who enter a market sequentially and compete on product positions and prices, this paper presents analytical results for optimal product positioning and pricing strategies. This paper shows that switching cost has no effect on firms' pricing strategies or on late entrant's profit. The paper also shows that switching cost will decrease first mover's positioning advantage and profit. Under the assumption of exogenous production costs, first mover actually has less market share and less profit than late entrant although it charges a higher price.

INTRODUCTION AND LITERATURE REVIEW

A firm's ability to adapt to changes is important to its success. Manufacturing flexibility has many dimensions and product flexibility is one of the most important ones. Work on product flexibility has been very fruitful. As suggested in Röller and Tomback (1993), and Goyal and Netessine (2006), firms often use product flexibility as a weapon to respond to competition. Almost all existing literature concludes that firms with product flexibility will implement it once they enter a market, with or without the presence of competitors.

In this paper, the pioneer company defers the use of product flexibility until it observes the competitor's strategies. Thus the first entrant fully exploits the advantages of being the pioneer and then uses flexibility later as a competitive weapon. Product flexibility allows the first mover to respond to the entry of a competitor by switching from the current product to a new one. This research explores the impact of the first mover's switching cost on product design decisions and first-mover advantages. The total switching cost is not fixed but related to both the original product decision as well as the new one. This paper shows that, in a duopoly market, it may not always be optimal for the pioneer company to use product flexibility as a competitive weapon. This finding is consistent with extant empirical studies.

Extant literature addresses first-mover advantages from many different aspects. Lieberman and Montgomery (1988, 1998) define first-mover advantages as the ability to earn profit. They also identify the mechanisms that lead to first-mover (dis)advantages. These mechanisms often arise from the first-movers' endogenous nature. There is a considerable amount of theoretical and empirical work (Urban, et. al 1986, Lambkin 1988, Kalyanaran and Urban 1992, Golder and Tellis 1993, Brown and Lattin 1994, Bowman and Gatignon 1996, Lee, et. al 2000). These articles support the notion that generally the first mover enjoys a permanent market share advantage and, further, that there is a positive correlation between the order of entries of all competitors and market shares. This paper actually shows that the pioneer may retain lower market share and lower profit with the presence of switching cost.

In the next section, the extant literature is reviewed. The model is described in Section 3. Section 4 summarizes the research and suggests directions for further work.

THE MODEL

We model the following situation: two firms enter a market sequentially, choose their product spatial positions first, and then compete on prices. The first mover has the choice to use flexibility to respond to the entry of competitor.

Assumption 1 (Customer Preferences). *Customer preferences are described by ideal point model , the pioneering contribution of Hotelling (1929). As in Götz (2005), Lilien, et. al (1995), and Tabuchi and Thisse (1995), customer preferences are assumed uniformly distributed in an interval of [a,b]*.

Without loss of generality, we rescale the interval to [-1/2,1/2] in this paper. Obviously, 0 will be the best location in the market as firms make product position decisions.

Assumption 2 (Spatial Position for Firms). *Following Lilien, et. al (1995), Tabuchi and Thisse (1995), firms are allowed to position their products anywhere along the real line* $\Re$.

To understand assumptions 1 and 2, one can consider juice as the product in question. Assumption 1 says customer' ideal points of the amount of sugar in each cup of juice is uniformly distributed in some interval, for example between 5 grams and 30 grams. Assumption 2 says the interval of [5 grams, 30 grams] does not prevent firms from producing juice that has more than 30 grams or less than 5 grams sugar per cup.

Assumption 3 (Customer Utility) *We assume customers with ideal point t value a product, positioned at q with price p , by using utility function* $u(q,t) = R - p - (q-t)^2$. *R is the reservation price of customers, which is assumed to be the same for all customers and high enough so that all customers buy one of two products (Tyagi 1999 & 2000).*

Note that in Hotelling's model, a higher value of position does not imply a better product. It denotes a position in the market with respect to a set of heterogenous customers. Assumption 3 says if a customer gets a cup of juice which has different amount of sugar from his/her ideal point, the customers' utility will be lower than the maximum amount of utility (s)he could get. And this disutility will increase as the difference between ideal point and the actually amount of sugar the customer gets increases.

Assumption 4 (Marginal Production Cost). *Firms may have different marginal production costs.* c_A *for first mover A and* c_B *for the late entrant B. To ensure the feasibility of duoplistic setting and make sure that no firm is so cost disadvantaged that it does not participate in the market, we assume* $0 < c_A - c_B < 3/4$ *(Tyagi 2000).*

This assumption says firms may have different production cost due to any exogenous situation.

Assumption 5 (Sequence of Actions). *Monopoly period: The first mover, firm A, chooses its position* q_{A1} *and price* p_{A1} *myopically. Competition period: The late entrant, firm B, chooses its*

position q_B as well as price p_B. Meanwhile firm A resets its product to new position q_{A2} and new price p_{A2} incurring a switching cost.

Why would firms in reality act in a myopic way? Hauser, Simester, and Wernefelt (1994) note that "all employees (managers, product designers, service providers, production workers, etc.) allocate their effort between actions that influence current period sales and actions that influence sales in the future. Unfortunately, employees generally more focus on the short term than the firm would like." Mizik and Jacobson (2007) also provide evidence to show that managers often have incentives to enhance short-term performance to increase firm's short-time stock prices even if they need to sacrifice long-time profits. Hence in this paper it will be interesting to explore the myopic case in which firm A is myopic in monopoly period and does not anticipate the entry of competitor.

Assumption 6 (Switching Cost). *When firm A adjusts its product strategy in competition period, it incurs a switching cost $k \cdot (q_{A2} - q_{A1})^2$ for moving from old to new positions.*

Since our ideal point distribution is symmetric along 0 and a higher value of *q* does not imply a better position, quadratic function is used to capture the notion that position change is expensive and the cost depends on the extent of change. The more change, the higher switching cost. The parameter *k* captures the flexibility of firm A in changing its product design. Smaller *k* implies better changing capability. This one-time product and process design related switching cost is independent of production volume.

ANALYSIS

let Π_i^j, $i \in \{A, B\}$, $j \in \{1,2\}$ denote firm i's profit in period j; Π_i, $i \in \{A, B\}$ denote firm i's total profit for the planning horizon.

Monopoly Period:

Firm A can position its product anywhere along the attribute space and charge a price as high as it can as long as $R - (t - q_{A1})^2 - p_{A1} \geq 0$ for all customers. Hence firm A is facing the following problem:

$$\underset{q_{A1}, p_{A1}}{Max}\ p_{A1} - c_A$$

Subject to: $R - p_{A1} - (t - q_{A1})^2 \geq 0$, for all $t \in [-1/2, 1/2]$

It is easy to see that firm A reaches its maximal profit when $q_{A1}^* = 0$ and $p_{A1}^* = R - 0.25$ and the optimal profit is $\Pi_A^{1*} = R - c_A - 0.25$.

The value of *R* will affect the magnitude of firm A's optimal profit in this period and thus the total profit over the whole time horizon but will not affect the nature of decisions.

Competition Period:

Under the ideal point model, when each firms offers a product positioned at q_i with price p_i, $i = 1,2$, customers with ideal point t would prefer q_1 to q_2 (assume $q_1 < q_2$) if and only if

$R-(t-q_1)^2-p_1 \geq R-(t-q_2)^2-p_2$ which implies $t < \frac{p_2-p_1}{2(q_2-q_1)}+\frac{q_1+q_2}{2}$. Hence t is the boundary of market shares.

Assume $q_{A2} < q_B$ throughout the paper (the analysis for $q_{A2} > q_B$ will be symmetric). Then $\frac{1}{2}+\frac{p_B-p_{A2}}{2(q_B-q_{A2})}+\frac{q_B-q_{A2}}{2}$ is the market share for firm A and $\frac{1}{2}-\frac{p_B-p_{A2}}{2(q_B-q_{A2})}-\frac{q_B-q_{A2}}{2}$ is the market share for firm B.

The firms' profits, Π_A^2 and Π_B, are now given by equations

$$\Pi_A^2 = \alpha\cdot(p_{A2}-c_A)\left(\frac{1}{2}+\frac{p_B-p_{A2}}{2(q_B-q_{A2})}+\frac{q_B-q_{A2}}{2}\right)-k\cdot(q_{A2}-q_{A1})^2,$$

$$\text{and } \Pi_B = \alpha\cdot(p_B-c_B)\left(\frac{1}{2}-\frac{p_B-p_{A2}}{2(q_B-q_{A2})}-\frac{q_B-q_{A2}}{2}\right),$$

where α is the duration of the period.

To solve the problem, prices are found first for any given q_{A2} and q_B and after inserting for the optimal prices, q_{A2}^* and q_B^* are determined. Since Π_A^2 is a concave function of p_{A2} and Π_B is a concave function of p_B, the first order conditions yield

$$p_{A2}^* = \frac{1}{3}(2c_A+c_B-3q_A+q_A^2+3q_B-2q_{A2}q_B+q_B^2)$$
$$p_B^* = \frac{1}{3}(c_A+2c_B-3q_A-q_A^2+3q_B+2q_{A2}q_B-q_B^2)$$

Substitute p_{A2}^* and p_B^* into Π_{A2} and Π_B. Differentiating Π_{A2} and Π_B with respect to q_{A2} and q_B respectively, by the first order conditions,

$$q_{A2}^* = -\alpha\cdot\frac{3-\sqrt{9-12(c_A-c_B)}}{9k}$$

$$q_B^* = \frac{(3k-2\alpha)(3-\sqrt{9-12(c_A-c_B)})}{18k}$$

Hence the prices and profits of firms A and B in period 2 are

$$p_{A2}^* = \frac{1}{9}(6+5c_A+4c_B-2\sqrt{9-12(c_A-c_B)})$$

$$p_B^* = \frac{1}{9}(3+4c_A+5c_B-\sqrt{9-12(c_A-c_B)})$$

$$\begin{aligned}\Pi_{A2}^* = \frac{4}{27k\left(3-\sqrt{9-12(c_A-c_B)}\right)}\cdot\{&9\alpha^2\left(1-(c_A-c_B)\right)\\&+2(\alpha-1)k\left(9+2c_A^2+12c_B+2c_B^2-4c_A(3+c_B)\right)\\&+\sqrt{9-12(c_A-c_B)}\left((2k+1)\left(3-2(c_A-c_B)\right)+\alpha^2(c_A-c_B-3)\right)\}\end{aligned}$$

$$\Pi_B^* = \frac{(1-\alpha)(3+4(c_A-c_B)-\sqrt{9-12(c_A-c_B)})^2}{27(3-\sqrt{9-12(c_A-c_B)})}$$

Following above expressions of the optimal qualities, prices and profits of firms A and B, the results are thus stated as follow.

Proposition 1 (i) Switching cost, k, has no effect on p_{A2}^*, p_B^*, or Π_B^*.
(ii) q_{A2}^*, q_B^*, and Π_{A2}^*decrease as k increases.
Proof:(i) The expressions of p_{A2}^*, p_B^*, and Π_B^* are independent of k. Hence the switching cost has no influence on them.
(ii) The expressions of q_{A2}^*, q_B^*, and Π_{A2}^* easily show that their numerators are independent of k and their denominators are the linear functions of k. Hence q_{A2}^*, q_B^*, and $\Pi_{A2}^*$are decreasing functions of k.

Given customers' ideal points are distributed uniformly in [-1/2,1/2] , 0 is the best location in the market. As a myopic first mover, firm A will position its product at 0 in period 1 for granted. In addition, the expressions of q_{A2}^*, q_B^* show that $q_{A2}^* < 0$ and $q_B^* > 0$. As k increases, q_{A2}^* decreases and moves away from the best market location, losing first mover advantage. Meanwhile, q_B^* decreases and moves toward the best market location, off-setting the first mover's advantage.

Proposition 2 (i) $p_{A2}^* > p_B^*$ for all feasible c_A and c_B.
(ii) Firm A has less market share than firm B in period 2 for all feasible c_A and c_B.
(iii) Firm A has less profit than firm B in period 2 for all feasible c_A and c_B.

Proof:(i) $p_A^{2*} - p_B^{2*} = \frac{(3+c_A-c_B)-\sqrt{9-12(c_A-c_B)}}{9} > 0$ implies $c_A - c_B < -18$ or $c_A - c_B > 0$. Given $0 < c_A - c_B < {}^3/_4$, the result follows.

(ii) $\frac{p_B - p_{A2}}{2(q_B - q_{A2})} + \frac{q_B - q_{A2}}{2}$ is the boundary of markets held by the two firms. $\frac{p_B - p_{A2}}{2(q_B - q_{A2})} + \frac{q_B - q_{A2}}{2} < 0$ is equivalent to $-3 + 8(c_A - c_B) + \sqrt{9 - 12(c_A - c_B)} > 0$, which implies $0 < c_A - c_B < {}^3/_4$.

(iii) $\Pi_{A2}^* - \Pi_B^* = \frac{1}{27k}(2\alpha^2(\sqrt{9-12(c_A-c_B)} - (3-2(c_A-c_B)) + 3(1-\alpha)k\Big(3 - 8(c_A-c_B) - \sqrt{9-12(c_A-c_B)}\Big))$, which is negative for $0 < c_A - c_B < {}^3/_4$.

Although firm A still enjoys price advantage, it has less market share and less profit than its competitor.

CONCLUSION

Analytical results for optimal product positioning and pricing strategies are presented in the setting of two competitors who enter a market sequentially and compete on product positions and prices. This article shows that switching cost has no effect on firms' pricing strategies or late

entrant's profit. The article also shows that switching cost decreases first mover's positioning advantage and profit. Under Assumption 4, first mover actually has less market share and less profit than late entrant in the competition period although it charges higher price.

In future, it will be interested to explore the effect of nonlinear production costs on product positioning and pricing strategies. It will also be interested to explore the robustness of results when late entrant can make a decision on time-to-market.

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EFFECTIVENESS OF KNOWLEDGE TRANSFER MECHANISMS FOR IMPLEMENTING PROCESS IMPROVEMENT FRAMEWORKS IN SERVICES OFFSHORING

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ABSTRACT

Process improvement frameworks promise consistent performance, better quality, and less rework for global service providers. However, implementing such frameworks can be both difficult and costly. Organizations may choose to structure process improvement projects using multiple implementations to facilitate knowledge transfer within and across units. Further, while a variety of knowledge transfer mechanisms are available it is an open question as to whether such mechanisms actually improve implementation performance and whether these effects differ in initial and subsequent implementations. We theorize the effectiveness of tool-based and team-based mechanisms and their interactions to transfer process knowledge in initial, repeated and customized implementations of a process improvement framework. We evaluate our theoretical model using detailed archival data collected in a field study of multiple implementations of the process improvement framework in an offshore delivery center for a large IT and business services provider. Our findings indicate that knowledge repositories are more effective in repeated and customized implementations than initial implementations. Further, knowledge repositories and personnel transfer are substitutive in repeated implementations but complementary in customized implementations.

INTRODUCTION

The sourcing of business services to third party firms has grown dramatically over the last decade (Maglio et al, 2006). Much of the growth in services sourcing can be attributed to the maturation of networking and software technologies that have made it easier to codify and transfer knowledge about services (Chesbrough & Spohrer, 2006). However, the services industry is still quite labor-intensive, and firms continue to search for initiatives that will lower costs or enhance service delivery. As a result, recent work has emphasized the need for a greater understanding of service system improvements and failures, in particular the role of organizational process improvement (Spohrer et al, 2007). Process improvement frameworks such as the Information Technology Infrastructure Library (ITIL) and the Capability Maturity Model Integration (CMMI) have historically played a key role in these areas (Gopal et al, 2002; Harter et al, 2000).

However, implementing process improvement frameworks across an organization can be extremely challenging. Individuals in various roles and units may need to fundamentally rethink

their work patterns and relationships, develop new cognitive frameworks and schemas, and embed these new structures into their work practices (Slaughter & Kirsch, 2006). Organizations implementing process improvement frameworks often must decompose and recreate work routines several times before new capabilities can be developed (Pan et al, 2007). Genuine improvement emanates from a deep and broad understanding of work processes, their patterns and their implications for restructuring organizational tasks. Firms that obtain the greatest performance increases from process improvement frameworks oftentimes go beyond the minimum standards of the framework, tailoring processes to their specific needs (Naveh & Marcus, 2004). Recent work on the diffusion of ISO9000 and ISO13000 has demonstrated that firms customize these frameworks in order to obtain greater economic benefits, as well as to achieve greater conformance to perceived industrial and cultural norms (Albuquerque et al, 2007).

The implementation of process improvement frameworks can be viewed from the perspective of knowledge transfer. Knowledge transfer is a dyadic exchange in which a recipient learns and applies knowledge transmitted from a source (Argote, 1999). Various mechanisms facilitate the creation, management and transfer of knowledge (Linderman et al, 2004). Several mechanisms for organizational knowledge transfer are available, including the movement of personnel (Darr et al, 1995), hiring individuals with new knowledge (Almeida & Kogut, 1999), and knowledge management systems (Alavi & Leidner, 2001). Mechanisms such as these can help individuals and project teams to retain and transfer knowledge, and consequently to implement process improvement frameworks more efficiently. However, the efficacy of any knowledge transfer mechanism may depend upon characteristics of the task and the environment in which the task is being performed (Slaughter & Kirsch, 2006). There can be diminishing returns to new knowledge, and not all learning and knowledge transfer methods are strictly compatible (Kattila & Ahuja, 2002).

More importantly, while a few studies have examined the direct effects of knowledge transfer mechanisms in a *single* implementation of process improvements (Slaughter & Kirsch, 2006), to the best of our knowledge, no studies have examined the efficacy of different knowledge transfer mechanisms in *repeated* implementations of process improvements. A "repeated" implementation is the repetition of the implementation of the practices in a process improvement framework in a *subsequent* business unit. Specifically we ask, *is a given knowledge transfer mechanism more effective in the initial or repeated implementation of a process improvement framework*? This is an important question from both theoretical and practical perspectives. In terms of theory, comparing the effectiveness of knowledge transfer mechanisms across different implementation contexts may shed light on the ways in which these mechanisms operate, and consequently the conditions under which they will be most effective. In terms of practice, managers of large implementation projects are often constrained in time and resources. Illustrating differences in knowledge transfer mechanism effectiveness across implementations may help managers to make better decisions that will help to optimize implementation efficiency.

We attempt to fill this gap in the literature by examining process improvement with respect to two specific knowledge transfer mechanisms - tools (knowledge repositories) and teams (personnel transfer). First, knowledge repositories (KR) are a type of knowledge management system in which documents or other artifacts of an organization are stored in a searchable format (Bock et al, 2008). They are particularly effective when the knowledge to be

stored and retrieved is explicit and easily codifiable (Alavi & Leidner, 2001). To be useful repositories of an organization's knowledge, KR must contain knowledge that is directly relevant to the organization, and this knowledge must be searchable and extractable (Kulkarni et al, 2007). Much of the existing academic research on KR has focused on motivating employees to contribute their knowledge to KR (Kankanhalli et al, 2005) or increasing the subsequent accessibility of the knowledge (Poston & Speier, 2005). Consequently, empirical studies on KR outcomes have typically used KR utilization, or perceived KR quality and satisfaction, as their dependent variables (Kulkarni et al, 2007; Poston & Speier, 2005). In contrast, we examine whether the utilization of KR for process improvement within organizations leads directly to higher implementation performance, and whether differences in KR effectiveness exist between initial and repeated implementations. While the relationship between general knowledge management *capabilities* and performance has been examined (Tanriverdi, 2005), to the best of our knowledge the link between KR usage and objective performance outcomes has not been established.

Second, implementation project units are often divided into multiple teams that are responsible for specific functional areas. The movement of personnel from one team to another (we will refer to this as *personnel transfer*) can help to facilitate knowledge transfer, particularly when the knowledge is tacit or requires direct observation (Argote, 1999). The transfer of new knowledge between work teams has been demonstrated in experimental research (Kane et al, 2005) and in tasks such as software development (Patnayakuni et al, 2007), but to the best of our knowledge has not been demonstrated in the context of process improvement implementation. In addition, while most prior studies have examined the impact of personnel transfer in isolation from other knowledge transfer mechanisms, we examine the concurrent use of personnel transfer and KR and their interactions within different implementation contexts.

In this study, we examine the use of tool- and team--based knowledge transfer mechanisms in the implementation of a process improvement framework designed specifically for service providers - the eSourcing Capability Model for Service Providers, or eSCM-SP (Hyder et al, 2009). The adoption of comprehensive process improvement frameworks such as the eSCM-SP is similar to the adoption of other process frameworks such as total quality management (TQM); common characteristics are multiple project teams and a multi-stage implementation project design. Despite the fact that the general process improvement framework remains the same across all units, the nature of the implementation tasks and the knowledge available to the team members within each implementation may vary significantly. Consequently, the effectiveness of the knowledge transfer mechanisms may differ depending upon whether they are used during the initial implementation or repeated implementations.

Our study provides a novel theoretical contribution by providing insight into the effectiveness of different types of knowledge transfer mechanisms across multiple implementations of practices in a process improvement framework, and by revealing the differences in the effectiveness of the mechanisms for each implementation. Further, our study reveals that the different knowledge transfer mechanisms are more or less effective depending on the level of customization required in the repeated implementation. We are able to empirically examine these phenomena due to detailed, primary data collected in a setting that is particularly well suited to this study - the implementation of the eSCM-SP process improvement framework in two business units at a large outsourcing service provider.

RELEVANT LITERATURE AND HYPOTHESES

Our research considers how tool-based and team-based knowledge transfer mechanisms relate to implementation performance. In this study we characterize implementation performance in terms of efficiency, specifically implementation duration. Since prior research has focused on the direct effects of these knowledge transfer mechanisms, in our study we focus upon how the effects of these mechanisms *differ* within different implementation contexts - initial, repeated, and customized. An *initial* implementation is simply the first implementation of a process framework within an organization. A *repeated* implementation occurs when the same process framework is implemented a subsequent time. A *customized* implementation occurs when the framework needs to be adapted or changed in a repeated implementation, for example due to the specific business process requirements of a particular unit.

The Implementation Context: Offshore Service Delivery

Knowledge management and transfer mechanisms are particularly important to process improvement and standardization in services because services are very labor-intensive (Rai & Sambamurthy, 2006). The increase in services offshoring implies that knowledge must be retained and transmitted across a wide range of geographical and organizational boundaries within a single organization (Metters & Marucheck, 2007). Standardized processes, and the mechanisms used to implement and retain those processes, are therefore expected to be instrumental in delivering services effectively across multiple sourcing locations. Service delivery centers, particularly offshore, are prone to high turnover rates; standardized processes may enable these organizations to better retain knowledge (Levina & Su, 2008). In addition, with larger outsourcing organizations clients may reside in multiple locations and personnel may be reassigned from client to client as resource needs dictate. Having a standardized process for service delivery may allow outsourcing organizations to move resources between clients more easily (Feldman & Pentland, 2003).

A process standardization framework prescribes *the use of documents, rules, guidelines, or activities aimed at achieving an optimum degree of order in a given context* (ISO, 1996). The framework we examine - the eSourcing Capability Model for Service Providers (eSCM-SP) – was developed by the IT Services Qualification Center (ITSqc) at Carnegie Mellon University specifically to address the critical issues related to IT-enabled sourcing (ISO, 1996). There are similarities between the eSCM-SP and other well-known process improvement frameworks, but the specific processes and emphases in the eSCM-SP are different. For example, the Control Objectives for Information and Related Technology (COBIT) contains processes for version and change control and for managing technology licenses, as the eSCM-SP does. However, COBIT is largely limited to the management of internal IT organizations and is not focused on external services providers, whether domestic or offshore (Iqbal et al, 2005). As another example, the CMMI is a maturity framework that addresses some of the requirements of the eSCM-SP but not areas that are critical to service providers such as service delivery or the transfer of resources to service providers (Paulk et al, 2005).

The eSCM-SP model consists of 84 processes for services outsourcing, each consisting of

a set of activities that must be implemented before the process is considered to be complete. Within the model, these processes are referred to as Practices. Each eSCM-SP Practice may be characterized along several dimensions, including Capability Level, Sourcing Life-cycle, and Capability Area. *Capability Areas* are logical groupings that represent critical outsourcing functions (e.g., Contracting, Technology Management, or Service Design and Delivery). They are particularly important in terms of knowledge transfer, since all Practices within a capability area are presumed to contain knowledge about related business processes. Thirteen of the Practices are also designated as "Support" Practices. While there are not formal precedence relationships defined among any Practices in the model, the activities contained in the Support Practices are often referenced in other Practies.

An example Practice in the eSCM-SP is "tch03 - Control Technology". This is a Level 2 Practice in the Technology Management Capability Area, and an Ongoing Practice in the Sourcing Life-cycle. The intent of this Practice is to "Establish and implement procedures to track and control changes to the technology infrastructure". The Practice contains four primary activities which are further divided into sub-activities: (1) identifying the types of technology infrastructure changes that need to be tracked and controlled; (2) selecting and documenting methods for tracking and controlling changes; (3) creating a technology inventory; and (4) maintaining documentation on technology changes (Hyder et al, 2009). This example illustrates a process which technology-enabled service providers need in order to be able to provide efficient and consistent service. Service providers can achieve certification in the model through evaluations conducted by an external team that reviews evidence of implementation of the Practices. Once a certification is given, it is valid for up to two years.

Types of Implementation Contexts and Knowledge Transfer Mechanisms

Firms introducing process improvement frameworks across multiple organizational units have many options in designing implementation projects. Smaller or highly centralized organizations may choose a "big bang" approach whereby the framework is introduced across the firm at a single point in time. With this approach differences among organizational units are minimized, and the firm does not have to operate using different sets of processes simultaneously (Markus et al, 2000). Another common approach taken by many large organizations is to implement the process improvement framework within a single business unit, then to extend it to other business units when the initial implementation is complete. From a knowledge transfer perspective, an advantage of this approach is that it introduces discrete milestones where knowledge may be evaluated and passed from one phase to the next (Laudon & Laudon, 2006). However, the knowledge that may be passed from one stage to the next is not the same at each stage, and the processes for utilizing that knowledge in each implementation context may differ.

Prior to the initial implementation of processes, the organization has one basis for knowledge: *ex ante* information about the processes themselves, that is, the process improvement framework. Personnel may obtain this information by reading documentation about the processes in the framework or gathering knowledge from other organizations that have implemented it. However, the organization has little knowledge about how to implement the processes in the framework within its particular operational environment. In order to learn how the framework

fits with the organization's process, the organization must spend time actually implementing it. By conducting the implementation, the organization learns about how the framework fits with organizational processes, as well as how to implement the framework more efficiently and effectively. This knowledge must be obtained by doing the actual implementation, because prior to the initial implementation causal ambiguity about how to best implement practices is high (Pisano, 1996).

After the initial implementation has occurred, the organization has two bases for knowledge: knowledge about the processes themselves and knowledge about how the processes were implemented in the initial unit. Implementations after the initial one may choose to make use of both bases of knowledge. To the extent that a subsequent unit is similar to the prior (i.e. initial) unit, the implementation knowledge that was accrued in the prior unit may be applied to the subsequent unit. The organization learns to implement processes in the initial implementation and then applies that knowledge to the subsequent ones (Pisano, 1996). However, if the implementation in the subsequent unit is not similar to the prior unit, the ability to apply this prior knowledge will be limited. This incongruence may occur if the two implementations possess different design characteristics or if the individuals in the implementation teams possess different skill sets or perform different tasks (Slaughter & Kirsch, 2006). Differences may also evolve as time elapses between knowledge acquisition and knowledge application, particularly when specializations or customizations are introduced between knowledge storage and knowledge retrieval (Carlisle & Rebentisch, 2003). In these cases, the implementation must be customized and additional learning must take place.

Figure 1 illustrates knowledge acquisition and transfer in the context of a process improvement project with three separate implementation stages. In Figure 1, we see that knowledge that is acquired through the implementation process in the initial implementation stage may be passed to a subsequent implementation stage. However, if new knowledge is required because of the need to customize processes, a new cycle of knowledge acquisition must occur. While implementation project teams are usually temporary, project management offices (PMOs) within an organization are often in a position to foster knowledge across projects or project stages (Julian, 2008).

Figure 1
KNOWLEDGE AND TASKS IN DIFFERENT IMPLEMENTATION CONTEXTS

	INITIAL	REPEATED	CUSTOMIZED
What is known at the beginning of the stage?	The process framework	The process framework	The process framework
		How the process was implemented previously	How the process was implemented previously
What task needs to be done?	Implement the process framework in the production environment	Validate that the process framework still fits in the production environment	Adapt or customize the process framework to meet the needs of the new environment

Multiple methods for knowledge transfer exist within the context of a single organization. Knowledge may be transferred through different forms of person-to-person communication such as regular meetings, informal conversations, or e-mail (Darr et al, 1995). It may also be transferred through the movement or sharing of individuals among teams or organizational units (Argote, 1999). People-based knowledge transfer mechanisms can be particularly effective when the knowledge to be transferred is tacit in nature (Maglio et al, 2006). However, not all forms of knowledge transfer require personal interaction. Knowledge may be easily stored and transferred in the form of knowledge management systems or other knowledge repositories (Alavi & Leidner, 2001), or in organizational routines or structure (Cyert & March, 1992).

Prior research has categorized this gamut of knowledge transfer mechanisms in various ways. Some research has focused on the physical nature of the artifacts used-for example, whether the mechanisms are person-based, technology-based, or structure-based (Argote, 1999). Other studies have focused on how the mechanisms are used – whether knowledge becomes codified or personalized, or whether the mechanism is used at an individual or a collective level (Boh, 2007). Taxonomies such as these are useful when considering how particular knowledge transfer mechanisms operate in specific contexts. In this study, we examine tool-based and people-based knowledge transfer mechanisms. Argote and Ingram (Argote & Ingram, 2000) characterize *members* as the human components of organizations and *tools*, including both hardware and software, as the technological component. With their framework, knowledge may be transferred by moving (or copying) these repositories, or by moving "networks" consisting of multiple repositories. In our study, we are interested in how the use of knowledge transfer mechanisms related to members and tools influences implementation duration, and whether the effect of these mechanisms differs among the initial, repeated and customized implementation contexts within a single organization. More specifically, we propose that while the transfer of team members is most effective in a customized implementation context, the use of knowledge

repositories is most effective in a repeated implementation context.

Knowledge Repositories

The ability to reuse knowledge appropriately has long been recognized as an important source of competitive advantage for organizations (Zander & Kogut, 2005). In order to effectively reuse knowledge, it is necessary to identify, store and apply the knowledge residing in the organization's employees, or the knowledge that the firm obtains from external sources, such that the firm is able to exploit existing capabilities or develop new capabilities (Grant, 1996). Knowledge repositories (KR) are important tools enabling the reuse of knowledge. KR are a particularly effective tool when the knowledge to be stored is simple and easily codifiable (Zander & Kogut, 2005). Generally, the utilization of KR is a multi-step process. First, knowledge must be codified into an electronic format. Next, the codified knowledge must be entered into the system. Upon entry the knowledge must be appropriately classified, or "tagged", so that it is searchable by other individuals. Finally, after the knowledge has been tagged it can be retrieved and reused multiple times by others who have access to the system. This reusability is a primary benefit of electronic KR - knowledge that is stored once can be used repeatedly, even by individuals in different locations (Alavi & Leidner, 2001). Although the entry of knowledge into the KR can create considerable costs in terms of time and effort, the available knowledge is expected to benefit personnel who can utilize this knowledge.

Within a process framework implementation, KR can be populated and reused during any implementation phase. When KR are populated during the initial implementation, team members within the initial implementation should be able to use the knowledge in the KR to facilitate further implementation tasks. For example, knowledge about the organization's existing policies or competitive environment in one area may help the implementation team to develop new processes for another area. This knowledge may be accessed repeatedly by the individuals that have entered the knowledge, or it may be accessed by other individuals that are responsible for related processes. However, KR are expected to provide the greatest value in repeated implementations. Implementation knowledge that has been acquired in the initial implementation is already available before the repeated implementation begins. In other words, personnel involved in a repeated implementation can examine how processes were implemented in the initial implementation, and repeat those implementation activities. Knowledge repositories are an important tool for storing codifiable implementation knowledge of this sort (Zander & Kogut, 2005).

There is a caveat. Knowledge that is stored in KR will be helpful in a repeated implementation only to the extent that the processes are similar to the processes in the initial implementation and do not require customization. An organization's knowledge is dynamic, growing and changing with time and experience. As time elapses between the storage of knowledge and its retrieval, the knowledge becomes less applicable and more difficult to integrate (Carlisle & Rebentisch, 2003). When implementing certain processes, changes must be made between the initial implementation and subsequent implementations. These processes must

be customized, for example due to organizational, legal, or cultural requirements. Knowledge also becomes more difficult to integrate as specializations or customizations are introduced between storage and retrieval (Carlisle & Rebentisch, 2003). The reuse of knowledge stored in a knowledge repository will be particularly impeded by the customization of processes, since knowledge that has been codified is more difficult to adapt (Zander & Kogut, 2005). The customization of processes to fit a particular context requires prior knowledge to be adapted. Adaptation is inherently a developmental, creative activity; an additional cycle of knowledge acquisition must take place in order to adapt processes to the new environment. Mechanisms that promote knowledge reuse such as KR may interfere with these activities (Oshri et al, 2005). However, because some repetition is expected to occur during the implementation of customized processes, KR are expected to facilitate knowledge reuse to a greater extent than in the initial implementation when there is no repetition. Thus:

H1a: *The use of KR is associated with higher performance in a repeated process implementation than in an initial process implementation.*

H1b: *The use of KR is associated with higher performance in a repeated process implementation than in a customized process implementation.*

H1c: *The use of KR is associated with higher performance in a customized process implementation than in an initial process implementation.*

Personnel Transfer

Knowledge may also be transferred by moving individuals from one organization, organizational unit or project team to another. This mechanism may be particularly effective when the knowledge is tacit and not easily articulated, since tacit knowledge often has a personal quality that requires a common understanding to communicate effectively (Nonaka, 1994). Knowledge must be articulated before it can be codified, and with tacit knowledge this can be difficult. The literature on project management suggests that personal networks are very important for transferring this type of knowledge, and that KR may be ineffective (Newell, 2004; Nonaka, 1994). Within large organizations, the movement of personnel from one unit to another has been shown to improve performance via transfer of knowledge about new processes (Darr et al, 1995). Research with small groups has also shown that the movement of personnel from one team to another can improve performance on creative tasks like idea generation, as well as physical tasks like origami (Choi & Thompson, 2005; Kane et al, 2005). However, the effectiveness of personnel transfer within the process implementation context has not been examined to a significant extent. Within an organization-wide process framework project, the presence and use of other knowledge transfer mechanisms may influence the effectiveness of personnel transfer (Haas & Hansen, 2004; Wong, 2004). This may be particularly true in a multiple-implementation setting where the specific use of these mechanisms may differ.

In the context of process framework projects, large implementations are often divided

into teams which are given responsibility for implementing sets of processes. With this structure, individuals working on a single implementation may be transferred from one team to another, either to balance workload or to intentionally share their expertise. When this transfer occurs, the knowledge that the individual possesses becomes available to the new team. Personnel transfer of this sort is a particularly effective knowledge transfer mechanism when knowledge must be adapted to meet the needs of the organization. Knowledge that is stored within people is tacit and contextual, and may be easily adapted to situational needs. Lessons learned from the implementation of one practice may be transferred to the implementation of other practices through personnel transfer. Therefore, personnel transfer is expected to be most effective in the initial implementation. In contrast, a repeated implementation involves reuse of knowledge which has been obtained in the initial implementation. Knowledge transferred by individuals may not be as valuable in this context.

When processes are repeated but require customization, additional knowledge must be acquired. Because of this, personnel transfer is expected to provide greater benefit during the implementation of customized processes than during the implementation of processes that are simply repeated. However, the effectiveness of personnel transfer as a knowledge transfer mechanism is expected to be lower in a customized implementation than in an initial implementation. During the initial implementation all personnel are performing essentially the same activity: development and implementation of new processes. It is in this environment that knowledge acquisition is maximized. Although knowledge acquisition occurs during the customization of processes, it is not as extensive as during the initial development of processes. Because the need to customize processes arises for different reasons, personnel involved in the customized implementation share fewer mutual experiences and a smaller common base of knowledge. Thus:

H2a: *The use of personnel transfer is associated with higher performance in an initial process implementation than in a repeated process implementation.*

H2b: *The use of personnel transfer is associated with higher performance in an initial process implementation than in a customized process implementation.*

H2c: *The use of personnel transfer is associated with higher performance in a customized process implementation than in a repeated process implementation.*

Combinations of Mechanisms

Increasing levels of knowledge transfer mechanism utilization are generally associated with more effective outcomes (Slaughter & Kirsch, 2006). This is because at least some level of knowledge is presumed to be transferred with each use of the transfer mechanism. However, research has also demonstrated that not all types of knowledge transfer are strictly compatible. For example, mechanisms that promote knowledge codification are difficult to use in conjunction with mechanisms that promote knowledge development and personalization (Haas &

Hansen, 2004). In addition, processes that involve exploration, or seeking new knowledge, are often incompatible with processes involving exploitation, or mining existing knowledge; while exploration emphasizes innovation, exploitation emphasizes efficiency (He & Wong, 2004; Wong, 2004).

The initial implementation is the context in which knowledge is acquired and stored. Personnel transfer is expected to be an effective mechanism for transferring knowledge in this context, as people can flexibly acquire, adapt and transfer knowledge when they move from one team to another to meet situational needs. In the initial implementation, knowledge repositories are being created and are not expected to be as helpful and may in fact interfere with the use of personnel transfer to move knowledge. In contrast, the repeated implementation primarily leverages prior knowledge residing in the knowledge repositories, and knowledge repositories are expected to be helpful in this context, while personnel transfer is not as helpful. Each of these implementations provides a context in which a single knowledge transfer mechanism is more suited to the context, while the other mechanism is less well suited. In these cases, the mechanisms when used together will interfere with or displace one another. In other words, if an organization wants to improve implementation performance in an initial implementation it can use personnel transfer or it can substitute the use knowledge repositories, but not use both simultaneously. As a result, the effectiveness of any one mechanism will be lower when used in conjunction with the other. Thus:

H3a: *In an initial process implementation, the use of personnel transfer and the use of KR are substitutive in their effects on performance.*

H3b: *In a repeated process implementation, the use of personnel transfer and the use of KR are substitutive in their effects on performance.*

In a customized implementation, two types of knowledge processes occur. First, personnel in the customized implementation refer to prior knowledge of what has been done in the initial implementation. Additionally, personnel adapt the previously implemented processes to the new context. Because both knowledge reuse and adaptation occur, both personnel transfer and knowledge repositories can be expected to provide value in the customized implementation context. Therefore, these mechanisms may complement each other,generating further efficiencies. For example, discussion among team members about the artifacts in the KR can help to establish their validity and applicability to the implementation context (Boh, 2008). This is particularly important when causal ambiguity is high and knowledge needs to be adapted (Slaughter & Kirsch, 2006). This suggests that:

H3c: *In a customized process implementation, the use of personnel transfer and the use of KR are complementary in their effects on performance.*

RESEARCH SETTING

Our study examined the implementation of the eSCM-SP in two business units of an offshore service delivery center of a large, multinational company with several thousand employees. The site has two primary business units: Financial Services and Human Resource Services. Prior to the eSCM-SP implementation, each of these units used the same organization-

Proprietary process methodology that is used by all service delivery units within the company. Also, both units were founded at the same time so differences in organizational knowledge and experience should be minimal. The site provides services directly to its clients offshore, and also provides internal services to other delivery centers within the organization (i.e., "insourcing").

The research site (i.e., the organization in our study) used a multi-stage implementation approach, where each stage involved the implementation of the eSCM-SP in a different business unit. Financial Services was the first unit to implement the practices in the eSCM-SP, and in the remainder of the paper we refer to this as the "initial implementation". After the completion of this implementation, the Human Resource Services unit underwent a subsequent implementation effort, and we refer to this as the "repeated implementation". The Human Resource Services implementation constitutes a repeated implementation due to the repetition of the implementation of each eSCM-SP Practice in a subsequent business unit. The research site devised an implementation plan for each unit that divided implementation activities into three main areas: analysis (current process design, gap analysis, and recommendations); development (creation and/or customization of processes and the artifacts supporting those processes); and rollout (communication, training of users, and transfer of ownership from the implementation team to the organization). A more detailed illustration of the implementation of one Practice appears in Appendix A.

A few characteristics of the two implementation efforts have bearing on the subsequent discussion. First, both units implemented the same set of eSCM-SP Practices, so the content of the process improvement framework was in most cases identical between units. However, certain Practices had to be customized to meet the specific needs of the Human Resource Services unit. This customization included differences in organization structure, legal requirements, documentation and training requirements, and requirements related to specific clients or deals. In the remainder of the paper we will refer to the implementation of such Practices as the "customized implementation". Second, while the same executive management structure was in place for both implementations, no individuals from the Financial Services implementation unit participated directly in the implementation unit for Human Resource Services. Third, each implementation unit was organized into teams (eight for the initial implementation, seven for the repeated implementation) that were given responsibility for specific Practices or eSCM-SP Capability Areas.

In addition, the general implementation approach was somewhat different between the two implementations. In the initial implementation the focus was on creating new process knowledge, making it operational and ensuring a good "fit" between the eSCM-SP Practices and the services that the organization was performing. Durations for each Practice were generally longer in this implementation, and Practices were implemented more sequentially as team members became familiar with them for the first time. Practices designated as Support Practices were also usually implemented earlier than other Practices. In the repeated implementation, the team members spent more time reusing existing process knowledge than they did developing new knowledge; the goal was to "roll out" the new processes to the unit as efficiently as possible. The tasks in this implementation were organized such that more work was done in parallel - in other words, more eSCM-SP Practices were implemented concurrently, rather than sequentially as was done in the initial implementation. When Practices required customization, a combination

of process knowledge reuse and knowledge creation was required. The choice of a multi-stage implementation approach, and these implementation characteristics, suggest that the assimilation of the eSCM-SP in our research site is similar to the adoption of large-scale process improvement frameworks in many organizations (Markus et al, 2000).

We evaluate the implementation of the eSCM-SP using field data collected from these two implementations. One important source of data was the organization's archival project plan records for each implementation. The organization structured each implementation as a project and tracked the delivery of each activity in each implementation project using a project management software tool. We extracted data on human resource and task assignment as well as planned and actual implementation duration from the project plan records for each implementation. Another important source of information was the eSCM-SP model documentation. We used this documentation to construct measures of the characteristics of each Practice. We accessed data from the organization's KR to assess KR use. Field data of this sort are well-suited to performance studies because the data are objective and unaffected by potential response biases or response rates. Finally, we conducted supplemental interviews with implementation participants to get background information relating to the implementation or to obtain clarification on questions. Overall, data collection took place between April 2006 and August 2008.

RESEARCH DESIGN AND MEASURES

Dependent Variable

Performance: Implementation Duration (LOGDURATION). The dependent variable used to test hypotheses 1 through 3 (implementation performance) is measured as the actual duration of the implementation for each Practice within the eSCM-SP, log-transformed to mitigate skewness. As noted, the implementation of the eSCM-SP was conducted in two distinct efforts: the initial implementation in the Financial Services business unit, and the repeated implementation in the Human Resource Services business unit. The organization implemented all of the Level 2 and Level 3 eSCM-SP Practices in each unit, yielding a total of 148 observations of implementation durations: 74 initial and 74 repeated. Among the 74 practices in the repeated implementation, 43 needed to be customized. Because the same set of Practices was implemented in both business units, we can directly compare the effects of the knowledge transfer mechanisms at the Practice level as we examine duration for each Practice in each implementation.

The efficiency of a process framework implementation may be measured in several ways, including duration, total cost or effort. We use implementation *duration* for two reasons. First, given a relatively fixed supply of resources, duration is a close facsimile for implementation effort and cost (PMI, 2000). Second, duration indicates the *total amount of time* that the organization must have personnel and other resources participating in the project. This is particularly important during the implementation of process improvements due to the potential for disruption in the daily activities of organizational members. For example, while the implementation project is ongoing, decisions about whether to contract new clients may need to be made with two sets of processes in mind. In addition, some work may need to be done twice – for example, reporting or documentation of decisions may need to be done using two different

methods or templates. The amount of additional work is a function of the *duration* of the implementation and not strictly the *effort* in terms of person-hours that are devoted to the project. Since a higher duration is more costly to the organization, higher values for duration denote lower implementation performance, and vice versa.

As a robustness check, we calculated the effort in terms of full-time equivalents (FTE's) needed to implement each Practice.We estimated our models using this measure as the dependent variable in place of duration. The results were very similar to the results reported here and are available upon request. We have chosen to use duration instead of FTE's partly because using FTE's would require us to make assumptions about work schedule and the allocation of Practices among team members.

Independent Variables

Knowledge Repository (KR_DOCS). The research site made use of a knowledge repository system during the eSCM-SP implementation process. Our measure addresses a basic question: During the implementation of each eSCM-SP Practice, did the implementation team use the knowledge repository to implement that Practice or not? Each document in the repository is tied to a specific eSCM-SP Practice. The variable KR_DOCS is binary and operationalized for each Practice as the use of documents *related to the Practice being implemented* at the start of that Practice's implementation, whether initial, repeated or customized. "Related" means that the Practice is in the same eSCM-SP Capability Area as the Practice in question. If a document from the KR were used to implement a particular Practice or a related Practice, the measure of KR_DOCS would be set to 1 for that Practice; otherwise KR_DOCS would have the value of 0 for that Practice. As an example, within a particular implementation, documents in the KR related to the eSCM Practice "tch01-Acquire Technology" were also used during the implementation of the Practice "tch02-Technology Licenses" since these documents are in the same Capability Area and contain related process knowledge. KR_DOCS would receive a value of 1 for Practice tch02, indicating that the documents were used during the implementation of Practice tch02. Our dataset indicates both the creation date and most recent usage date of each document in the repository.

Personnel Transfer (P_TRANSFER). Many individuals participated on multiple teams within an implementation, facilitating knowledge transfer across Practices within that implementation. A binary variable was created for each Practice indicating whether members of the implementation team assigned to that Practice had been transferred from other teams within the implementation unit. Our data reveals that in all such cases only one team member was transferred, so the binary variable also indicates the number of people moved from team to team. In both units, all employees had been hired within 12 months of the start of the initial implementation; for many employees, the eSCM-SP implementation was their first assignment with the organization. Further, the number of people with 6 to 12 months of experience with the organization was similar between the initial implementation (4 people) and the repeated and customized implementations (3 people).

One concern with this measure is that it might be picking up cumulative learning effects; in other words, team members are only transferred after a certain number of Practices have been implemented, so organizational learning increases as personnel transfer becomes more frequent. As an additional test, we separately added two different Practice-level control variables to our

baseline model: elapsed project duration time and cumulative number of Practices implemented. Neither of these variables was significant, nor did they affect the direction or significance of any of the other independent variables, suggesting that our measure accurately identifies the influence of the personnel transfer mechanism.

Repeated Implementation (REPEATED). Practices that were implemented during the repeated implementation are identified using a binary variable. In effect, this variable acts as an intercept term which indicates the average difference in duration between the initial and repeated implementations.

Customized Implementation (CUSTOMIZED). Individuals at the research site identified the Practices that had to be customized in the repeated implementation. We identified five different sets of requirements that may necessitate customization: legal, organizational, client-specific, documentation, and training. Our measure of customization is continuous and indicates the degree of customization required; customization along one dimension would receive a value of one while customization along five dimensions would receive a value of five.

Control Variables

Planned Duration (PLANNED_DURATION). Prior to implementing the eSCM-SP, the implementation teams generated project plans and estimates of implementation duration at the Practice level. Teams began by reviewing eSCM-SP Practice information and then gathering knowledge about organizational processes relevant to each Practice. This knowledge included artifacts, data collection sheets, work instructions, policies, and other documents. Teams then conducted a gap analysis to determine the extent to which new process knowledge would need to be developed at the Practice level. Practices were grouped into three categories: minor changes required between the existing process and the eSCM Practice, major changes required, or completely new processes that would need to be developed from scratch. Based on the gap analysis and these groupings, each Practice was assigned a different estimated duration. Practices in certain Capability Areas with legal implications - for example, Contracting and Risk Management - were assigned additional review cycles which also lengthened their estimated durations. The teams used a consistent, internally documented procedure for developing the estimates and followed this procedure in formulating planned durations for all Practices. We include these estimates of planned duration for each Practice as an additional variable to control for any innate differences in Practices that are not captured in our other control variables.

Tacitness (TACIT). Generally, knowledge that is tacit or not well understood is more difficult to transfer than explicit knowledge (Nonaka, 1994). In part, this is because tacit knowledge cannot be easily articulated, documented and communicated. Practices that contain a higher degree of tacit knowledge are expected to be more difficult to implement, resulting in longer durations. To control for this possibility, we developed a set of questions in order to evaluate the extent to which each Practice is dependent upon tacit knowledge for its implementation. Guidelines for formulating the questions were derived from the three factors of tacit knowledge defined by Sternberg (1986): the degree of prior organizational knowledge required to implement the Practice; the degree to which the Practice requires creative or innovative thinking; and the degree to which the activity must be customized or adapted to meet engagement-level or service-level requirements. After some pilot testing, the final set of questions (see Appendix B) was completed by a panel of four experts who are knowledgeable

about the eSCM-SP. These individuals are either employees of the ITSqc or employees of ITSqc Consortium members. Interrater agreement was calculated using the R_{WG} index (James et al, 1993); the mean correlation was satisfactory at 0.88. The ratings were averaged to generate a mean tacitness score for each Practice.

Implementation Complexity (IMPLEMENTATION_COMPLEXITY). Practices in the eSCM-SP may be independent or may be linked or coupled with other practices. For example, the eSCM-SP documentation states that the Practice knw05 (Engagement Knowledge) is related to Practice prf06 (Make Improvements). Knw05 is a Practice that organizations use to help them "Analyze and use knowledge gained from client engagements," while prf06 is a Practice to "Make improvements based on reviews of organizational performance." One focus of knw05 is on using engagement knowledge for improvement on current and future engagements. Managing this improvement is the focus of prf06, and this is why the Practices are linked or coupled (Hyder et al, 2009). A Practice with links to many other Practices is expected to have a higher implementation complexity in that it would require more careful planning and sequencing of that Practice's implementation. This implies that having to consider other, coupled Practices will increase implementation times for the Practice in question. Therefore, we control for the *ex-ante* complexity of implementation for a Practice by measuring the degree to which the Practice is connected to other Practices within the eSCM-SP. This level of connectedness was calculated using UCINET (Borgatti et al, 2002), a social network analysis tool. A map of dependencies among Practices was extracted from the details of the model (Hyder et al, 2009). Based on these dependencies, UCINET was used to generate a number of measures indicating the degree of interrelatedness for each Practice (node) to all others in the model (see Appendix C). The implementation complexity measure we chose is Eigenvector Centrality, which assesses the degree of connectedness of one node to all others in the network (Hanneman, 2005). A higher measure of Eigenvector Centrality indicates that a Practice is coupled with a greater number of other Practices, which themselves are coupled with a greater number of Practices, and so on. It is important to note that our measure of implementation complexity is an *ex ante* measure based only on the structure of the eSCM-SP and the relationships among Practices in the model. The measure is intended as a control variable and is not related to features of the actual implementation of Practices at the research site.

Time on Project (EXPERIENCE). One concern might be that individuals are able to implement Practices faster because of their cumulative experience on the project, rather than learning via the knowledge transfer mechanisms we examine. We control for this by including a variable indicating the total amount of time that each implementation team member spent on the project before starting the implementation of the Practice. This variable assesses *individual* learning which may be attained through the cumulative implementation of any Practices, as opposed to our other measures that identify the effects of specific knowledge transfer mechanisms. In learning studies it is common to use units of output as a measure of experience, rather than elapsed time. As a robustness check, we substituted the number of Practices implemented by the team member for the variable indicating the amount of time spent on the project. The results were very similar to the results reported here and are available upon request.

Workload (PRACTICES_PER_RESOURCE). Another concern might be that an implementation team would be able to implement Practices more quickly because fewer Practices are allocated to it. To control for this possibility, we include a variable that indicates the average number of Practices assigned to each person on the team. For example, a team with

three people that is given responsibility for six Practices this variable would receive a value of two.

Ongoing Practices (ONGOING). A binary variable was created to designate whether a Practice was an Ongoing Practice or belonged to one of the Sourcing Life-cycles (Delivery, Completion, or Initiation). Ongoing Practices are more likely to involve persistent changes to organizational processes, while the other Practices are only used at particular times. In addition, Ongoing Practices are more likely to require customization. Thus, the implementation process for Ongoing Practices may differ from Practices in other phases of the sourcing life cycle, and we control for this possibility.

Appendix D provides definitions and examples of each variable in our model.

Statistical Model and Analysis

The data were analyzed hierarchically using Ordinary Least Squares regression. First, we estimated a model using only the control variables and the main effects of each of the knowledge transfer variables across all three implementations. Second, the interactions identifying the use of knowledge transfer mechanisms in the repeated implementation were added. Finally, we added the interactions identifying the use of knowledge transfer mechanisms in the customized implementation. (The continuous independent variable CUSTOMIZED was centered before interaction with other variables. For this reason, to evaluate hypothesis tests we use a mean value of zero for this variable. The control variable PLANNED_DURATION was also centered within each implementation). Because our dataset includes two observations for each eSCM-SP Practice, we use robust standard errors with clustering at the Practice level to allow for potential correlation in the error terms within Practice. The fully specified linear model for the implementation of Practice *i* in implementation *j* is

$$
\begin{aligned}
LOGDURATION_{ij} = \; & \beta_0 + \beta_1 P\_TRANSFER_{ij} + \beta_2 KR\_DOCS_{ij} + \\
& \beta_3 REPEATED_{ij} + \beta_4 (REPEATED_{ij} * P\_TRANSFER_{ij}) + \\
& \beta_5 (REPEATED_{ij} * KR\_DOCS_{ij}) + \\
& \beta_6 CUSTOMIZED_{ij} + \beta_7 (CUSTOMIZED_{ij} * P\_TRANSFER_{ij}) + \\
& \beta_8 (CUSTOMIZED_{ij} * KR\_DOCS_{ij}) + \\
& \beta_9 (P\_TRANSFER_{ij} * KR\_DOCS_{ij}) + \\
& \beta_{10} (REPEATED_{ij} * P\_TRANSFER_{ij} * KR\_DOCS_{ij}) + \\
& \beta_{11} (CUSTOMIZED_{ij} * P\_TRANSFER_{ij} * KR\_DOCS_{ij}) + \\
& \beta_{12} TACIT_i + \beta_{13} IMPLEMENTATION\_COMPLEXITY_i + \\
& \beta_{14} EXPERIENCE_{ij} + \beta_{15} ONGOING_i + \\
& \beta_{16} PLANNED\_DURATION_{ij} + \\
& \beta_{17} PRACTICES\_PER\_RESOURCE_{ij} + \varepsilon_{ij}
\end{aligned}
$$

Because lower implementation durations are desirable, unlike most empirical models the independent variables that have a *negative* effect on duration are considered favorable. Collinearity diagnostics reveal that the highest variance inflation factor for the data is 13.25 and

the highest condition index is 26.03, both of which are within the acceptable range of collinearity for data of this nature (Belsley et al, 1980; Kennedy, (2003) In addition, boxplots of the dependent variable did not reveal any outliers in the data.

RESULTS

Descriptive data and pairwise correlations are reported in Tables 1 and 2. Estimated coefficients and standard errors for the implementation duration regressions are reported in Table 3. When the regression data are pooled across both implementation units with no interactions distinguishing between units (Table 3, Column 1) there are two noteworthy findings. First, the variable measuring the repeated implementation is negative and significant, indicating lower average implementation times for Practices in that implementation. Second, coefficients for all control variables are in the expected direction which should strengthen the validity of these variables in our final model.

Table 1
DESCRIPTIVE STATISTICS

Variable	Mean	SD	Min	Max
1. logduration	3.983	0.859	2.303	5.768
2. p_transfer	0.446	0.499	0	1
3. kr_docs	0.493	0.502	0	1
4. repeated	0.500	0.502	0	1
5. customized	0.480	0.821	0	3
6. tacit	16.277	2.183	12	22.667
7. implementation_complexity	5.643	11.990	0	57.12
8. ongoing	0.568	0.497	0	1
9. experience	8.277	18.675	0	98
10. planned_duration	17.186	6.176	10	29
11. practices_per_resource	6.033	2.340	1	11

Table 2
CORRELATION MATRIX

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	1.000									
(2)	-0.328*	1.000								
(3)	0.055*	-0.097	1.000							
(4)	-0.773*	0.245	0.203*	1.000						
(5)	-0.503*	-0.094	0.016	0.587*	1.000					
(6)	0.022	0.094	-0.013	-0.007	0.068	1.000				
(7)	0.088	0.022	-0.255	0.000	0.078*	-0.136	1.000			
(8)	0.141	-0.644	0.043	0.000	0.362*	-0.043	0.150	1.000		
(9)	-0.221*	0.199	0.018	0.100	0.033	0.181*	-0.109	-0.137	1.000	
(10)	0.030	0.329*	-0.179	0.000	-0.217	0.193*	-0.007	-0.402*	-0.034	1.000
(11)	-0.476*	0.387*	0.186	0.629*	-0.024	0.112	-0.120	-0.271*	-0.137	0.347

To test hypotheses 1a through 1c - in which we posit the comparative effects of the knowledge repository in different implementation contexts - we first differentiate our model with respect to KR_DOCS. This differentiation yields the expression $\beta_2 + \beta_5(REPEATED_{ij}) + \beta_8(CUSTOMIZED_{ij}) + \beta_9 (P\_TRANSFER_{ij}) + \beta_{10} (REPEATED_{ij} * P\_TRANSFER_{ij}) + \beta_{11}$

*($CUSTOMIZED_{ij}$ * $P\_TRANSFER_{ij}$).* We then compute the value of that expression by substituting in the values that distinguish between the specific implementation contexts. With H1a, we test whether KR is more effective at reducing implementation duration in the repeated implementation than in the initial implementation. For simplicity, in this section and in Table 4 we refer to KR_m as the effect of knowledge repositories in a particular implementation and PT_m as the effect of personnel transfer in a particular implementation. The subscript *m* denotes the implementation. For example, $KR_{initial}$ denotes the marginal effect of the knowledge repository in the initial implementation. Thus, H1a may also be expressed as whether ($KR_{repeated}$ - $KR_{initial}$) < 0. Since this test does not involve the variable *CUSTOMIZED*, it is set to 0. *REPEATED* is set to 1 when computing the value of $KR_{repeated}$ and set to 0 when computing the value of $KR_{initial}$. Thus for H1a, $KR_{repeated}$ - $KR_{initial}$ = ((β_2 + β_5*($REPEATED_{ij}$)* + β_9($P\_TRANSFER_{ij}$) + β_{10}($REPEATED_{ij}$ * $P\_TRANSFER_{ij}$)) - (β_2 + β_9($P\_TRANSFER_{ij}$)), resulting in a test of whether β_5*($REPEATED_{ij}$)* + β_{10}($REPEATED_{ij}$ * $P\_TRANSFER_{ij}$) < 0. At the mean value for personnel transfer and using the estimated coefficients, this yields -1.405 + (0.811 * 0.446) = -1.043 which is significantly less than 0 ($p < 0.001$). Thus, H1a is supported.

With H1b, we test whether KR is more effective at reducing implementation duration in the repeated implementation than in the customized implementation, i.e. whether ($KR_{customized}$ − $KR_{repeated}$) > 0. To evaluate this test we use the differentiated expression above, setting *REPEATED* to 1 when computing the value of $KR_{repeated}$ and *CUSTOMIZED* to 1.65 (its mean when it is turned on) when computing the value of $KR_{customized}$. Thus for H1b, $KR_{customized}$ − $KR_{repeated}$ = ((β_2 + β_5 *($REPEATED_{ij}$)* + β_8*($CUSTOMIZED_{ij}$)* + β_9($P\_TRANSFER_{ij}$) + β_{10}($REPEATED_{ij}$ * $P\_TRANSFER_{ij}$) + β_{11}($CUSTOMIZED_{ij}$ * $P\_TRANSFER_{ij}$)) - (β_2 + β_5*($REPEATED_{ij}$)* + β_9($P\_TRANSFER_{ij}$) + β_{10}($REPEATED_{ij}$ * $P\_TRANSFER_{ij}$)), resulting in a test of whether β_8*($CUSTOMIZED_{ij}$)* + β_{11}($CUSTOMIZED_{ij}$ * $P\_TRANSFER_{ij}$) > 0. At the mean value for personnel transfer and using the estimated coefficients, this yields (0.717 * 1.65) + (-0.820 * 0.446 * 1.65) = 0.580 which is significantly greater than 0 ($p < 0.02$). Thus, H1b is supported.

Table 3
TIME TO IMPLEMENT RESULTS

	(1)	(2)	(3)
	logged duration	logged duration	logged duration
p_transfer	-0.110	-0.203	-0.314
	(0.112)	(0.120)$^{+}$	(0.144)*
kr_docs	0.431	0.704	0.858
	(0.086)**	(0.136)**	(0.143)**
repeated	-1.151	-0.542	-0.446
	(0.172)**	(0.222)*	(0.240)$^{+}$
repeated_x_p_transfer		-0.317	-0.378
		(0.314)	(0.300)
repeated_x_kr_docs		-0.693	-1.405
		(0.199)**	(0.255)**
customized	-0.152	-0.427	-0.575
	(0.084)$^{+}$	(0.128)**	(0.133)**
customized_x_p_transfer		0.283	0.493
		(0.147)$^{+}$	(0.176)**
customized_x_kr_docs		0.114	0.717
		(0.131)	(0.189)**

p_transfer_x_kr_docs			-0.163
			(0.275)
repeated_x_p_transfer_x_kr_docs			0.811
			(0.312)*
customized_x_p_transfer_x_kr_docs			-0.820
			(0.250)**
tacit	0.024	0.010	0.010
	(0.019)	(0.019)	(0.018)
implementation_compexity	0.009	0.007	0.005
	(0.004)*	(0.003)*	(0.003)
ongoing	0.257	0.085	0.170
	(0.118)*	(0.145)	(0.139)
experience	-0.005	-0.004	-0.003
	(0.002)*	(0.002)*	(0.002)
planned duration	0.831	0.941	0.772
	(0.332)*	(0.320)**	(0.312)*
practices_per_resource	-0.004	-0.000	0.004
	(0.006)	(0.009)	(0.009)
Constant	3.909	4.079	4.047
	(0.332)**	(0.338)**	(0.320)**
Observations	148	148	148
R-squared	0.72	0.75	0.79
Adjusted R-squared	0.70	0.73	0.76
Change in R-squared		F(4,133) = 4.79, p < .005	F(3,130) = 6.41, p < .001

Finally, with H1c we test whether KR is more effective at reducing implementation times in the customized implementation than in the initial implementation, i.e., ($KR_{customized} - KR_{initial}$) < 0. To evaluate this test we set *REPEATED* to 1 and *CUSTOMIZED* to 1.65 when computing the value of $KR_{customized}$ and to 0 when computing the value of $KR_{initial}$. Thus for H1c, $KR_{customized} - KR_{initial} = ((\beta_2 + \beta_5 (REPEATED_{ij}) + \beta_8(CUSTOMIZED_{ij}) + \beta_9(P\_TRANSFER_{ij}) + \beta_{10}(REPEATED_{ij} * P\_TRANSFER_{ij}) + \beta_{11}(CUSTOMIZED_{ij} * P\_TRANSFER_{ij})) - (\beta_2 + \beta_9(P\_TRANSFER_{ij}))$, resulting in a test of whether $\beta_5(REPEATED_{ij}) + \beta_8 (CUSTOMIZED_{ij}) + \beta_{10}(REPEATED_{ij} * P\_TRANSFER_{ij}) + \beta_{11}(CUSTOMIZED_{ij} * P\_TRANSFER_{ij}) < 0$. At the mean value for personnel transfer and using the estimated coefficients, this yields -1.405 + (0.717 * 1.65) + (0.811 * 0.446) + (-0.820 * 0.446 * 1.65) = -0.464 which is significantly less than 0 ($p < 0.02$). Thus, H1c is supported as well as H1a and H1b. The results suggest that KR is more effective in implementation contexts where more reuse of knowledge is possible. After exponentiating the combinations of coefficients we can see that compared with the initial implementation, KR usage resulted in a time reduction of 64.8% in the repeated implementation but a time reduction of only 37.1% in the customized implementation (for example, the effect of KR in the repeated implementation = $(1-e^{-1.048}) = (1-0.352) = 0.648$)).

To test hypotheses 2a through 2c –in which we posit the comparative effects of personnel transfer in different implementation contexts – we first differentiate our model with respect to P_TRANSFER. This differentiation yields the expression $\beta_1 + \beta_4(REPEATED_{ij}) + \beta_7(CUSTOMIZED_{ij}) + \beta_9(KR\_DOCS_{ij}) + \beta_{10}(REPEATED_{ij} * KR\_DOCS_{ij}) + \beta_{11}(CUSTOMIZED_{ij} * KR\_DOCS_{ij})$. We then compute the value of that expression by substituting in the values that distinguish between the specific implementation contexts. With H2a we test whether personnel

transfer is more effective in reducing implementation duration in the initial implementation than in the repeated implementation, i.e., whether ($PT_{repeated}$ - $PT_{initial}$) > 0. Since this test does not involve the variable *CUSTOMIZED*, it is set to 0. *REPEATED* is set to 1 when computing the value of $PT_{repeated}$ and set to 0 when computing the value of $PT_{initial}$. Thus for H2a, $PT_{repeated}$ - $PT_{initial}$ = ((β_1 + β_4*(REPEATED$_{ij}$)* + β_9(*KR_DOCS*$_{ij}$) + β_{10}(*REPEATED*$_{ij}$ * *KR_DOCS*$_{ij}$)) - (β_1 + β_9(*KR_DOCS*$_{ij}$)), resulting in a test of whether β_4*(REPEATED$_{ij}$)* + β_{10}(*REPEATED*$_{ij}$ * *KR_DOCS*$_{ij}$) > 0. At the mean value for *KR_DOCS* and using the estimated coefficients, this yields -0.378 + (0.811 * 0.493) = 0.022 which is not significantly different from 0 (p = 0.925). Thus, H2a is not supported.

With H2b we test whether personnel transfer is more effective in reducing implementation duration in the initial implementation than in the customized implementation, i.e., ($PT_{customized}$ − $PT_{initial}$) > 0. To evaluate this test we use the differentiated expression above, setting *REPEATED* to 1 and *CUSTOMIZED* to 1.65 when computing the value of $PT_{customized}$ and to 0 when computing the value of $PT_{initial}$. Thus for H2b $PT_{customized}$ − $PT_{initial}$ = ((β_1 + β_4*(REPEATED$_{ij}$)* + β_7*(CUSTOMIZED$_{ij}$)* + β_9(*KR_DOCS*$_{ij}$) + β_{10}(*REPEATED*$_{ij}$ * *KR_DOCS*$_{ij}$) + β_{11}(*CUSTOMIZED*$_{ij}$ * *KR_DOCS*$_{ij}$)) - (β_2 + β_9(*KR_DOCS*$_{ij}$)), resulting in a test of whether β_4*(REPEATED$_{ij}$)* + β_7*(CUSTOMIZED$_{ij}$)* +β_{10}(*REPEATED*$_{ij}$ * *KR_DOCS*$_{ij}$) + β_{11}(*CUSTOMIZED*$_{ij}$ * *KR_DOCS*$_{ij}$) > 0. At the mean value for *KR_DOCS* and using the estimated coefficients, this yields -0.378 + (0.493 * 1.65) + (0.811 * 0.493) + (-0.820 * 0.493 * 1.65) = 0.168 which is not significantly different from 0 (p < 0.453). Thus, H2b is not supported.

Finally, with H2c we test whether personnel transfer is more effective in reducing implementation duration in the customized implementation than in the repeated implementation, i.e. whether ($PT_{customized}$ − $PT_{repeated}$) < 0. To evaluate this test, we set *REPEATED* to 1 when computing the value of $PT_{repeated}$ and *CUSTOMIZED* to 1.65 when computing the value of $PT_{customized}$. Thus for H2c, $PT_{customized}$ − $PT_{repeated}$ = ((β_1 + β_4*(REPEATED$_{ij}$)* + β_7*(CUSTOMIZED$_{ij}$)* + β_9(*KR_DOCS*$_{ij}$) + β_{10}(*REPEATED*$_{ij}$ * *KR_DOCS*$_{ij}$) + β_{11}(*CUSTOMIZED*$_{ij}$ * *KR_DOCS*$_{ij}$)) - (β_1 + β_4*(REPEATED$_{ij}$)* + β_9(*KR_DOCS*$_{ij}$) + β_{10}(*REPEATED*$_{ij}$ **KR_DOCS*$_{ij}$)), resulting in a test of whether β_7*(CUSTOMIZED$_{ij}$)* + β_{11}(*CUSTOMIZED*$_{ij}$ * *KR_DOCS*$_{ij}$) < 0. At the mean value for *KR_DOCS* and using the estimated coefficients, this yields (0.493 * 1.65) + (-0.820 * 0.493 * 1.65) = 0.146 which is not significantly different from 0 (p = 0.478). Thus, H2c is not supported. Our results for hypothesis 2 all suggest that there is no significant difference in the effectiveness of personnel transfer among the initial, repeated and customized implementations.

With hypothesis 3, we examine substitution and complementarities between mechanisms. Differentiating our model with respect to the interaction between *P_TRANSFER* and *KR_DOCS* yields the expression β_9 + β_{10} *(REPEATED$_{ij}$)* + β_{11} *(CUSTOMIZED$_{ij}$)*. To test H3a we simply evaluate β_9 since in the initial implementation *REPEATED* and *CUSTOMIZED* are both set to 0. This coefficient is neither in the expected direction nor statistically significant (β_9 = -0.163, p = 0.542). Thus, we do not have support for hypothesis 3a. To test hypothesis 3b we use the differentiated expression above and set *REPEATED* to 1 and *CUSTOMIZED* to 0 to reflect the repeated implementation. Using the estimated coefficients, this expression yields a value of -0.163 + 0.811 = 0.648. This value is positive and statistically significant (p < 0.02), so H3b is supported. Finally, to test H3c in the customized implementation we set *REPEATED* to 1 and *CUSTOMIZED* to 1.65. Using the estimated coefficients, this expression yields a value of -0.163 + 0.811 – (0.820 * 1.65) = -0.704. This value is negative and statistically significant (p < 0.02), so H3c is supported. Results supporting H3b and H3c suggest that KR and personnel transfer are

substitutive in repeated implementations but complementary in customized implementations. Table 4 provides a summary of all hypothesis tests. We discuss our results in the next section.

Table 4
HYPOTHESIS TESTS

Hypothesis	Coefficient	Standard Deviation	Result
H1a: $KR_{Repeated} - KR_{Initial} < 0$	-1.043	0.223	SUPPORTED ($p < 0.001$)
H1b: $KR_{Customized} - KR_{Repeated} > 0$	0.580	0.231	SUPPORTED ($p < 0.020$)
H1c: $KR_{Customized} - KR_{Initial} < 0$	-0.464	0.197	SUPPORTED ($p < 0.020$)
H2a: $PT_{Repeated} - PT_{Initial} > 0$	0.022	0.334	NOT SUPPORTED ($p = 0.925$)
H2b: $PT_{Customized} - PT_{Initial} > 0$	0.168	0.338	NOT SUPPORTED ($p = 0.593$)
H2c: $PT_{Customized} - PT_{Repeated} < 0$	0.146	0.204	NOT SUPPORTED ($p = 0.478$)
H3a: Initial: KR and PT are substitutes	-0.163	0.247	NOT SUPPORTED ($p = 0.542$)
H3b: Repeated: KR and PT are substitutes	0.648	0.275	SUPPORTED ($p < 0.020$)
H3c: Customized: KR and PT are complements	-0.704	0.211	SUPPORTED ($p < 0.020$)

DISCUSSION

In this study, we examine the effectiveness of knowledge transfer mechanisms in the implementation of a process improvement framework for services outsourcing and offshoring. Specifically, we examine the effects of knowledge repositories and personnel transfer in three different implementation contexts: an initial implementation, a repeated implementation, and a customized implementation. The use of these mechanisms is particularly important in this context because services are labor-intensive and prone to high turnover rates, so the retention and transfer of knowledge is critical. In addition, outsourcing service providers often use multiple units for service delivery, increasing the importance of the management of process knowledge.

With hypothesis 1 we examine the relative impact of KR in three implementation contexts. We find support for all three of our hypotheses. The results for H1a indicate that KR are more effective at reducing implementation times in repeated implementations than in initial implementations. Services firms that utilize KR often have trouble motivating their employees to enter the necessary data to make the systems effective because data entry has short-term costs for the employee (Kankanhalli et al, 2005). Significantly, our results demonstrate that the use of KR throughout repeated implementations can provide tangible benefits in the form of reduced implementation durations. As more repetitions are built into the implementation schedule, the potential for knowledge reuse increases – as long as the knowledge is accessible and applicable. Our study is among the first to empirically demonstrate the impact of KR usage on process implementation duration, an objective performance outcome. These results may be relevant to prior work that has examined employees' motivation to contribute to and utilize knowledge repositories (Kulkarni et al, 2007). Specifically, the results suggest that to maximize the effectiveness of KR in process implementations, managers should give team members appropriate incentives to ensure that they enter as much relevant knowledge as possible into the KR, even if it does not provide as much value in the initial implementation. Managers in

repeated implementations should also encourage the utilization of this knowledge and also refine it as necessary for future use. However, the results for H1b also suggest that enthusiasm for KR usage may need to be tempered by the extent to which the organization needs to customize processes in subsequent implementations. Processes that require customization after the initial implementation do not obtain the same level of benefits from KR as those that are simply repeated; in fact, virtually no performance improvement is realized when customization is required. Therefore, if a majority of practices need to be customized from one implementation to the next, the use of KR may not be warranted. In the services offshoring setting, this may occur when processes are implemented across business lines that offer substantially different services (Chesbrough & Spohrer, 2006).

We did not find any support for hypothesis 2, which posits differences in the effectiveness of personnel transfer between implementations. To understand this result further, we calculated the marginal effects for both personnel transfer and the knowledge repository within each implementation. The marginal effects reveal whether a particular mechanism affects performance for a particular implementation. Further, we calculated these marginal effects at the mean, low and high values of the other knowledge transfer mechanism-see Table 5 for these values. Table 5 suggests that when KR usage is at its mean, personnel transfer appears to have similar effects in each implementation, i.e., there does not appear to be a particular benefit of personnel transfer in one implementation versus another. This is why hypothesis 2 is not supported. However, the picture changes when we vary the level of usage of KR. Within the repeated implementation, we see that personnel transfer is helpful when KR use is low (one standard deviation below the mean) but not when KR use is high (one standard deviation above the mean). This may indicate that when documents are not available in the KR, personnel transfer is able to substitute for KR usage as an effective means for transferring knowledge. The fact that our results indicate substitution in the repeated implementation (H3b) lends support to this idea. In the customized implementation we see the opposite pattern: higher levels of KR use are associated with greater efficiencies from personnel transfer. This provides additional support for the notion of complementarities between KR use and personnel transfer in the customized implementation (H3c). In fact, post-hoc tests reveal that we would have found support for hypotheses 2b and 2c if we had evaluated them respectively at low and high values of *KR_DOCS* instead of at its mean.

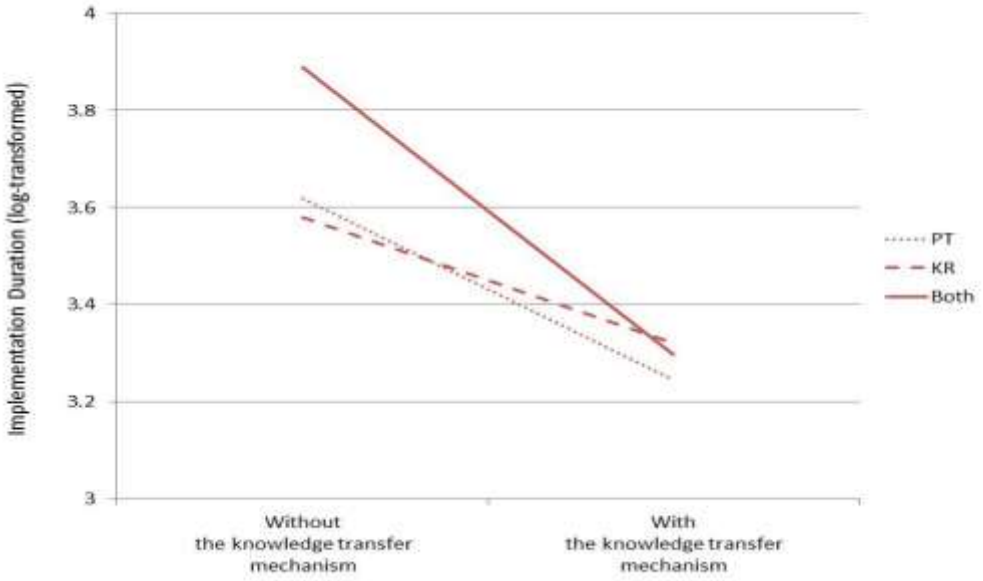
Table 5
MARGINAL EFFECTS OF KNOWLEDGE TRANSFER MECHANISMS
Combined coefficients using Table 3, column 3

	INITIAL			**REPEATED**			**CUSTOMIZED**		
Knowledge Repository	Low PT	Mean PT	High PT	Low PT	Mean PT	High PT	Low PT	Mean PT	High PT
	0.858**	0.785**	0.704**	-0.547**	-0.258*	0.065	0.636**	0.322*	-0.030
Personnel Transfer	Low KR	Mean KR	High KR	Low KR	Mean KR	High KR	Low KR	Mean KR	High KR
	-0.314+	-0.394*	-0.476+	-0.692**	-0.372	-0.047	0.121	-0.226	-0.580*

With hypothesis 3, we evaluate interactions between KR and personnel transfer. We do not find support for hypothesis 3a, suggesting that there is neither complementarity nor

substitution between these mechanisms in the initial implementation. As the marginal effects in Table 5 indicate, KR are simply not effective at lowering implementation times in the initial implementation, while personnel transfer is somewhat effective. In evaluating H3b, we find support for substitution between KR and personnel transfer. Figure 2 shows the net effect of these mechanisms for the repeated implementation, with all variables except for *P_TRANSFER* and *KR_DOCS* evaluated at their means. Using both knowledge transfer mechanisms appears to result in the greatest efficiency gains. However, the negative slope of the "Both" line is not as steep as the sum of the slopes of the "PT" and "KR" lines. This suggests that a combination of personnel transfer and KR is not as efficient as might be anticipated if the individual effects were evaluated separately. With hypothesis 3c, we find support for complementarities between these mechanisms. Figure 3 illustrates the interactions between KR and personnel transfer for the customized implementation, with all other variables evaluated at their means. There, we see that the negative slope of the "Both" line is greater than the combined slopes of the other two lines, suggesting that use of both mechanisms decreases implementation duration even more than their individual effects. As reflected in Table 5 and in Figure 3, in the customized implementation, personnel transfer and KR are effective when used together, but not as effective when used separately. In fact, if anything, KR appears to be somewhat detrimental in the customized implementation when used alone, although the results are not statistically significant. Recent work has suggested that service processes may be customized either during the initial design of a service architecture or by service employees in the course of everyday use (Voss et al, 2009). Following from this, a plausible explanation for our findings is that there are context-specific differences between the initial and customized implementations that render the use of knowledge transfer mechanisms less effective for customized processes-for example, a reduced implementation cycle, or the fact that different types of implementation tasks are occurring in parallel. Another possibility is that personnel transfer and the subsequent discussion among team members about the KR can lead to greater understanding about its validity and applicability to the implementation context (Boh, 2008). The customization of processes to meet new conditions may be best left to a post-implementation phase when new conditions are actually encountered. Our findings regarding customization provide an additional opportunity for future research.

Figure 2
KNOWLEDGE TRANSFER MECHANISMS IN REPEATED IMPLEMENTATION

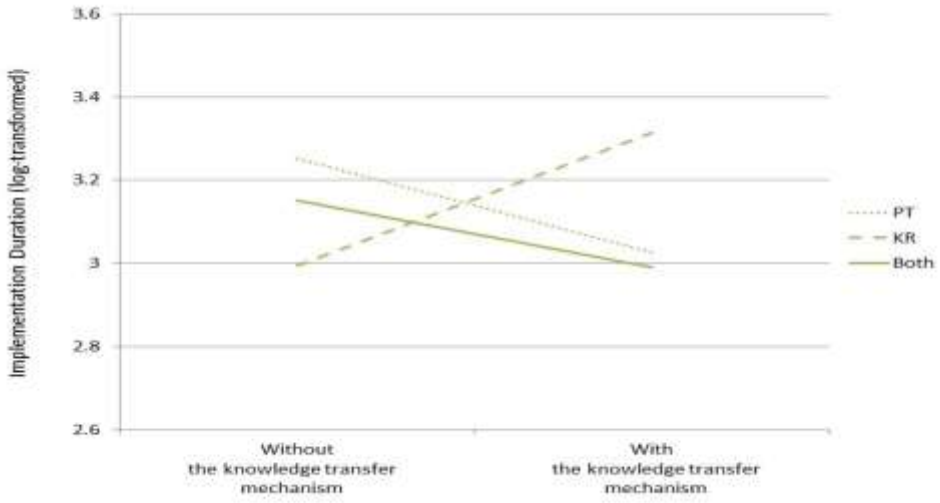


CONCLUSION

This study evaluates the effectiveness of two different types of knowledge transfer mechanisms in the implementation of a process improvement framework in an offshore delivery center for a large IT and business services provider. Our findings reveal that the use of knowledge repositories is significantly more effective at lowering implementation durations in a repeated implementation than in an initial or customized implementation. In contrast, the transfer of individuals across teams within an implementation unit did not exhibit differences in effectiveness among implementation contexts. Further, we find complementarities between these mechanisms in a customized implementation and substitution between these mechanisms in a repeated implementation. Our study provides a theoretical contribution by extending previous work examining the benefits of knowledge transfer mechanisms in process improvement contexts. Specifically, our study theorizes and empirically examines the concurrent use of tool-based and team-based mechanisms for knowledge transfer and the effectiveness of these mechanisms under different conditions of knowledge creation, reuse, and customization. We extend theories of knowledge transfer by examining the fit between organizational context and specific knowledge transfer mechanisms. To our knowledge, this is the first study to examine the interactions between these mechanisms and conditions within an organization. Our findings reveal the effectiveness of different knowledge transfer mechanisms in reducing effort in initial and repeated implementations of a process improvement framework. In addition, our results

show how the need to customize processes in a repeated implementation affects the influence of these mechanisms on implementation durations.

Figure 3
KNOWLEDGE TRANSFER MECHANISMS IN CUSTOMIZED IMPLEMENTATION



Our study has important theoretical implications for researchers who examine knowledge management and transfer in the implementation of new processes. The primary contribution of our study is in examining the effectiveness of different knowledge transfer mechanisms in the initial implementation of processes followed by repeated implementations of those processes. Prior work which has studied these mechanisms has primarily evaluated their use in a single iteration of a task (Kane et al, 2005) or under a single set of task conditions (Gray & Durcikova, 2005). By considering different implementation contexts from the perspective of the type of knowledge acquisition and transfer that occurs in each of those contexts, our study provides a more differentiated view of the effectiveness of these mechanisms. Further, our study examines whether knowledge transfer mechanisms are as effective when the processes to be implemented must also be customized to fit organizational requirements. The context of our study affords us a unique opportunity to examine this question, since service processes are often variable and must be adapted to meet changing customer needs (Chesbrough & Spohrer, 2006). Our findings also provide some support for the benefits of a multi-stage implementation strategy for propagating new processes across an organization. A multi-stage implementation strategy provides checkpoints that allow organizations to evaluate the knowledge that they have created and obtained and to determine its applicability to future work (Kankanhalli et al, 2005). Given the differing degrees of effectiveness in knowledge transfer mechanisms across implementations, organizations using a multi-stage implementation strategy should be able to structure their team members and the use of their tools to achieve maximum efficiency. Furthermore, even after controlling for different degrees of knowledge transfer mechanism usage and effectiveness, the estimated results show that the multi-stage implementation strategy yields an average of 20.4 days less time to implement each Practice in the repeated implementation for practices that were

not customized. There were 31 Practices in the repeated implementation at our research site, so our estimated results indicate a savings of 632.4 days. Assuming a labor rate of $200 a day, this amounts to a savings of approximately $110, 670.

As with any study, ours has some limitations. In particular, we do not have data on the number of times each document in the KR was accessed. Prior research has shown that the frequency of KR access can be influenced by factors such as the user's learning orientation, the user's task and the task environment (Durcikova et al, 2011; Gray & Durcikova, 2005). Our current measure of KR access is binary at the Practice level, i.e. whether or not the KR was used for the implementation of a Practice in a particular implementation stage. Therefore if anything, we would expect that data on the frequency of KR access would strengthen the results we obtain for Hypothesis 1. However, the potential effect of frequency of KR access on Hypothesis 3 is not as clear.

While examining a single organization enhances the internal validity of our study, there is the possibility that it may limit the generalizability of our results. Our organization is a multinational service provider that is representative of many large organizations that choose to implement process improvement frameworks, so our results should be applicable to those organizations. We also point out that this organization did have prior experience implementing previous technical and process methodologies and this experience may have contributed to their overall success in implementing the eSCM-SP. An interesting question might be whether the results would hold if this was a newer organization that did not have this prior experience. This remains a possibility for future research.

Our research is innovative in several ways. First, we integrate previous research in knowledge management and transfer, quality management practices, and the implementation of process improvement frameworks. In contrast to prior work in these areas which has utilized survey methods to capture a broad cross-section of users, our research design involves an in-depth field study in which we investigate the implementation of practices within one large service provider. While this potentially limits our ability to generalize the results to other settings, it increases internal validity by enabling us to control for cross-sectional differences among firms and to isolate how characteristics of knowledge transfer mechanisms affect implementation efficiency. Second, the research setting is relevant. Services science is an area that is capturing increasing interest in business and academia (Metters & Marucheck, 2007), and major IT firms such as IBM have identified services sciences as a priority area for research and hiring (Jana, 2007). Offshore outsourcing of services is labor-intensive and occurs across many organizational contexts, so the standardization of work processes is very important in this setting. The eSCM-SP is one of the first process improvement models specifically targeted toward offshore service organizations. While our study does examine the implementation of a specific process improvement framework in a particular company, the characteristics of the implementation should make our findings generalizable to a broad range of process improvement frameworks that cross multiple organizational units in multiple locations.

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APPENDIX A
IMPLEMENTATION ILLUSTRATION

The following is a list of steps in the initial implementation of the Practice del02, "Train Clients". The description of this Practice is "Establish and implement procedures to train clients and end-users". The Practice is a Procedure Practice at Capability Level 2 within the Service Delivery Capability Area. The following steps come from project plans provided by the research site.

Task	Start Date	End Date	Duration
Read and summarize existing documentation	3/10/2004	3/10/2004	1 day
Review as-is process	3/11/2004	3/12/2004	2 days
Gap analysis and documentation	3/15/2004	3/15/2004	1 day
Documentation of recommendations based on gap analysis	3/16/2004	3/16/2004	.5 days
Review with eSCM team and incorporate review comments	3/16/2004	3/16/2004	.5 days
Review gaps with Project Office and plan for actions to bridge gaps	3/17/2004	3/17/2004	.5 days
Develop Practice from scratch	3/18/2004	3/26/2004	6.5 days
Develop training material	4/6/2004	4/6/2004	1 day
Develop communication plan	4/6/2004	4/6/2004	1 day
Change Review Panel	4/14/2004	4/14/2004	1 day
Incorporate Change Review Panel comments	4/15/2004	4/15/2004	2 days
Compliance review	4/19/2004	4/22/2004	4 days
Incorporation of review comments	4/23/2004	4/26/2004	1.5 days
Training	5/6/2004	5/6/2004	1 day
Put procedure into Operational Environment	5/7/2004	5/10/2004	2 days
Transfer of ownership from eSCM team to process owners	5/10/2004	5/10/2004	0 days
TOTAL	**3/10/2004**	**5/10/2004**	**44 days**

APPENDIX B
TACITNESS QUESTIONNAIRE

Instructions: Please read the description of each Practice and its corresponding activities. Then, answer the following questions for each Practice. Indicate your answer by circling the appropriate numbered response.

1. How much knowledge about factors internal to the organization would you need in order to implement this Practice?

1	2	3	4	5
Very little		A moderate amount		A lot

2. How much knowledge about characteristics of the organization's external environment would you need in order to implement this Practice?

1	2	3	4	5
Very little		A moderate amount		A lot

3. To what extent is the intent of this Practice clearly defined?*

1	2	3	4	5
Not clearly		Somewhat	Very clearly	

4. To what extent would the implementation of this Practice require innovative or creative thinking?

1	2	3	4	5
Not at all		A moderate amount		Very much

5. To what extent do the steps for performing this Practice need to be altered or tailored when performing it for different types of services?

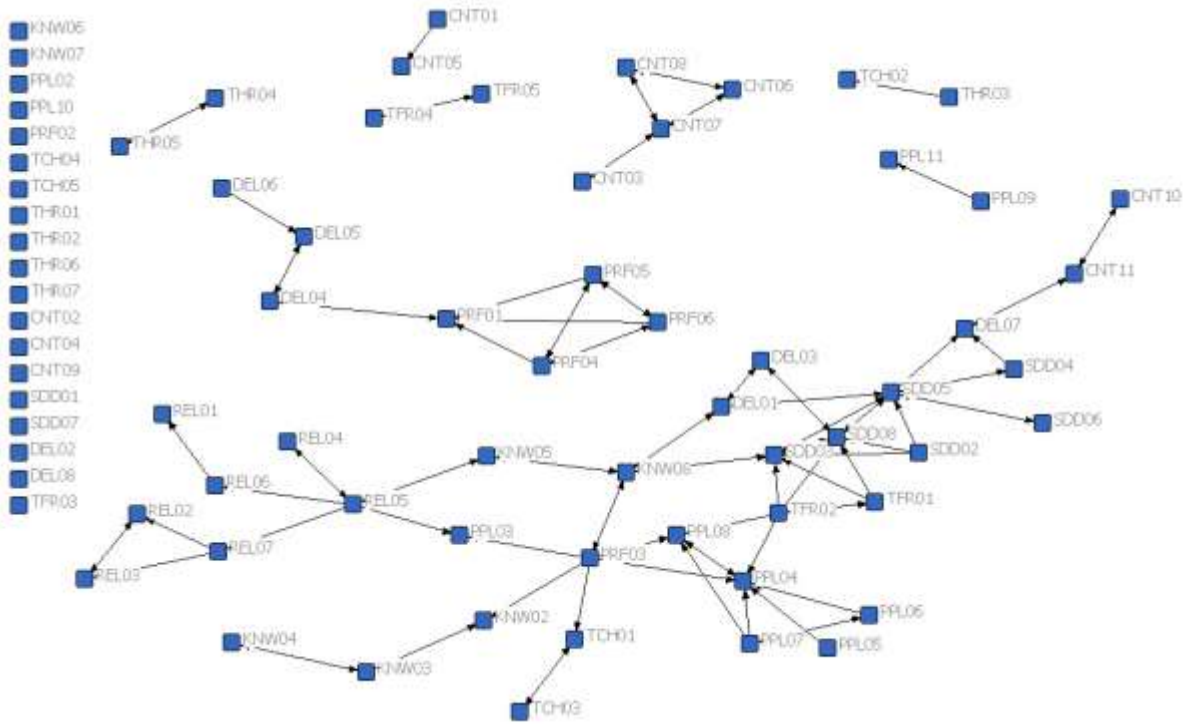
1	2	3	4	5
Not at all		Somewhat	Very much	

6. How much would the steps for performing this Practice need to be altered or tailored to meet the needs of specific clients (engagements)?

1	2	3	4	5
Very Little		A moderate amount	A lot	

***** indicates questions that were reverse-coded

Appendix C
NETWORK OF ESCM-SP PRACTICES FOR IMPLEMENTATION COMPLEXITY MEASURE



This diagram shows relationships between each of the eSCM-SP Practices that were implemented at the research site; in other words, all Practices at Capability Levels 2 and 3. These relationships were used to generate an eigenvector centrality measure for each Practice (Hanneman and Riddle, 2005). For example, the practice sdd01 (Communicate requirements) is not directly linked to any other Practices, so its eigenvector centrality measure is 0. In contrast, the Practice sdd02 (Design and deploy services) is directly linked to three other Practices, which themselves are directly linked to ten additional practices, and so forth. The eigenvector centrality measure for sdd02 is 9.62, which puts it in the 75th percentile. The centrality measure is used as a proxy for implementation complexity.

Hanneman, Robert A., and Riddle, M. *Introduction to Social Network Methods*. Riverside, CA: University of California, Riverside, 2005.

APPENDIX D
VARIABLES AND EXAMPLES

Variable	Source	Example value	Description
LOGDURATION	Project plans	4.331	Dependent variable. Actual duration of implementation for a particular eSCM-SP Practice, in days. The example value 4.331 is the log transformation of 76, which is the number of implementation days listed in the project plan for Practice ppl02.
TEAM_SHARE	Project plans	1	Within the repeated implementation, a person on implementation team A has been transferred from implementation team B.
KR_DOCS	Project knowledge repository	1	Within the initial implementation, a team implements Practice tch03 (Control technology). Documents from the related Practice tch02 (Technology licenses) are present and were used during the tch03 implementation.
TACIT	Coded by experts (see Appendix B)	19	This is the tacitness rating for Practice rel01 (Client interactions), as determined by a panel of coders. This rating puts Practice rel01 in the 90th percentile, indicating that a fairly high degree of tacit knowledge is needed to carry out the Practice.
IMPLEMENTATION_ COMPLEXITY	eSCM-SP model documentation (Hyder et al, 2005)	12.73	This is the complexity rating for practice sdd05 (Service design). This rating is the eigenvector centrality measure for this Practice within the network of all Practices as defined by the eSCM-SP authors. This rating puts practice sdd05 in the 90th percentile, indicating that the Practice is highly connected to other Practices in the model (see also Appendix C)
EXPERIENCE	Project plans	14	Within the customized implementation, a person implements practice rel03 (Manage suppliers & partners). She has participated in the implementation for 14 days prior to the start of this Practice.
ONGOING	eSCM-SP model documentation (Hyder et al, 2005)	1	Practice knw07 (Version & change control) is an Ongoing Practice in the sourcing life-cycle, as defined by the eSCM-SP authors.
PLANNED_ DURATION	Project plans	23	Prior to the initial implementation, the implementation team estimated that Practice thr06 (Statutory & regulatory compliance) would take 23 days to implement.
PRACTICES_PER_	Project plans	3	During the initial implementation, one team

RESOURCE			consisted of three people and was assigned 9 practices.
REPEATED	Implementation stage, defined by organization	1	Indicates the repeated implementation.
CUSTOMIZED	Implementation stage, defined by organization. Number of dimensions for customization determined via interviews with project participants.	2	Indicates a Practice that needs to be customized (i.e., customized implementation). A value of 2 means that the Practice needs to be customized along 2 dimensions.

SMALL BUSINESS COMPLIANCE WITH PCI DSS

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ABSTRACT

Americans increasingly use payment cards (debit cards and credit cards) for their purchases. To satisfy their customers and thus increase sales, more small businesses accept payment cards. Accepting payment cards, however, comes with additional risks and costs. One of those costs is complying with the Payment Card Industry Data Security Standard (PCI DSS) – a set of security standards developed in 2004 as a cooperative effort among card issuers such as Visa and MasterCard to protect cardholder data. This standard was developed and is updated by the PCI Security Standards Council and applies to any entity that processes, stores or transmits cardholder data.

The focus of the PCI Council was initially on very large merchants with millions of payment card transactions per year. Those efforts have paid off and it now appears that the PCI Council is turning its focus to small merchants. Recognizing the high costs and technical barriers to the PCI compliance process, in 2015 the council created a taskforce dedicated to improving small merchant card security. Also in 2015, Visa issued a security bulletin stating that all small merchants that accept Visa cards must be in PCI compliance by 2017. This new focus of the PCI Council seems to indicate that small merchants who have not currently gained PCI compliance are going to face increasing pressure to do so.

PCI DSS requires the merchant to take a number of actions as part of their compliance. These include, but are not limited to, installing and automatically updating anti-virus software, completing a self-assessment, developing a security plan, having their network evaluated. Complying with PCI DSS is difficult for small businesses, and it is not always done, even by businesses that accept payment cards.

This study examines small business compliance with PCI DSS. A compliance model based on earlier research on security policy compliance is developed. The model posits that compliance with PCI DSS depends on the business's intention to comply and that intention to comply is influenced by its awareness of PCI DSS, normative beliefs, peer behavior, self-efficacy, value of complying and the cost of compliance. Additionally, the knowledge of PCI DSS depends on the business's general IT awareness coupled with communications from their merchant bank. This model is tested with data gathered from 74 small, rural businesses in western North Carolina.

Parts of the model are supported. Knowledge of PCI DSS is associated with general IT security knowledge and merchant bank communication. This knowledge of PCI DSS coupled with self-efficacy and peer behavior does influence the business's intention to comply. Surprisingly, nether neither the cost of compliance nor the benefit of compliance (cost of non-

compliance) affect the businesses' intent to comply. Finally, the businesses' intent to comply is associated with actual compliance. Our results suggest that only slightly more than ten percent of the small businesses are compliant with PCI DSS. Thus intention is not enough. More is needed, but what that is remains uncertain and in need of further study.

INTRODUCTION

Americans love their credit and debit cards. Over 66% of all point of sale transactions involve a payment card (McCue 2013). Even though consumers want to use payment cards, only half of all small businesses accept payment cards (Dennis 2008, McCue 2013). Thus, almost half of small businesses do NOT accept payment cards. Of those businesses that do not accept payment cards, 58% are asked by their customers to accept payment cards (McCue 2013).

Those small businesses that start accepting payment cards have the opportunity to significantly increase revenues. Intuit research found that 83% of small businesses that start accepting credit cards saw an increase in business. Fifty-two percent of those increased revenues by at least $1,000 per month and 18% increased revenues by over $20,000 per month (Campbell 2013). Extending these numbers implies that small businesses could increase revenues by over $100 billion a year by accepting payment cards.

While small businesses can increase revenues by accepting payment cards, doing so comes with costs and risks. There is a cost to processing payment card transactions, but more importantly, there is the risk that customers' payment card data will be stolen. To reduce that risk, businesses must adhere to the Payment Card Industry (PCI) Data Security Standard (DSS). In general, small businesses do not understand information technology security, and they do not adhere to good security practices. A PWC survey found that 74% of the small businesses in the United Kingdom had a security breach in 2014-2105, that 52% do nothing to prevent against cybercrime and 85% have no plans to increase spending on security (Hugh, 2015). This mirrors a Symantec survey that found that 77% of small businesses in the US say they are safe from cyber threats and 83% have not security plan. Yet 40% of the cyberattacks Symantec prevented in 2012 targeted businesses with fewer than 500 employees (Symantec 2012).

In this paper, we seek to understand the degree to which small businesses understand and adhere to PCI DSS and what drives their compliance.

WHAT IS PCI?

The Payment Card Industry Security Standards Council was formed in 2004 as a cooperative effort among card issuers such as Visa and MasterCard to develop a set of security standards to protect cardholder data (PCI Security, n.d.). This effort resulted in the PCI Data Security Standard (PCI DSS), a security standard for any entity that processes, stores or transmits cardholder data. The most current DSS standard -- Version 3.1 -- was released April 2015 (PCI Security Standards Council, 2015).

The costs associated with achieving and maintaining PCI DSS compliance can be very high. A Gartner survey found large merchants spend on average $2.1 million to achieve PCI compliance (Gartner, 2011). Clearly this is not possible for smaller merchants. In recognition of this, the DSS categorizes merchants by the number of card transactions they have per year with

the largest -- Level 1 - merchants having greater than six million card transactions per year down to Level 4 merchants with fewer than twenty thousand transactions per year (Mastercard, n.d.).

HISTORY OF PCI ENFORCEMENT

The PCI Council initially focused on helping Level 1 Merchants achieve PCI Compliance. Motivating these large merchants was probably made easier by the fact that some of the largest card data breaches in history occurred in 2008-2010 (Kerber, Ross, 2007; Sharp, 2008; Vijayan, 2009) - early in the history of PCI. These high visibility data breaches and the associated costs and bad publicity certainly highlighted to large merchants the costs of failing to secure their card data.

After a number of years these efforts appear to be paying off. The 2015 Verizon PCI Compliance Report found an 80% increase in the number of companies that are validated as PCI compliant (Verizon, 2015). Given this success, it appears the PCI Council and card issuing companies are now beginning to focus on improving the PCI Compliance of the smaller, Level 4 Merchants. In October 2015 Visa issued a security bulleting stating that it will require Level 4 merchants to be in full PCI compliance by January 2017 (Visa, 2015) While the size of the data breaches for large merchants tends to be much larger -- due to the much higher card transaction volumes – the PCI Council believes that small merchants are highly prized targets because they do not have the technical resources to apply the PCI standard to protect their card data (PCI Security Standards Council, 2015). While a small merchant's data breach is much less likely to appear in the news than a large data breach, the threats and costs to small merchants are nonetheless very real.

PCI COMPLIANCE FOR SMALL MERCHANTS

To prove their compliance, larger merchants are annually required to hire a Qualified Security Assessor (QSA) to validate a merchant's PCI compliance and to produce a Report on Compliance (ROC). The costs associated both with this assessment and making changes required to pass the examination are significant. In recognition of this, the PCI Council has created much shorter annual Self-Assessment Questionnaires (SAQ) for smaller merchants. But in order for this to be a good solution, the SAQ must be something small merchants with no IT staff or funds for hiring IT consultants can complete. While the PCI council has a number of documents to help the small merchant, the question remains: is it reasonable to expect that a small merchant do a self-assessment of their cardholder security hardware, software and processes?

Recognizing the significant barriers to small merchant PCI Compliance, the PCI Council launched an industry taskforce in May 2015 dedicated to improving small merchant card security (PCI Security Standards Council, 2015). According to the PCI Council: "Small merchants are highly prized targets when it comes to cyberattacks and hacking. These businesses typically do not have the technical knowledge or resources to understand how to apply PCI Standards to protect payment data against today's threats." (PCI Security Standards Council, 2015).

Another approach to improving small merchant compliance is shown by Visa's new security requirements for the acquiring banks of small merchants that want to be able to accept Visa cards. In order for a merchant to be able to accept card payments it must have a relationship with an acquiring bank which provides the link to the credit card companies when the merchant

customer's want to use a payment card. An acquiring bank would typically have many merchant customers and would be expected to be knowledgeable about PCI compliance. In this new security requirement Visa is requiring acquiring banks to guarantee that their small merchants are in PCI Compliance or risk fines if a data breach occurs and the merchant was found to not be in compliance (Visa, 2015).

THE COST OF NON-PCI COMPLIANCE FOR SMALL MERCHANTS

The costs of a data breach can be very high. A 2015 Cost of Data Breach survey found the total average cost of a data breach for an organization was $6.5 million (Ponemon, 2015). The merchant would also likely have to pay for a security audit to determine how the breach occurred and may have to close their business while this possible multi-week audit is done. In addition, the October 2015 requirement of EMV (Chip and Pin) (EMV stands for Eurocard, MasterCard & Visa) use means that if a data breach occurs for a merchant that did not meet this requirement and the fraud was due to counterfeit payment cards, the merchant would be liable for the costs of that fraud (Kitten, 2015).

While merchants with relatively low volume of card use may think it would be cheaper to pay the fraud than upgrade their Point of Sale (POS) system to EMV, data breaches are typically caused by the introduction of malware to the POS system, and that malware can remain there for many months -- gathering customer card data that is used for fraud. In that case the volume of the card fraud incidents the merchant would be liable for would be significantly greater.

In addition to fines and the payment of fraudulent charges, additional possible costs to merchants who experience a data breach include: customer notification of the breach, paying for credit monitoring services, a security investigation into how the breach occurred and steps that would have to be taken to insure a breach did not re-occur. Taken together it is clear that there is the very real risk of a small merchant going out of business as a result of the costs associated with a data breach.

LITERATURE REVIEW

There is some research on whether employees adhere to their organization's security policies and the factors that affect their adherence. Chen and colleagues (Chen et al. 2013) use general deterrence theory to examine both a carrot and stick approach to employees' intention to adhere to their security policies. Both can be effective, but employees prefer a reward structure. Dojkovski, et. Al. (Dojkovski, et al. 2007) examine developing a security culture rather than implementing rewards and punishments for adhering to security policies. For Small and Medium Enterprises (SMEs), implementing a culture of security is difficult. Management lacks an understanding of the importance of security. This results in a lack of policies and lack of communication, and in the end, what is critical is the need to recruit and hire people with strong ethical values. Herath and Rao (Herath and Rao 2009) extend these ideas by developing a model that incorporates deterrence theory and the effect of organizational commitment on security compliance intentions. They find that appropriate understanding of the threats and an organizational commitment to security have a significant, positive influence on users' intention to comply with corporate security policies. In all of these, the focus is on the intention to comply. Siponen and Pahnila (Siponen and Pahnila 2010), extend this to examine (self-reported) actually

compliance. In this study, intention to comply and deterrence affect compliance, but rewards do not.

Most of these studies focus on large businesses and businesses with formal security policies and practices. Small businesses face the same security threats that large businesses face. However, they have fewer resources to address these security issues, which results in a different attitude towards security (Kelly 2011). Most small business owners are unfamiliar with IT security and are unaware of current security threats. They do not believe that their business will be targeted - it is too small - so security takes a back seat to other things (Ashford, 2014; Gupta, A. and R. Hammond, 2005). This leads to very small businesses (those with few than 20 employees) having poor security practices. They are unlikely to do formal risk assessments or have a security a security policy much less to have employees who follow those policies (Dimopoulos, et al. 2004).

Other researchers have found that small business are following industry best practices (Keller et. Al. 2005). This may be related to the definition of a small business being one with fewer than 500 employees. Businesses with hundreds of employees are large enough to have their own IT functions - a situation very different from the small retail establishments used in this study.

MODEL

We propose a model to explain a small business's compliance with PCI DSS. This model is based on earlier information systems (IS) research examining adherence to organizational security policies (e.g., Bulgurcu et al. 2010, Herath and Rao 2009, Siponen et al. 2010, Cannoy and Salam 2010). These, and other IS adoption and use studies, are built on earlier research in psychology and sociology, including the Theory of Reasoned Action (TRA) (Ajzen & Fishbein 1980), the Theory of Planned Behavior (TPB) (Ajzen 1991), Protection Motivation Theory (PMT) (Rogers 1975), Rational Choice Theory (RCT) and Deterrence Theory (DT). The goal is to understand and explain peoples' actions. In this case, their adherence to the PCI DSS, which is model in Figure 1.

Based on the Theory of Reasoned Action, intention precedes behavior and stronger intention to act increases the likelihood of action (Azjen et al. 1986). Siponen et al. (Siponen et al. 2010) find this is the case for actual compliance with information security policies. They argue that awareness of security policies and the importance of security is key to employee motivation to comply; although they do not specifically measure or include awareness of the organization's information security policy. Thus,

H1: Intention to comply with PCI DSS positively influences actual PCI compliance.

Intention to comply, however, is predicated first on a person's awareness of the need to comply. In the case of small retailers, many business owners who accept payment cards have never heard of PCI DSS. Since these business owner do not know about PCI DSS, they cannot comply with it. Additionally, if they do not know about PCI DSS, their understanding of the cost of non-compliance – being unable to accept payment cards - will be incomplete.

H2: Awareness of PCI DSS is positively associated with intention to comply with PCI DSS

PCI Awareness

While most people are aware of the risks of identity thefts as a result of widely publicized data breaches and ubiquitous advertisements for Life-Lock™, that does not mean that small business owners understand their role and responsibilities in keeping payment card data secure. Many small business owners have little IT knowledge and little knowledge of security (Symantec 2012). Accordingly, those with a better understanding of IT security in general are more likely to know about and understand PCI DSS.

As part of deciding to accept payment cards, small businesses must obtain a merchant account to process the payment card transactions. These accounts may be obtained from the business's regular bank, from another bank specializing in merchant services or through a payment gateway. There are also approaches for accepting credit cards, such as Square™, that do not require the business to have a merchant account. But even then, the business is responsible for being PCI DSS compliant. Whatever approach the business uses to process payment card transactions, its vendor(s) are the natural place for the business to learn about PCI DSS. Therefore:

H3: General IT security knowledge is positively associated with knowledge of PCI DSS

H4: Better communication with their merchant bank is positively associated with knowledge of PCI DSS.

Theoretical Drivers of Behavior

Given that the business owner is aware of PCI DSS, the various theoretical models of behavior identify numerous factors that affect behavioral intention, including attitudes toward the behavior (TRA, TPB), subjective norms (TRA, TPB), self-efficacy (TPB, PMT), the benefits of the behavior (RCT, DT, PMT) and the cost of the behavior (RCT, PMT).

The subjective norms are essentially social pressure that affects the business owners' perceptions about how they should behave. This peer pressure acts as an emotional force guiding an individual's actions. For the small business owner, that peer pressure could come from their customers or community. Thus,

H5: The Business's normative beliefs about payment card security is positively associated with intention to comply with PCI DSS

H6: The Business's owners' beliefs about their peers' behavior with respect to payment card security is positively associated with intention to comply with PCI DSS.

A person's desire to take a certain action, such as complying with the PCI DSS, is moderated by their belief in their ability to succeed in that action. If a person is confident that their action will be successful and that they will reap the benefits from their action, they are more likely to take action. Alternatively, why put forth the effort if you are certain of failure? Therefore:

H7: The Business's self-efficacy with respect to payment card security is positively associated with intention to comply with PCI DSS.

While self-efficacy affects the decision maker's belief in their ability to successfully take action, the benefit of the behavior or conversely the cost of not taking action determine the payoff to the decision maker. The primary benefit of complying with PCI DSS is the reduction in risk associated with a data breach. Since risk is traditionally measured based on the likelihood of an event and the resulting cost of the event, these two constructs are separated out. If the business considers either the likelihood of a data breach or the impact on its business from a data breach as low, then the benefit from implementing PCI DSS is also low. Thus

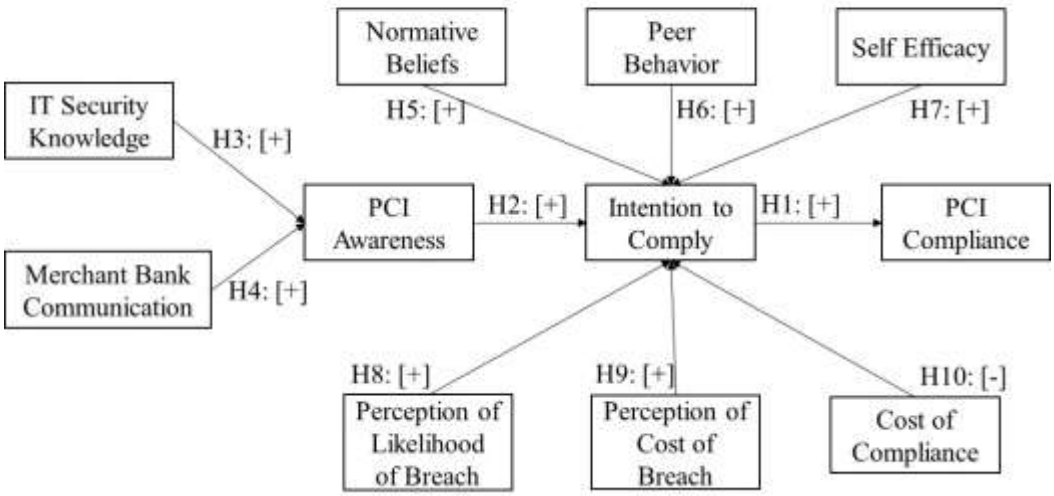
H8: The Business's assessment of the likelihood of a data breach is positively associated with intention to comply with PCI DSS (If they believe a breach is likely, they are more likely to comply)

H9: The Business's assessment of the impact or cost of a data breach is positively associated with intention to comply with PCI DSS (The higher the cost of a breach, the more likely compliance).

While a high cost of non-compliance with PCI DSS (alternatively a high benefit from complying with PCI DSS) increases a business's incentive to comply, this can be offset by the cost of compliance. Complying with PCI DSS can be cumbersome - especially for a small business owner with little or no IT skills. In addition to the paperwork required by compliance, the small business owner must select and install PCI compliant software and ensure that that software is updated and maintained. They must also ensure that their network is secure and pay to have it audited. The higher the cost of complying, the lower the likelihood the business owner will comply with PCI DSS. Therefore:

H10: The cost of complying with PCI DSS is negatively associated with intention to comply with PCI DSS.

Figure 1. Model of PCI DSS Compliance



ITEM DEVELOPMENT

To test this model, we developed a 32 question survey. The survey contained measurement items for the constructs described above. These measurement items were developed based on the literature. When possible, both construct and measurement items from prior studies were used to ensure consistency with prior research and reliability. In some cases, the wording for the measure was altered slightly to fit the goal of this study. For example: "I intend to comply with the requirements of the ISP of my organization in the future (Bulgurcu et al. 2010)" was modified to "I intend to comply with PCI DSS." Table 1 presents the constructs, measurement items and sources. Each measurement item except PCI compliance used a seven-point Likert scale.

The behavior studied, in this case PCI compliance, is a standard construct in TPB and TRA models and is the ultimate construct modeled in (Siponen et al. 2010). PCI compliance is based on actions taken by the firm. While there are numerous actions required by a firm to be PCI compliant, we based PCI compliance on the business's completion of the PCI self-assessment questionnaire, scanning their network for vulnerabilities, having a written security policy and automatically updating their antivirus software. PCI compliance was coded as either yes (all four items were in compliance) or no (at least one item was not in compliance).

Table 1
ITEM AND CONSTRUCTION DEVELOPMENT

Construct & Sources	Measurement Items	Measurement Items Sources
PCI Compliance (PCIComp) Siponen et. Al. 2010 Cannoy and Salam 2010	Do you have a written security policy When was your network last scanned for vulnerabilities When did you last complete a PCI self-assessment Is your anti-virus software automatically updated	These items are new. Siponen et. Al. 2010 uses self-reported statements of compliance rather than an assessment of whether the organization complies.
Intention to Comply (Intent) Siponen et. Al. 2010 Herath and Rao 2009 Bulurcu et Al. 2010 Cannoy and Salam 2010	I intend to comply with PCI DSS I intend to carry out my responsibilities specified in the PCI DSS	I intend to comply with the requirements of the ISP of my organization in the future (Bulurcu et Al. 2010) I intend to carry out my responsibilities prescribed in the ISP of my organization when I use information and technology in the future. (Bulurcu et Al. 2010)
Self-Efficacy (Self-E) Siponen et. Al. 2010 Bulurcu et Al. 2010	I or an IT consultant my business uses have the necessary - to fulfill the PCI requirements. Skills Knowledge Competencies	I have the necessary - to fulfill the requirements of the ISP. skills knowledge competencies (Bulurcu et Al. 2010)
Normative Beliefs (NormBel) Siponen et. Al. 2010 Herath and Rao 2009 Bulurcu et Al. 2010	My customers think I should implement PCI compliance My bank thinks I should implement PCI compliance	_____ think that I should comply with the requirements of the ISP. My colleagues My executives My managers (Bulurcu et Al. 2010)

Table 1
ITEM AND CONSTRUCTION DEVELOPMENT

Construct & Sources	Measurement Items	Measurement Items Sources
Cannoy and Salam 2010	My community think I should implement PCI compliance	
PCI Awareness (PCIAware) Bulurcu et Al. 2010	I know the PCI guidelines Are you aware of the Payment Card Industry (PCI) Data Security Standard (DSS)?	I know the rules and regulations prescribed by the ISP of myOrganization I understand the rules and regulations prescribed by the ISP of my organization. I know my responsibilities as prescribed in the ISP to enhance the IS security of my organization. (Bulurcu et Al. 2010)
Perceived Cost of Breach (PercCost) Siponen et. Al. 2010 Herath and Rao 2009 Bulurcu et Al. 2010	The profitability of my business would be threatened if I lost payment card data. Fines and penalties for small businesses are significant if payment card data is compromised. I risk going out of business if payment card data is stolen	These items are new. Other studies focus on the cost to the individual of compliance rather than the cost to the organization. Since the business owner is the respondent, the costs incurred by the small business are also incurred by the business owner.
Perceived Likelihood of Breach (PercLike) Siponen et. Al. 2010 Herath and Rao 2009	Hackers and criminals target large businesses, not small ones It is unlikely that my payment card system (POS system) will be compromised Few small businesses have their payment card data stolen	These items are new. Other studies focus on the likelihood of the individual being caught not adhering to company policy rather than the likelihood of a breach.
General IT Security Knowledge (GenITSK) Bulurcu et Al. 2010	I know enough about IT security to protect the company's payment card data. I am confident in my knowledge of computer security I am confident in my knowledge of network security I know how to create strong passwords	These items are new. Bulurcu et. Al. ask about awareness of IT security. Here, the concern is with the business owner's understanding of IT security related to their ability to comply with PCI DSS.
Communication with Merchant Bank (CommMB) Siponen et. Al. 2010 Cannoy and Salam 2010	PCI policy has been clearly communicated with me. My merchant bank provides support for PCI compliance I can ask my merchant bank any questions I have about PCI	IA Policy has been clearly communicated to me. I was well informed about the IA policy through company newsletters (Cannoy and Salam 2010)
PCI Cost (PCICost) Herath and Rao 2009 Bulurcu et Al. 2010	Conducting PCI compliance practices poses a hindrance PCI compliance is expensive Becoming and remaining PCI compliant is time consuming	Complying with the requirements of the ISP is _____ for me. time consuming burdensome costly (Bulurcu et Al. 2010)
Peer Behavior (PeerBeh)	I am responsible for following the PCI guidelines	I believe other employees comply with the organization IS security policies.

Table 1 ITEM AND CONSTRUCTION DEVELOPMENT		
Construct & Sources	**Measurement Items**	**Measurement Items Sources**
Herath and Rao 2009	Other small businesses like mine follow PCI guidelines	I am convinced other employees comply with the organization IS security policies. (Herath and Rao 2009)

The instrument was tested with field experts to increase reliability and understandability. A group of experts in PCI were solicited to ensure content validity and to improve the wording of each item. Based on their recommendations, several items were reworded. A group of small business owners, similar to those who would complete the questionnaire, participated in a pilot test to improve the instructions and to ensure that the questions were understandable to our target participants.

DATA

The data for this research started with the Frontier yellow pages for Bryson City, Cashiers, Cherokee, Cullowhee, Dillsboro, Franklin, Highlands, and Sylva, North Carolina. These yellow pages cover three rural counties in western North Carolina: Macon, Jackson and Swain. These counties are poor and rural. Macon County's population is approximately 34,000 with a median household income of approximately $38,000. Over 20% of the population lives below the poverty level. Jackson County's population is approximately 41,000 with a median household income of approximately $37,000. Over 21% of the population lives below the poverty level. Swain County's population is approximately 14,000 with a median household income of approximately $36,000. Over 27% of the population lives below the poverty level.

The yellow pages are divided into business categories. Within each category businesses are listed. The business category and the number of businesses listed in each category was captured. A random number was assigned to each category using Excel's Rand() function. The categories were sorted by their assigned random number. A cutoff point was selected that resulted in just under 1000 businesses in the selected categories (note that there were some duplicates).

A Google search was conducted for each business category to identify additional businesses in Macon, Jackson and Swain counties that were identified as being in the listed category. Any business listed in the yellow pages, but not found by the Google category search was searched for directly using the business name and city. For all businesses identified, their address and phone number were captured. Approximately 2000 organizations were identified. Government organizations (e.g., the US Post Office), large businesses (e.g., Walmart) and industrial companies (e.g., APAC Atlantic, Inc.) were eliminated from the pool.

Participants completed all self-report measures in a single, 32 item surveys. We initially mailed a post card to all 1000 potential participants announcing the study, which was followed two weeks later by a mailed hard copy of the survey itself. A month after that, we sent another postcard to all participants who did not respond to the initial mailing to remind them to return the survey and to offer an online version via Qualtrics.

Of the approximately 700 surveys that reached their target, 103 were attempted and returned. Twenty-five of the returned surveys were dropped from further consideration due to

excessive missing data. Of those 25, 12 of them completed the survey, but they did not accept credit cards or debit cards, so most of the answers did not apply. For those surveys with acceptable levels of missing data, we used scale mean replacement to impute missing values. The remaining 74 subjects resulted in a final response rate of = 11%.

RESULTS

Table 1 shows the means, standard deviations, and correlations among all variables. We used a series of hierarchical OLS regressions and Hayes' (2013) PROCESS method for testing the significance of relationships in the full mediated logistic regression model using the bias corrected and accelerated confidence intervals.

Of the completed surveys, only eight of the businesses were fully compliant with PCI DSS. Thirty of the businesses explicitly indicated that they were not compliant by answering at least one of the four PCI compliance questions in a way that showed them fulfilling their PCI obligations. The remaining businesses in the sample did not know if they were in compliance or not. We made the assumption that since these respondents had not heard of PCI DSS, it is unlikely that they were compliant with it.

Table 2
MEANS, STANDARDS DEVIATION, AND CORRELATION AMONG CONSTRUCTS

Table 2.
Means, standard deviations, and correlations among constructs

Construct	M	SD	1	2	3	4	5	6	7	8	9	10
1. Communication	3.78	0.91										
2. PCI Cost	2.89	1.01	-0.27									
3. Gen. IT Security Knowledge	3.31	1.03	0.23	-0.21								
4. Intent to Comply	4.49	0.68	0.53**	-0.24	0.13							
5. Perceived Likelihood of Breach	3.04	0.77	-0.11	0.49**	0.10	-0.17						
6. Normative Belief	3.69	1.03	0.29	-0.17	0.17	0.28	-0.27					
7. PCI Compliance	3.34	0.45	0.15	-0.21	0.25*	0.29	-0.03	0.08				
8. Peer Behavior	3.90	0.65	0.51**	-0.08	0.21	0.53**	-0.18	0.23	0.08			
9. PCI Awareness	3.80	1.24	0.40*	-0.11	0.36	0.34	0.21	0.05	0.22	0.34*		
10. Perceived Cost of Breach	3.40	0.85	0.38*	0.03	0.05	0.32	-0.27*	0.16	0.21	0.26	0.05	
11. Self-efficacy	4.05	1.03	0.38*	-0.34*	0.46**	0.43**	-0.14	0.33*	0.35*	0.24	0.43**	0.04

N=74; p*<.05; P**<.01

In our first set of results, we test the predictors of PCI Awareness as hypothesized in H3 and H4 using OLS regression. We find support for both the communication that the firm has with its bank (**β**=0.24, p<0.05) as well as the respondents general knowledge of IT security (**β**=0.30, p<0.01) in influencing their awareness of PCI protocols (R2=0.17, F=7.30).

In the second model, we tested H2 and H5-H10, which includes the influence of PCI Awareness, as well as the other factors, on Intent to Comply. We found non-significant results for the cost of PCI to implement (**β**=-0.14, p>0.05), the likelihood of breach of security (**β**=0.05, p>0.05), the perceived cost of a breach (**β**=0.17, p>0.05) and the normative beliefs about PCI (**β**=0.09, p>0.05). In support of H7, however, we did find that respondent self-efficacy (**β**=0.21, p<0.05) positively predicted intent to comply, as did the behavior of the respondents peers (**β**=0.42, p<0.01), which supports H6 (R2=0.41, F=6.58). We also found that awareness of PCI (**β**=0.19, p<0.05) positively predicted intent to comply, thus supporting H2.

Table 3
REGRESSION RESULTS

	β	*s.e.*	*Z*	*sig.*	R^2	*F*
Dependent variable: PCI Awareness						
Communication	0.24	0.21	2.09	0.04		
Gen. IT Security Knowledge	0.30	0.14	2.65	0.01	0.17	7.30**
Dependent variable: Intent to Comply						
PCI Cost	-0.14	0.07	-1.26	0.21		
Perceived Likelihood of Breach	0.05	0.08	0.46	0.64		
Normative Beliefs	0.09	0.07	0.87	0.39		
Perceived Cost of Breach	0.17	0.07	1.66	0.10		
Self-efficacy	0.21	0.08	1.96	0.05*		
PCI Awareness	0.24	0.09	2.16	0.03*		
Peer Behavior	0.42	0.10	4.05	0.00**	0.41	6.58**
N=74; *p<.05, **p<0.01						

In Table 4, we show the results of the testing of Hypothesis 1 in which intent to comply on the part of the respondent mediates the relationship between PCI Awareness and actual compliance with PCI requirements. Using Hayes (2013) PROCESS script, we found that when people intend to comply, they seem to follow through on that intent. However, awareness of PCI is not enough to encourage businesses to comply as neither the direct effect of awareness on compliance (**β**=0.37, p=0.39), nor the indirect effect via intent to comply were significant (**β**=0.32, p=0.18). Thus, even though banks seemingly do a good job of promoting PCI awareness and individuals have the necessary security knowledge, that awareness does not translate to compliance.

Table 4
REGRESSION RESULTS OF THE INTEGRATED MODEL

	β	*s.e.*	*Z*	*sig.*
Integrated Model Dependent Variable: PCI Compliance				
Direct Effects				
PCI Awareness	0.37	0.43	0.86	0.39
Intent to Comply	3.39	1.70	1.99	0.5*
Indirect Effects				
PCI Awareness→Intent to Comply	0.32	0.24	1.34	0.18
N=74; df=2; *p<.05, **p<0.01				

CONCLUSIONS

This study highlights the difference between earlier studies on security policy compliance at large organizations and small business's compliance with PCI DSS. Understanding the similarities and differences is critical as the payment card industry focuses more on small retailer compliance with PCI DSS and strives to increase their level of compliance. Increasing that level of compliance is important to reducing the $7.5 billion (Harrow, 2015) in fraud while simultaneously continuing to allow small businesses to accept payment cards.

Like Siponen et al. (2010), intention to comply significantly influences actual compliance. This is critical. Merchant banks need to get their small business customers to want to comply with PCI DSS. As with earlier studies, self-efficacy and peer behavior is positively related to the business owners' intention to comply, thus improving these could improve compliance with PCI DSS. The self-efficacy in this study asked about the business owner's ability comply OR the ability of a consultant that they use. Three Quarters of the businesses that were compliant used external IT support for PCI DSS compliance. When working with small retailers, merchant banks may want to enlist the help of local IT experts to work with the local retailers. Merchant banks may also want to work with their clients in a way that brings together the small business community. This can increase the business owners' expectations that their peers will also comply with PCI DSS.

Unlike the earlier studies, neither the cost of compliance nor the benefit of compliance affects the owner's intention to comply. This could be because small business owners did not believe the cost to comply was high. Their average response was less than 3.0 - they neither agreed nor disagreed that the cost of PCI compliance was expensive or a hindrance to their business. They also did not believe that if they did not comply that the cost to their business would be significant. They felt that both the chance of a breach and cost of a breach was low. This could mean that merchant banks first need to convince small retailers of the risk of non-compliance. This may be necessary before educating them on PCI DSS itself will be effective.

Finally, and most importantly, PCI awareness did not significantly influence PCI DSS compliance. This means that education efforts related to PCI DSS will be insufficient. Any education efforts must address more factors.

Better understanding of how to increase compliance with PCI DSS by small businesses is needed. Awareness is not sufficient. As larger businesses make their systems more secure, fraud will migrate to smaller businesses - as will focus on PCI DSS compliance. While this study started the process, a larger-scale study is needed.

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AIRLINE QUALITY, LOAD FACTORS AND PERFORMANCE

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ABSTRACT

This paper examines the relationship between airline quality and domestic US airline performance. How to measure quality and performance in the airline industry has been problematic in prior research, resulting in conflicting conclusions. Quality is commonly measured by a customer satisfaction construct created by the researcher for the study or alternatively by a published quality construct such as the Airline Quality Rating (AQR). The constructs are usually linear combinations of published airline statistics. Performance in the airline industry can be measured by traditional input/output ratios such as the ratio of operating income to operating cost, financial measures such as ROI, or non-financial measures such as passenger load factors. In this paper we argue a form of passenger load factors is the appropriate performance measure when addressing the impact of airline quality on performance. The data and statistical methodology selected have also been a source of confounding results in prior research. In this research a monthly sample of data for 15 domestic US airlines taken over 10 years is collected from multiple sources.Cross sectional time series panel models are developed that reveal a complex and statistically significant relationship between quality and load factors. As part of this analysis we make the argument that the results are consistent whether one uses a published quality measure such as the AQR or creates a new construct to measure quality.

INTRODUCTION

Prior research has produced mixed results regarding the relationship between quality and its effect on performance in the airline industry. This divergence may be a result of different approaches used to measure both elements. One measure of quality is the Airline Quality Rating (AQR). AQR is commonly used to assess quality in the airline industry and has been a published statistic for over two decades. It utilizes objective elements purported to be important to airline travelers, and combines them into a composite score. However, the AQR score has been criticized in academic research for not having the proper informational content. In fact, prior research often replaces it with the source data used to calculate the composite score.

Furthermore, using AQR as a measure of quality can produce seemingly contradictory results. A recent study by researchers at Wichita State and Embry-Riddle Universities showed that while passenger complaints related to the annual airline quality rating system were down last year, lost baggage and late arrivals increased (Airline Quality Rating, 2014). Customer satisfaction with U.S. carriers is lower than either hotels or online travel agencies. The American Customer Satisfaction Index, also conducted annually, results in ratings based on a 100-point scale (About the Airline, n.d.). Given that grades fall into traditional 10-point breaks (90 and above = A, 80 to89 = B, etc.), hotels and online travel agencies earned solid C's, respectively.

The domestic airlineIndustry, however, earned a D. The interesting paradox is that hile the 2013 airline quality Rating (AQR) is up, other measures of customer satisfaction are down.Measuring performance in the airline industry has also been problematic. Traditional operational measures, such as the ratio of operating income to operating costs, are commonly used in prior research. This traditional approach has been criticized owing to lack of variability within the industry, and the fact that extraneous variation, such as fuel hedging policies, cloud performance. Perhaps a non-financial measure is better used. We suggest a statistically significant explanation of the complex relationship between airline quality, as measured by the AQR, and customer choice of airline, as measured by a form of load factors. We also compare results of the relationship using AQR and its underlying components. We begin with a review of relevant literature, move to data and methodology, present results, and end with discussion.

LITERATURE REVIEW

There are many articles exploring the relationship between quality and performance. In this research we draw upon the following. Anderson and Mittal (2000) discuss the linkages among measureable attributes, customer satisfaction, customer retention, and profitability. They present a theoretical argument that the linkages are asymmetric and non-linear. They show that a decrease in an attribute such as mishandled baggage, may have a larger effect on customer satisfaction than a corresponding increase in the same attribute. In other words, the slope of the loss function is much steeper than the slope of the gain function. They posit the same type of relationship exists for the linkage between customer satisfaction and customer retention. As a result, they believe for each firm an optimal point exists for customer satisfaction attributes. Spending to increase customer satisfaction beyond that point yields diminishing returns. On the other hand, allowing that attribute to decline immediately results in decreased profits.

Banker, Potter, and Srinivasan (2000) found that non-financial measures of performance such as quality and customer satisfaction are leading indicators of future performance. This result contrasts with Ittner and Larker (1998), who found limited support for customer satisfaction being a leading indicator of customer behavior, growth in the number of customers or performance as measured by financial accounting results. Banker et al. argued that the results of studies that do not find this relationship may have model specification problems such as omitted variables and spurious correlation that can be corrected with a properly specified time series model with an adequate time span. Babakus, Bienstock, and Van Scotter (2004) studied the linkage between merchandise and service quality and retail store performance. They argue that higher performance levels lag changes in quality, bringing into question cross sectional or short time frame studies. Their study was based on Bagozzi's (1992) framework of appraisal leads to affective response leads to behavior. Appraisal is customer perceived quality related to the competition, affective response is the customer's satisfaction, and behavior is performance. Sales growth and customer count were used as performance measures. This is analogous to using load factors in this paper. The ultimate conclusion of the work was that service leads to customer satisfaction, which in turn leads to increased performance.Using five years of data for 27 airlines, Demydyuk (2011) found that airlines are consistently unprofitable, and passengers or passenger distance are better predictors of future financial performance than revenues, costs or load factors. Demydyuk found this to be the case for both low cost carriers and full service airlines.

The findings are based on the concept that the marginal cost per additional passenger is very low so maximizing passengers, hence revenues, will maximize profits. Demydyuk found that load factors and passengers are related to profitability for low cost carriers, but not for full service carriers. Revenue per seat was found to be related to profitability for full service carriers, but not for low cost carriers.

Park, Robertson, and Wu (2004) argued that high quality passenger service is essential for airlines. In a study of air passengers in Korea, they observed that service, value, satisfaction and airline image were positively related to customer's choice of airline.

They followed with a subsequent study in 2006 of domestic Australian airlines. The study confirmed significant relationships found in the 2004 piece and suggested further exploration of individual measures of service quality. Wittman (2014) looked at differences between low cost and full service carriers. Key to that work is his observation that passengers on low cost airlines are less likely to complain about service quality than those choosing full service organizations. That finding suggests that both image and value remain important elements of airline service.

The proper formulation of the statistical model and variables used to measure quality and performance has varied in prior research. Anderson, Fornell, and Lehman (1994) studied 77 firms across a variety of industries. They proposed a three part model wherein expectations are a blend of prior expectations and prior quality; satisfaction consists of quality, price, and expectations; and profitability is a function of prior satisfaction. The model was tested using time series with lagged relationships, first differences, and trend terms. They argued that the lagged dependent variables capture the effect of terms not in the equations. Empirical results showed that satisfaction was positively associated with current and prior quality, and profitability was positively associated with satisfaction. They concluded that economic returns from improving customer satisfaction will occur in future time periods.

Alternatively, Dresner and Xu (1995) examined the relationship between customer servicend profitability in the airline industry between 1988 and 1990 using quarterly data for thirteen airlines. Profitability was measured as the ratio of operating revenues to operating expenses. The research used a two stage panel regression. In the first stage complaints were modeled as a function of on time performance, over-booking, and mishandled baggage. In the second stage profitability was modeled as a function of the estimated complaints from stage one, on-time performance, ticket over-sales, mishandled baggage, and dummy variables for quarter and airline. In both models on time performance, over-booking, and mishandled baggage were found to be significant predictors. The authors argue that using on time performance, ticket over-sales, and mishandled baggage in both stages of the model, which essentially double counts them, produces unbiased coefficient estimates. The authors also note they attempted to incorporate lagged relationships, but found the results less significant.

Anderson, Fornell, and Rust (1997) suggest there is disagreement as to how to best test the relationships of satisfaction, productivity, and profitability. They argue specification issues require a model incorporating differences, fixed effects and lagged variables. They concluded that the relationship between customer satisfaction and productivity was negative for service firms, such as airlines, and positive for goods-producing firms. The relationship between ROI and customer satisfaction was found to be less positive in service industries and concave downwards. The work shows that for service industries such as airlines higher ROI is associated with relatively high customer satisfaction and relatively low productivity. In this research we will follow in the direction of Anderson (1994, 1997) and incorporate time series elements including lagged relationships between quality and performance.

Behn and Riley's (1999) research focused on whether nonfinancial data could be used to predict financial performance. They studied six airlines from 1990 through 1996. Financial performance was measured by three different dependent variables: operating income, operating revenue and operating expenses. A complaint construct, load factor, market share, available miles, a dummy variable for year, and a dummy variable for airline were used as independent variables. A combination of monthly and quarterly data was used in their study. The customer complaint construct was estimated as a function of on time service, mishandled baggage, overbookings, in-flight service, a dummy variable for year, and a dummy variable for airline. It is interesting to note that the airline dummy variable was found to have no significance, but still used in the analysis.

For financial performance six different models were estimated, each using three independent variables for the first month of the quarter and the first two months of the quarter. First month of the quarter complaints were significant for all three dependent variables, whereas month 2 complaints were significant only in predicting operating income. The significance of the other independent variables was mixed. As the authors note, the research is limited in its lack of accounting for individual airline differences, thereby limiting the study's generalizability. The significance of yearly dummy variables and differences in significance between month one and two's ability to predict quarter end results raises questions about the time series nature of the data. In this research we will attempt to improve upon Behn and Riley's study by using an alternative performance measure and incorporating individual differences.

Stevens, Dong and Dresner (2012) also investigated the relationship between customer satisfaction and financial performance in the airline industry. They studied quarterly data for 12 airlines from 2003 through 2009. Financial performance was measured as the ratio of operating revenue to operating cost. Customer satisfaction was measured as a function of a complaint construct, market concentration by route, number of seats offered; market share by route, involuntary denied boardings, stage length and operating costs. The complaint construct was estimated using percentage of on time flights, lost baggage, involuntarily denied boardings, and flight cancelations. A panel regression model incorporating individual and time effects was used in the analysis. The analysis showed that in concentrated markets customer satisfaction's effect on profitability is moderated, thus giving airlines less incentive to increase customer satisfaction in highly concentrated markets. This result is consistent with Mazzeo (2003), where it was observed that airline delays were longer and more prevalent on routes that had only one service provider or through airports with few service providers. Mazzeo concluded that airlines do not have an incentive to provide higher levels of quality in areas where they face little competition.

A confounding source of extraneous variation found in some prior research may be attributable to fuel hedging policies, one of the dominant factors affecting airline operating profits. Differences in fuel hedging practices may confound the relationship between quality and performance if traditional financial based productivity measures, such as the ratio of operating revenue to operating costs, are used. We note that British Airways hedged 45% of its fuel costs and Lufthansa hedged 80% of its fuel costs in 2004 (Business Travel World, 2004). Halls (2005) and Jens and Wall (2008, 2009) discern differences in types of hedging and the extent to which airlines hedge fuel costs. They find benefits from hedging occur during times of increasing fuel costs, but hedging results in increased costs when fuel prices fall. The benefits and costs are mitigated by the extent of hedging and the type of hedging undertaken.

Carter, Rogers, and Simkins (2006) studied the relationship between hedging and firm value for 28 domestic US airlines between 1992 and 2003. Of those, 18 employed some type of fuel hedging during that time period. Fuel costs by airline ranged from a low of 8.5% of operating

costs to a high of 18.8%. Fuel hedging was reported to be as high as 80% for Southwest Airlines. They also found a positive relationship between hedging and firm value.

Prior research shows a variety of financial and non-financial measures have been used to gauge quality and performance with mixed results. Even using the same measures has resulted in contradictory findings. In this research we will address the sources of the contradictory results by using a large sample over a long time span, by careful selection of quality and performance measures and by application of appropriate time series methodologies.

DATA

The data for this research were obtained from two sources, The Research and Innovative Technology Administration (RITA) Bureau of Transportation Statistics and the Airline Quality Rating Report Advanced Aviation Analytics Institute for Research. The variables used in this research are defined in Table 1.

Table 1
VARIABLE DEFINITIONS

AQR	Airline Quality Rating.
CC	Customer Complaints – Number of complaints reported to the U. S. Department of Transportation per one hundred thousand passengers. This includes complaints related to flight problems, over sales, reservations, ticketing, and boarding, fares, refunds, baggage, customer service, disability, advertising, discrimination, animals and other complaints.
DB	Denied Boardings – Number of passengers per ten thousand holding a confirmed reservation that were denied boarding.
LFM	Load Factor in Miles – Passenger miles flown divided by seat miles available.
MB	Mishandled Baggage – Number of mishandled baggage reports per one thousand passengers. This includes lost, damaged, delayed or pilfered baggage.
OT	On-Time - Percentage of flights arriving within 15 minutes of scheduled arrival time.

The variables CC, DB, MB and OT were obtained from the Airline Quality Rating Report Advanced Aviation Analytics Institute for Research (Bowen & Headley, 2003-2013). These statistics are also available from the Research and Innovative Technology Administration (RITA) Bureau of Transportation Statistics. Date, number of passengers per flight, number of seats available per flight, miles per flight and airline were obtained from the Research and Innovative Technology Administration Bureau of Transportation Statistics. AQR and LFM are the result of author's calculations. The equation used for AQR calculations was provided by Brent Bowen and Dean Headley at the Airline Quality Rating Report Advanced Aviation Analytics Institute for Research and is shown in Equation 1(Bowen & Headley, 2013). The AQR is essentially a weighted average of four attributes measuring quality and customer satisfaction.

$$AQR = (8.63 * \mathrm{OT} - 8.03 * \mathrm{DB} - 7.92 * \mathrm{MB} - 7.17 * \mathrm{CC}) / 31.75 \qquad (1)$$

Bowen and Headley originally Estimated the relative weights in the ARQ formula by surveying airline industry experts as to their opinion of what consumers would rate as important. In 2002 Bowen and Headley confirmed the relative weights with a large survey of frequent flyers. The weights in the AQR formula have remained constant over the time period utilized in this study.

As noted earlier in this paper measuring performance in the airline industry is problematic. Prior research has used two main approaches: traditional financial output/input ratios or variants

on the number of customers. The performance measure (dependent variable) selected for this studyis the LFM. This is consistent with studies by Creel and Farell (2001), Davila and Venkatachalam(2004), Demydyuk (2011), and Henriques de Araujo, et.al. (2010). Using load factors avoids problems with measures, such as revenues and expenses, which can be affected by factors extraneous to this study (fuel hedging policies). There are various versions of load factors. Some incorporate miles flown and capacity while others simply use raw number of customers. LFM used in this study incorporates both passenger miles flown and capacity, and is shown in equation 2.

$$LFM = \frac{\sum(\text{Number of Passangers per flight} * \text{miles per flight})}{\sum(\text{Seats available per flight} * \text{miles per flight})} \quad (2)$$

Although data for some of the airlines is available prior to 2003 it has been shown that there were significant changes in air travel patterns from the pre 9/11 era to the post 9/11 era (Moss, Lui, & Moss, 2013). These include changes in seasonal travel patterns and percentage of air travels flying for tourism versus business. It has also been shown that there was a significant intervention in passenger air travel on 9/11 and in the subsequent months following 9/11 (Moss, Ryan, & Moss, 2008). To avoid a structural change in the middle of the time series and significant interventions confounding the results of this research the analysis is limited to the post 9/11 era.

The literature review offered important direction for this research. Consistent with previous work, we employ a time series panel methodology. Second, we attempt to control for seasonality, trends, and hedging in an effort to un-clutter the data. Third, we deploy non-financial measures to obtain a "clean" look at performance. We utilize a combination of both macro and individual measures of service quality in our analyses. Finally, a discussion of results follows.

METHODOLOGY

A cross-sectional time-series regression for panel data, shown in equation 3, is utilized in this research (Hsiao, 1986).

$$yit = \sum Bxit + Ei + Mt + Nit \quad (3)$$
$$\text{For } i = 1 to 15, t = 1 \text{ to } 120$$

Where: x is the vector of independent variables
B is the vector of regression coefficients
E_i is the individual effect
M_t is the time effect
N_{it} is the random error term

Table 2

TIME SPANS AND AVERAGES

	Airline	AQR span	LFM Span	LFM	AQR	CC	DB	MB	OT
1	AirTran	1/03-12/12	1/03-12/12	0.76	(0.77)	0.83	0.48	2.71	0.79
2	Alaska	1/03-12/12	1/03-12/12	0.78	(1.19)	0.55	1.10	4.01	0.80
3	American	1/03-12/12	1/03-12/12	0.81	(1.49)	1.26	0.75	4.89	0.76
4	American Eagle	1/03-12/12	1/03-12/12	0.72	(2.76)	0.94	1.58	9.44	0.75
5	Continental	1/03-12/11	1/03-12/11	0.82	(1.36)	1.11	1.58	3.69	0.78
6	Delta	1/03-12/12	1/03-12/12	0.81	(1.65)	1.32	1.27	4.99	0.79
7	ExpressJet	4/08-12/12	1/03-12/11	0.75	(1.69)	0.42	1.21	6.00	0.76
8	Frontier	5/05-12/12	5/05-12/12	0.80	(1.18)	0.70	0.94	3.26	0.69
9	Hawaiian	1/05-12/12	1/05-12/12	0.87	(0.65)	0.69	0.11	2.48	0.83
10	Jet Blue	1/03-12/12	1/03-12/12	0.81	(0.75)	0.71	0.02	3.20	0.76
11	Mesa	1/06-12/12	1/03-12/12	0.76	(2.11)	0.59	1.60	5.52	0.65
12	SkyWest	1/04-12/12	1/03-12/12	0.78	(2.12)	0.59	0.99	7.76	0.81
13	Southwest	1/03-12/12	1/03-12/12	0.74	(1.08)	0.22	0.99	4.03	0.82
14	United	1/03-12/12	1/03-12/12	0.82	(1.49)	1.74	0.89	4.34	0.78
15	US Air	1/03-12/12	1/03-12/12	0.80	(1.68)	1.70	1.05	4.99	0.79

One advantage of a cross sectional time series regression model for panel data is that the regression parameters are estimated with all available observations, whereas a monthly index would have a maximum of 120 observations. Indexing would also eliminate the ability to test for differences in response by airline. Pooling all available observations without regard to time period would remove the possibility of incorporating lagged relationships in the model and would not capture changes over time.

The fixed effects version of the cross sectional time series model also provides tests for response differences relative to time (M_t) or individual airline (E_i). These tests involve partitioning the data by year and by airline and performing an ANOVA on the partitioned data to test for main effects relative to time period or airline (Hsiao, 1986). A finding that time period is significant indicates that the mean response across airline differs by month. On average for all 15 airlines, the model may systematically over-predict in some months and under-predict in others. Time effects can be attributed to events that affect the entire industry in a given month, such as weather delays. A finding that individual or airline effects are significant indicates that some airlines have higher or lower LFMs or AQR scores relative to other airlines regardless of the time period analyzed and

there maybe trends in the data.

A simple correlation between AQR and LFM by airline is .52 for this data set. Although this indicates airlines with higher AQR also tend to have higher LFM's it does not address the effect that changes in quality may have on LFM. This correlation could simply be due to better airline management. Likewise, both LFM and AQR have trends over time that will create spurious correlations in a simple regression model thus overstating the R^2 and statistical significance of the results. The methodology selected for this research will correct for both of these problems and address the question of how changes in AQR relative to individual airline and time period averages relate to changes in LFM.

As noted by Butler (1994), seasonality is extremely important and often overlooked in travel research. The data in this research does exhibit seasonal variations. Seasonality can pose problems in estimating time series models (RATS, 2010). For airline passenger data failure to account for seasonality may again lead to spurious correlations and an overstated R^2. There are two approaches for dealing with seasonality: remove the seasonal variation prior to estimating the time series model or incorporate the seasonal variation in the time series model (Moss et al., 2013; RATS 2010). In this research seasonal variation is removed prior to estimation of the time series equations. Removing seasonality from a series can provide a more accurate estimation of the trend portion of a forecasting model (Bowerman, 1993).

By using a decomposition method, an estimate of seasonal variation can be obtained in the form of seasonal indices which are then used to remove the seasonal variation from the time series; thus, isolating variation attributable to long term trends and interventions (Bowerman, 1993; Makridakis, Wheelwright, & Hyndman, 1998; Moss, Ryan & Wagoner, 2003; Moss et al, 2008). In the decomposition approach, the seasonal indices represent the average percentage of annual passengers for each month of the year. The seasonal index for month j ($j=1,\ldots,12$) is calculated as in equation 4.

$$Seasonal\ Index\, i = \frac{1}{nJ} * \sum njsij \qquad (4)$$

Where:

j is the month of the year

n_j is the number of the j-th month in the series

S_{ij} is the i-th "raw" seasonal index for month j

$S_{ij}=Y_t/CMA_t$, CMA_t is the centered moving average at time t

RESULTS

The LFM by month for each of the 15 airlines used in this research is shown in Figure 1. Figure 2 shows the average LFM across all 15 airlines.

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Figure 1
MONTHLY LFM BY AIRLINE 2003-2012

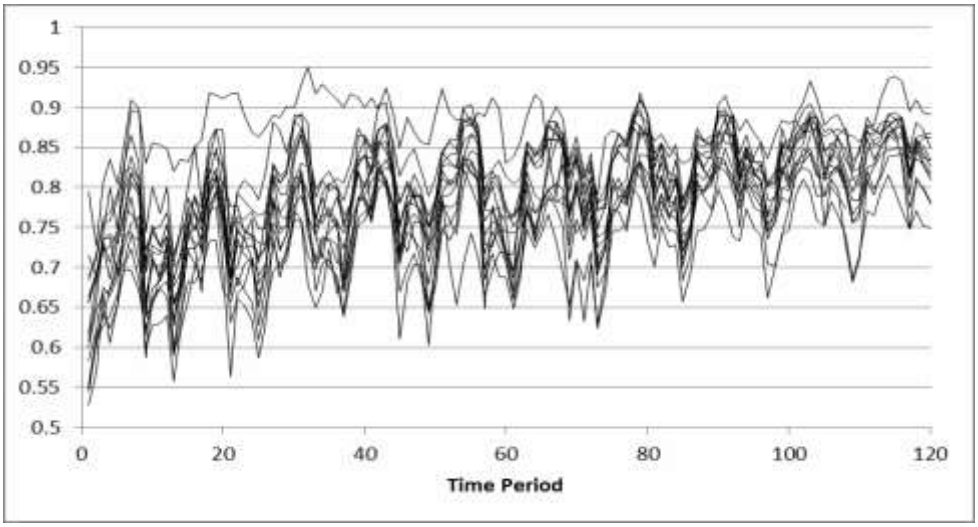


Figure 2
AVERAGE LFM BY MONTH 2003-2012

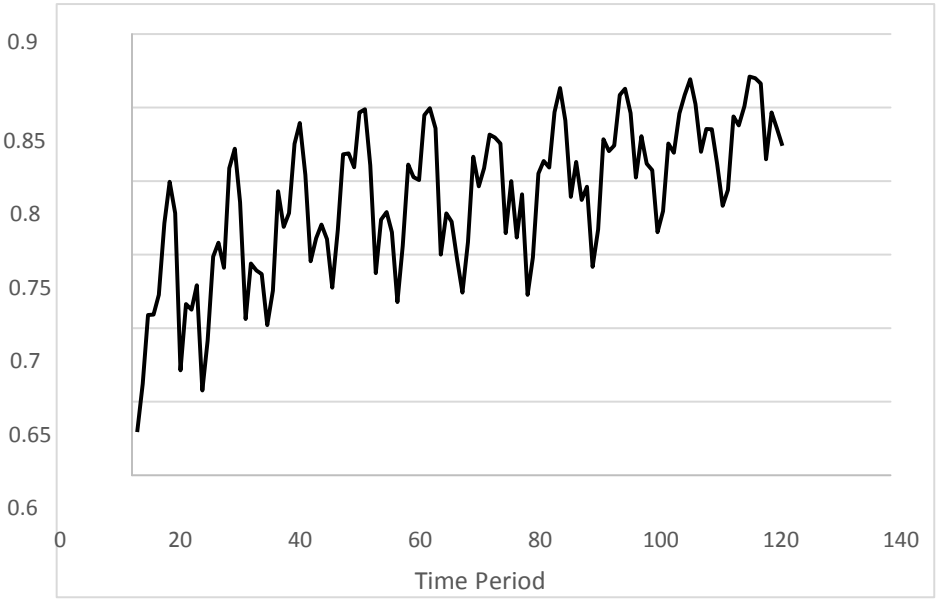
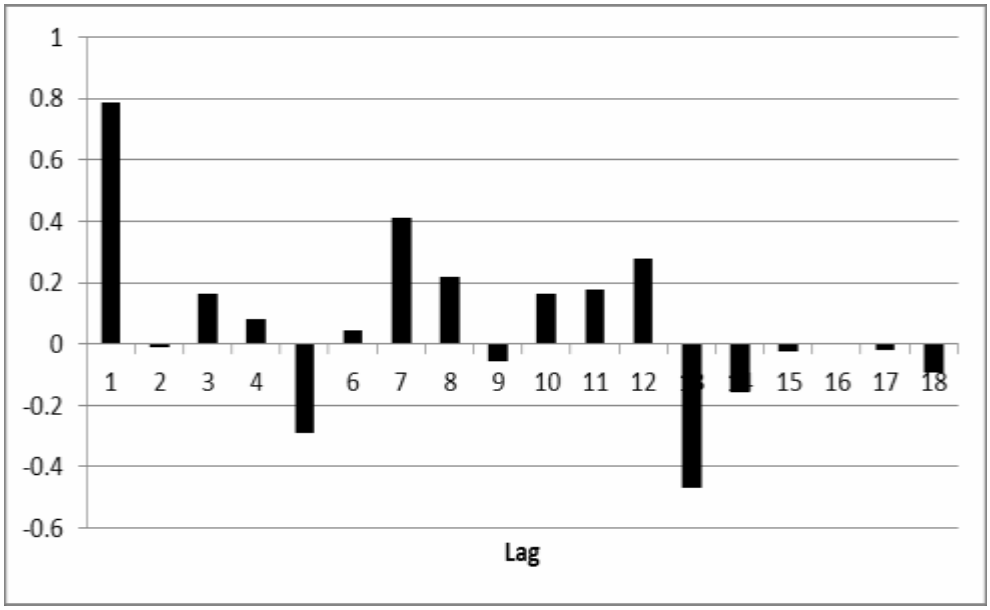


Figure 1 shows a distinct seasonal and trend pattern in the LFMs by individual airline with distinct differences between airlines. This can also be observed in Table 1 were average LFM by airline ranges from a low of 72% to a high of 87%. Figure 2 shows that whereas there are differences between airlines there is also a large degree of commonality between airlines as evidenced by the upward trend and pronounced seasonality that is observed. The trends and seasonality are confirmed by the auto-correlation function (ACF, not shown) and the partial autocorrelation function (PACF) of the LFM shown in Figure 3.

Figure 3
PACF for LFM



The seasonal indices for LFM are shown in Table 3. The industry exhibits a common seasonal pattern but with some differences by airline. The shift in seasonal pattern by airline can be attributed to regional differences between the airlines geographical areas of service. Therefore, each airline's LFM is seasonally adjusted with its own individual seasonal indices.

Table 3
RATIO-TO-CENTERED MOVING AVERAGE SEASONAL INDICES FOR LFM

	Airline														
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.92	0.91	0.94	0.94	0.92	0.88	0.89	0.96	0.89	0.93	0.93	0.92	0.89	0.91	0.91
2	0.94	0.95	0.96	0.95	0.95	0.93	0.96	0.99	0.95	0.96	0.94	0.96	0.93	0.94	0.96
3	1.02	1.03	1.03	1.01	1.03	1.02	1.05	1.01	1.01	1.00	1.01	1.03	1.04	1.01	1.02
4	1.02	1.01	1.02	1.01	1.01	1.01	1.02	1.01	1.01	0.99	1.02	1.02	1.02	1.00	1.02
5	1.01	1.00	0.99	1.01	1.00	1.01	1.02	1.01	1.04	1.02	1.02	1.02	1.03	1.02	1.03
6	1.07	1.04	1.04	1.05	1.07	1.09	1.08	1.01	1.09	1.05	1.07	1.06	1.08	1.06	1.07
7	1.09	1.07	1.08	1.07	1.10	1.11	1.10	1.01	1.06	1.05	1.07	1.07	1.11	1.07	1.07
8	1.04	1.07	1.07	1.05	1.06	1.07	1.05	1.03	1.01	1.03	1.04	1.04	1.06	1.02	1.02

9	0.94	0.96	0.93	0.96	0.95	0.97	0.90	1.00	0.96	0.99	0.97	0.95	0.93	0.96	0.96
10	0.99	0.95	0.98	0.99	0.99	1.00	0.99	1.02	1.01	1.01	1.00	0.99	0.98	1.01	0.99
11	0.98	0.99	0.97	0.99	0.96	0.97	0.97	1.00	0.99	0.99	0.97	0.98	0.96	1.00	0.99
12	0.97	1.01	0.99	0.98	0.97	0.96	0.96	0.98	0.98	0.98	0.97	0.96	0.96	1.00	0.97

The seasonally adjusted LFM by airline and average seasonally adjusted LFM for the 15 airlines are shown in Figures 4 and 5.

Figure 4
SEASONALLY ADJUSTED LFM BY AIRLINE, 2003-2012

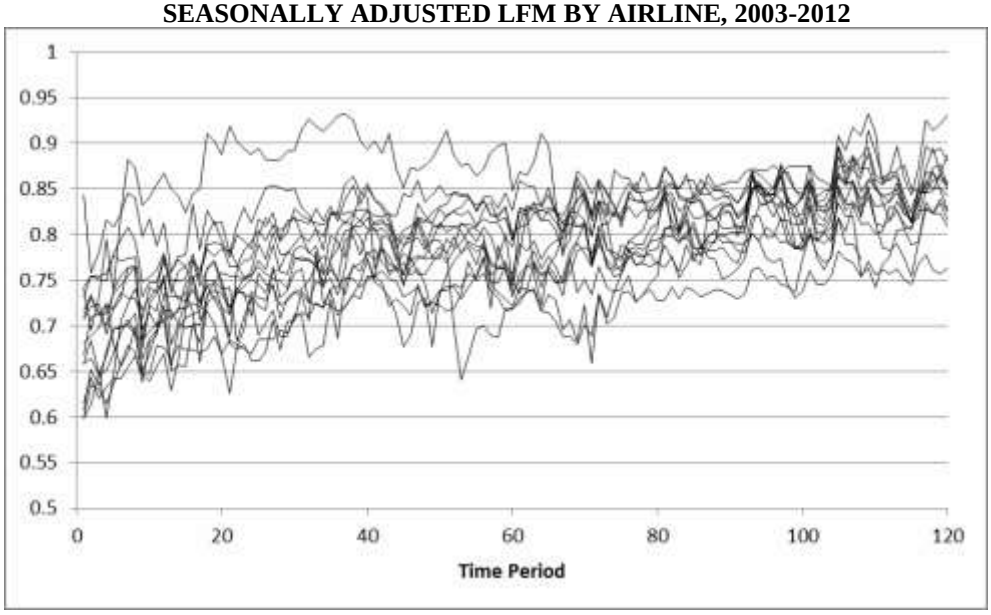
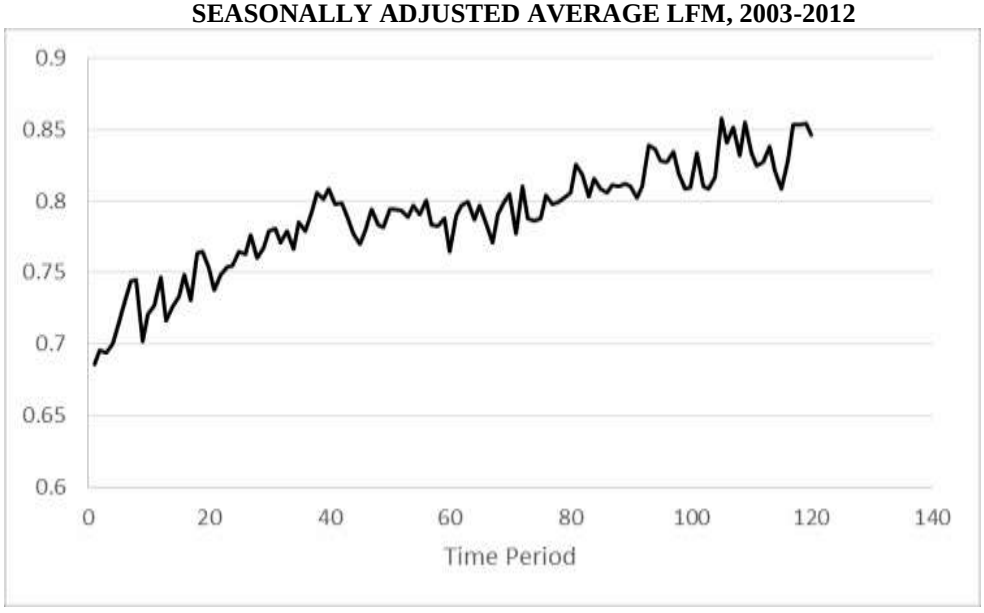


Figure 5
SEASONALLY ADJUSTED AVERAGE LFM, 2003-2012



As shown in Figures 4 and 5, the seasonal variations from each individual series and on average have been removed. This is confirmed by the ACF and PACF of the seasonally adjusted LFM (not shown). The LFM in Figures 4 and 5 do however still exhibit an overall upward industry trend over time, overall industry wide deviations in specific time periods and differences in mean response by airline regardless of time period. A panel test, shown in Table 4, confirms these observations.

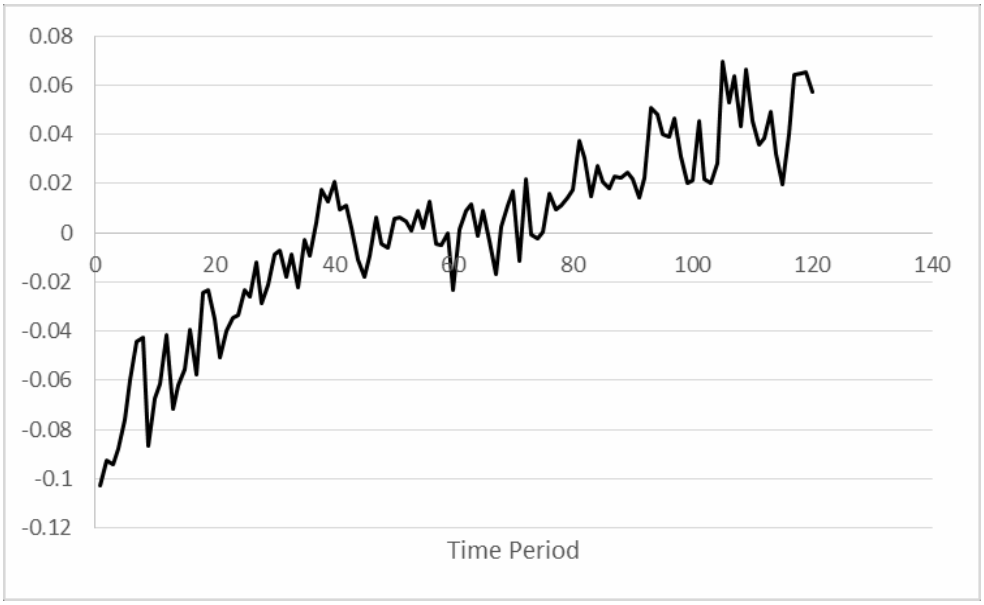
Table 4
PANEL TEST FOR SEASONALLY ADJUSTED LFM

Analysis of Variance for Series seasonally adjusted LFM

Source	F-Statistic	Sign. Level
INDIV	221.794	0.000
TIME	27.314	0.000

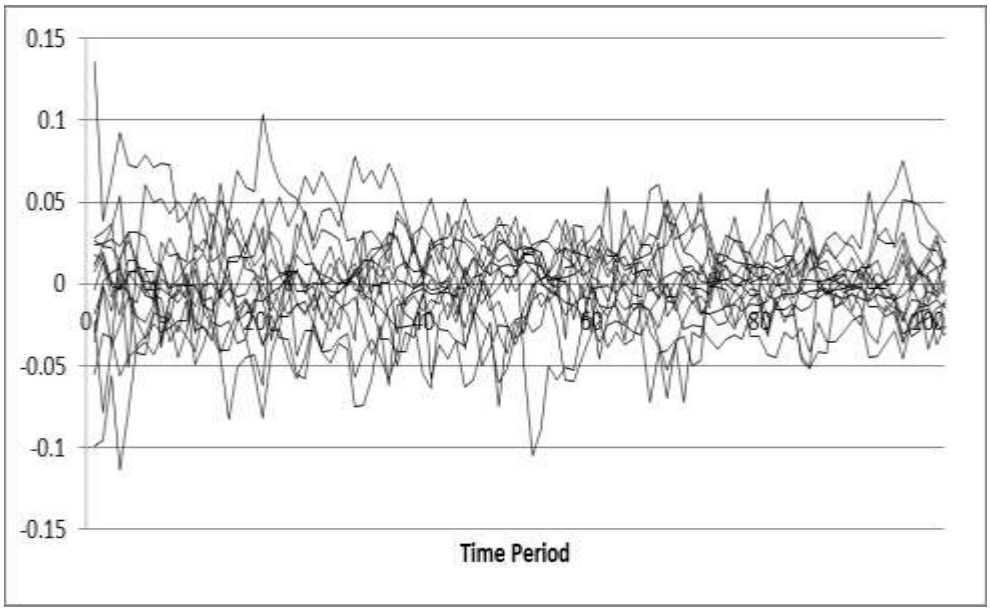
Individual panel adjustment for the seasonally adjusted LFM on average is shown in Figure 6. The overall differences by airline have been removed from the series, as shown in Figure 6, but there is still an overall industry trend upwards.

Figure 6
AVERAGE SEASONALLY ADJUSTED LFM PANELED BY INDIVIDUAL



A panel adjustment for time period removes the overall industry trends and specific time period differences (not shown). Figure 7 shows the results of paneling the seasonally adjusted LFM by both individual and time period. Individual differences over time, the overall positive industry wide trend and specific time period industry wide deviations have been removed resulting in a panel data set with constant means and no individual effects. This is confirmed by the ACF and PACF of the adjusted series (not shown).

Figure 7
SEASONALLY ADJUSTED LFM PANELED BY INDIVIDUAL AND TIME



A panel test for the individual and time paneled series confirms that individual and time effects have been removed (not shown). The seasonally adjusted LFM paneled by time and individual results in a variable that is measuring the difference between each individual airline's AQR score versus overall industry average for that time period and is this monthly difference more or less than the individual airlines normal performance. This can restated as how each airline is performing compared to industry average and is the airline performance when compared to industry average improving or declining period to period.

Individual airline and average AQR scores, shown in Figures 8 and 9, exhibit the similar seasonal, trend and differences between airlines and over time as the LFMs. Therefore AQR scores are also seasonally adjusted and paneled by time period and individual airline.

Figure 8
AQR BY AIRLINE, 2003-2012

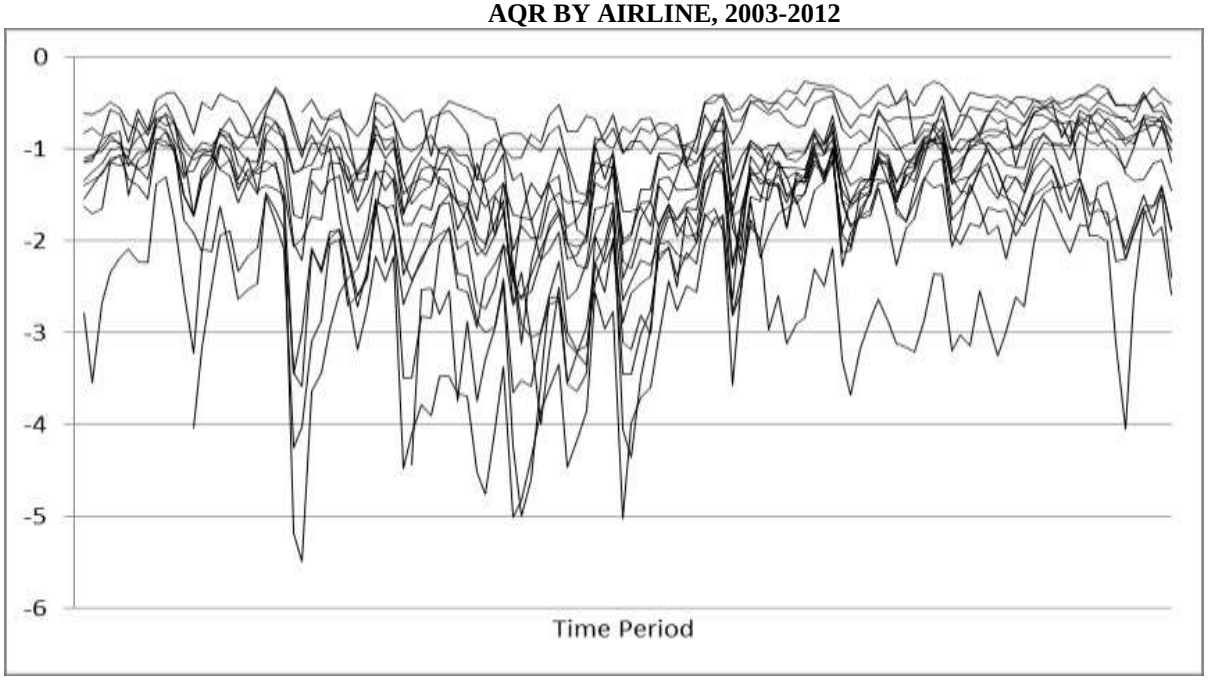
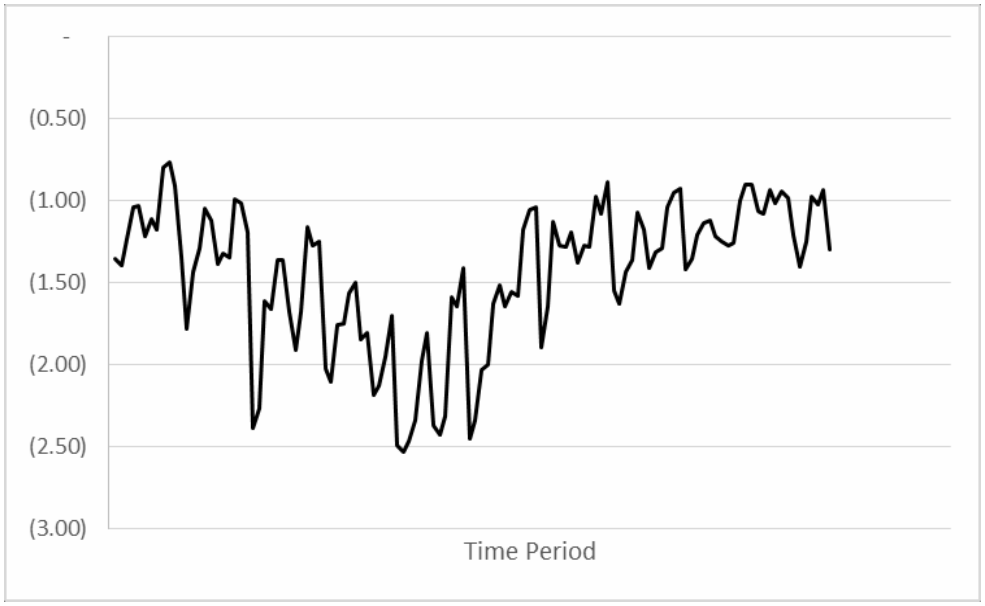


Figure 9
AVERAGE AQR BY AIRLINE, 2003-2012



A panel regression, shown in Table 5, results in the following model for the LFM. The LFM and AQR scores used in estimating the equation shown in Table 5 have been seasonally adjusted using individual seasonal indices and paneled by time and individual airline. Lags are shown in brackets, {lag}.

Table 5
PANEL REGRESSION

Variable	Coeff	Std Coef.	Sign.
LFM{1}	0.740	.737	0.000
LFM{4}	0.092	.074	0.001
LFM{5}	(0.070)	(.073)	0.014
LFM{7}	0.059	.090	0.009
LFM{11}	0.087	.135	0.000
AQR	(0.004)	(.059)	0.016
AQR{1}	0.003	.047	0.031
AQR{7}	0.003	.069	0.023
AQR{12}	(0.003)	(.070)	0.017
R^2	0.685		
Durbin-Watson	2.04		
		Sign.	
Ljung-Box Q	17.39	.136	
Hausman Test	46.25	.000	
Individual Effects	F = 1.115	0.338	
Time Effects	F = 0.191	1.000	

The Durbin-Watson statistic, the ACF and PACF, the Ljung-Box Q statistic all indicate the residuals derived from the equation shown in Table 5 are white noise. A panel tests confirms there are no time or individual differences remaining in the residual series. A Hausman test confirms the fixed effects model is the correct form of the panel model for this data. The 68.5% R^2 is for the paneled data, the R^2 for the original series is 93%. The equation in Table 5 shows an inverse relationship between seasonally adjusted LFM and the seasonally adjusted AQR on a current basis. The model also shows a positive relationship on a lagged basis. This model shows as airline load factors increase their concurrent AQR scores suffer. However, increasing current AQR will result in a positive change in future load factors. This conflicting result confirms Anderson et.al.'s proposition that there is a tradeoff between customer satisfaction and profitability and there is a lagged relationship between improvements in quality and improvement in performance.

To determine if the information content of the seasonally adjusted AQR is sufficient to explain the relationship between quality and seasonally adjusted LFM the model is estimated using the four source variables that contribute to AQR scores. Results are shown in Table 6.

Table 6 PANEL REGRESSION USING UNDERLYING AQR VARIABLES		
Variable	Coeff	Sign.
LFM{1}	0.734	0.000
LFM{4}	0.089	0.001
LFM{5}	(0.064)	0.023
LFM{7}	0.058	0.008
LFM{11}	0.083	0.000
OT	(0.030)	0.001
OT{2}	0.030	0.001
OT{7}	0.025	0.005
DB	0.003	0.018
DB{1}	(0.003)	0.014
DB{11}	0.001	0.050
MB{1}	(0.001)	0.063
MB{2}	0.001	0.040
MB{8}	(0.001)	0.058
MB{10}	0.001	0.081
CC{6}	0.002	0.062
CC{7}	(0.002)	0.017
R^2	0.696	
Durbin-Watson	2.06	
		Sign.
Ljung-Box Q	15.43	.219
Hausman Test	49.04	.000
Individual Effects	F = 1.259	.226
Time Effects	F = 0.213	1.000

Using the individual components of the seasonally adjusted AQR score in the panel regression results in a far more complex model, and adds little to the explanatory power of the model. There is an increase in R^2 of only .011. The Durbin Watson statistic, the ACF and PACF, the Ljung-Box Q statistic all confirm the residuals are a white noise series. A panel test shows there are no time or individual differences in the residuals. A Hausman test confirms the fixed effects model is the correct form of the panel model. The relationships between seasonally adjusted OT, seasonally adjusted DB and seasonally adjusted MB and seasonally adjusted LFM are consistent with the relationship found between the seasonally adjusted AQR score and seasonally adjusted LFM. CC contains much of the same information as OT, DB and MB and it is, therefore, not surprising it is not more prevalent in the model.

DISCUSSION

Empirical results of this study provide conclusive evidence that AQR scores are related to load factors in the airline industry. The results also indicate that the AQR score does capture essential content often cited as measures of quality in the airline industry: on time performance, lost luggage, denied boardings and customer complaints. In addition, the AQR has the advantage of being a statistic that is readily available benchmark for airlines, and it has been published for a considerable time. The resulting conclusions are first, that there is little to be gained by creating a new construct from the underlying variables to replace the AQR in studies of this type. Second, that changes in quality relative to individual airline average and time period average do relate to

changes in LFM. The methodology used allows us to conclude that this relationship holds across airlines regardless of the individual airline's comparative quality or load factors.

Study findings indicate an inverse relationship between quality, as measured by the AQR score, and load factors on a current time period basis. This may seem contradictory to accepted quality management theory. However, this conclusion can be explained by analyzing what load factors are measuring. Load factors are a form of capacity utilization. As load factors increase there is more stress on the system. This means more passengers enplane and deplane per flight, higher seat utilization, more passengers for a fixed size flight crew to service, and more baggage to handle per flight. The added stress is likely to increase lost luggage, time to enplane and deplane (resulting in delays), denied boardings, and customer complaints: all components of the AQR score. This result supports Anderson and Mittal's (2000) position that there is an optimal point for customer satisfaction attributes.

The lagged positive relationship between AQR and load factors is consistent with quality management theory. Airlines that provide higher quality generate future passengers via reputation and repeat customers. The key for carriers is to maintain or balance AQR levels when demand increases and load factors go up. Clearly, capacity should increase or decrease in anticipation of seasonal demand. Airlines might consider shifting aircraft types and numbers to better fit passenger flow. Changes in routing software could be made that would automatically route connecting traffic through better weather hubs in anticipation of poor weather seasons. During periods of good weather across the US, connecting flights could be automatically shifted to lower demand airports, reducing system stress.

Finally, ground employee and air crew training should emphasize their key role in airline image, particularly when system capacity is stretched. Management must push decision making to the lowest level possible and allow their staffs the ability to immediately ameliorate gaps in cabin service, refunds, baggage handling, and treatment of delayed or denied passengers. In the air, something as simple as a free drink or meal could be offered (along with a helpful attitude on the part of cabin crew). On the ground, discount or free travel, lodging, food, or future cabin upgrades might be utilized. Training and automatically shifting capacity could also help. The individual differences among airlines over time observed in this research indicate that some are better than others in this regard. Future research could address the financial gains on a current basis resulting from high load factors versus the future loss resulting from the decline in quality resulting from the higher load factors.

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OPEN STANDARDS AND LICENSE CHOICE IN OPEN SOURCE SOFTWARE

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ABSTRACT

Open standards are important in markets for Internet technology to ensure interoperability of software components across the Internet. Many applications of the Internet technology experience network effects.Owners of open source software may benefit from network effects and influence future standards development through their license choice. This study analyzes the data of 118 open source software projects that develop Internet technology to explore the relationship between open standards and the license choice made by software owners. It tests the hypothesis of standardization and the hypothesis of commercialization. Results of the statistical analysis show that programmers devote more efforts to Internet projects using nonrestrictive licenses due to the importance of network effects and standards development in Internet technology. Further investigation of a larger sample of all open source software projects shows that projects with the topic of Internet are more likely to choose nonrestrictive licenses than the restrictive ones, especially when the intended audience is developer or system administrator. The results lend support to the theory of network effects and the standardization hypothesis.

INTRODUCTION

Technological standards are technical specifications that determine the compatibility or interoperability of different technologies. Open standards, as opposed to proprietary standards, are standards that are freely and publicly available for implementation and use. Open standards enable interoperability of software components so that different devices and applications can work together across the Internet. Open standards have stimulated innovations in the Internet technology and have led to the growth of new business areas such as e-Commerce, automation of data processing, and cloud services.

Many products and services of the Internet technology experience network effects. Network effects occur when the value of a product to an individual user increases with the number of the other users. The existence of network effects makes standards particularly important in markets for Internet technology. According to the Internet Society, a non-profit and professional organization that determines and publishes many open standards for the Internet (http://www.internetsociety.org, accessed on November 5, 2015), a technology is more likely to become a standard if it is widely used. And a technology will gain more users after it is established as a standard. The additional benefits of becoming a standard include the capability to affect the direction of future standards development (Gamalielsson et al., 2015).

Open standards and open source software are closely related. The source code of open source software is free for users to access, modify, and redistribute. Open standards reduce the risk of lock-in among different open source technologies and enable collaborative development within open source communities. It is widely recognized that open source communities have

contributed significantly to the establishment of key standards for the Internet (see e.g. Bresnahan & Yin, 2007; Friedrich, 2011).

Ghosh (2005) argues that owners of an interoperable technology can control the development of the standard through licensing conditions that discriminate or exclude certain groups of users. Owners of an open source software can choose to release the software under an open source license that is approved by the Open Source Initiative (OSI). The open source licenses can be divided into two categories: restrictive and nonrestrictive. The restrictive license requires that modified versions of the open source code remain open and prohibits the mixing of open and proprietary code. That is, if a proprietary project incorporates code released under a restrictive license, then this project must also be distributed under the terms of the same license. This is called the "viral" nature of the restrictive license (Feller & Fitzgerald, 2002, p. 19). In contrast, the nonrestrictive license may or may not require the modified versions of the open source code be open and allows the mixing of open and proprietary code. Code released under nonrestrictive licenses can be incorporated into other code without affecting the openness of the incorporating project (see, e.g., Lerner & Tirole, 2002). GPL (General Public License) is an example of restrictive license and LGPL (Less General Public License) is an example of nonrestrictive license.

In the existing literature there are studies that discuss the relationship between open standards and licensing terms of technology. Gamalielsson et al. (2015) argue that permissive licensing terms involving zero royalty of patents are crucial for increasing software interoperability. Ghosh (2005) analyzes the use of LGPL license in an open source word processing software, OpenOffice, to argue that open standards should be compatible with open source licenses to promote competition in the market. Lerner and Tirole (2005) suggest that standards might be an important concern to open source projects in the area of Internet.

There are empirical studies that investigate the relation between license type and the success of open source software. The findings are mixed. Lerner and Tirole (2005) find that the restrictiveness of open source license has a negative impact on developer input. Stewart et al. (2006) find that nonrestrictive licenses tend to stimulate greater user interest. Subramaniam et al. (2009) find that restrictive licenses have a negative impact on developer input, but a positive impact on user interest.

This study explores the impact of open standards and network effects on the license choice made by open source software owners. It investigates a sample of open source projects that develop Internet technology since open standards and network effects are important to the market of Internet technology.This study finds a negative relationship between the restrictiveness of license and the developer effort in these projects.

The main contribution of this study is to provide empirical evidence to cast light on the impact of standards development on license choice in open source software. Prior studies have not tested the relations between standards and open source license. This study uses a unique sample of open source software aimed at developing Internet technology, which complements the prior empirical work on open source software.

We begin the next section by discussing hypotheses: the standardization (or network effects) hypothesis and the commercialization (or competitive advantage) hypothesis. We then present an empirical analysis of the projects focusing on Internet technology to test the above hypotheses. We further investigate how license choice in all open source projects might respond to project topic and intended audience. The paper is organized as follows. Section 2 discusses the

hypotheses that lay foundation for the empirical analysis. Section 3 describes the data. Section 4 presents results of regression analysis and section 5 concludes.

HYPOTHESES

In this section we develop competing hypotheses of programmer efforts as a response to the license choice of open source projects.

Internet technology is subject to network effects: the value of a technology to a user increases with the number of other users of the same technology. For example, the value of a social network website to a single user is limited if there are not many other users of the same website.

The network externality not only exists among users, but also exists between developers and users (Bresnahan & Yin, 2007). All else equal, a user will choose a technology with the most associated applications. A large number of developers indicates greater availability of future applications of the technology. Thus the user's utility increases with the number of developers. Similarly, developers will tend to put their effort into a technology that have the largest user group. A larger number of users increases the probability that a technology becomes a standard. The developers get rewards from standardization through increase in software usage, improvement in software interoperability, and influence on future development direction. The developers' utility thus increases with the number of users.

For open source software projects that develop Internet technology, the benefits of standardization are significant. For websites, e-Business, and cloud services to work, there must be compatibility and interoperability of different software modules and components. Open standards, by making standards freely available to the public, have reduced the hold-up problem between different technologies and greatly boosted innovations in the Internet technology.

The network externality between users and developers also exists in that developers of open source projects get feedback such as bug reports from users and fix the bugs. The quality of the projects therefore increase as more people use the software. Both the programmers and the users benefit from the continued improvement of the program. Some studies further argue that users of open source projects are also developers. In many cases, programmers create open source software for their own direct use (see Lundvall & Vinding, 2004; Von Hippel, 2002; Raymond, 2000).

Friedrich (2011) argues that the owner of a new technology can keep it private to gain competitive advantage, or to share it with the public by making it into a standard. Similarly, owners of open source projects can strategically choose license type to achieve their goals. They can choose restrictive licenses to keep all future contributions to the project open, preventing private firms from "hijacking" the open source technology (see Tirole & Lerner, 2002). The restrictive licenses thus gives the original innovators competitive advantage if they want to commercialize the open source project in the future. Alternatively, the owners can choose nonrestrictive licenses so that the spread and market acceptance is faster, which is crucial to establish a standard. The costs are that the earlier innovators may not receive contributions from private firms because they can keep their subsequent work private when incorporating open source code released under nonrestrictive licenses. For open source projects in Internet technology, the benefits of standardization may exceed the costs of lost contributions. For open source projects where commercialization is a more important goal, the benefits of fast spread may be smaller than the costs of being hijacked by private firms. To summarize, the creators of

open source technology will choose nonrestrictive licenses for the projects that are essential for establishing or implementing standards and choose restrictive license for projects that they plan to commercialize.

H1 The standardization hypothesis. Programmers contribute more efforts to open source projects with nonrestrictive licenses to gain network externality and facilitate standards establishment.

H2 The commercialization hypothesis. Programmers contribute more efforts to open source projects with restrictive license to gain competitive advantage and facilitate future commercialization.

DATA

The dataset are selected from projects listed on freshmeat.net. The website was started in year 1997 and had been the largest index of Linux, UNIX, and cross-platform software, mostly released under an open source license. In year 2009, all freshmeat.net projects were integrated into sourceforge.net, which is another repository of open source software. Subsequently freshmeat.net was renamed to freecode.com and is no longer updated since June 2014 due to low traffic levels (see http://freecode.com/about and https://sourceforge.net/blog/freshmeat-integration/ , accessed on December 1, 2015). This study uses the freshmeat data as of year 2009 to remove the impact of the lower activity level on freshmeat.net after the integration with sourceforge.net.

As of August, 2009, freshmeat.net contained approximately 44,000 projects, most of which conform to the Open Source Definition. Both qualitative and quantitative information is available for each of the projects. The qualitative variables include project title, author, license type, intended audience, programming language, development status, and topic of program. The topic of a program can be games/entertainment, Internet (including browsers, HTTP servers, and site management, etc.), Software Development (examples are compilers, bug tracking tools, and libraries), and Systems (examples are operating systems, system administration, and networking). The intended audience includes End user, Developer,System administrator, and others. According to the terms and provisions of each license, the license is restrictive if it is GPL (General Public License), and nonrestrictive otherwise.

The quantitative variables include age of the project, date of last update, date of last release, vitality score, popularity score, rating, and number of subscribers. The vitality score for a project is formulated to reward the number of releases and to punish the days elapsed since last release. The popularity score takes into account of the number of record hits, the number of URL hits, and the number of subscriptions, where record hits is the number of accesses to the project page hosted at Freshmeat.net, and URL hits is the number of accesses for every URL associated with a project that leads off of freshmeat.net to the download site of the project.

A lot of projects are listed with multiple intended audience and multiple topics. We select the projects with single intended audience and single topic. Thus 16442 projects are left in the sample, among which 118 projects have the topic of Internet. Table 1 lists the means and standard deviations of the quantitative variables.

Table 1
DESCRIPTIVE STATISTICS

	Sample of all projects		Subsample of Internet projects	
	Mean	S. D.	Mean	S. D.
Added (days ago)	1139	634	787	474
Last release (days ago)	1033	639	589	384
Vitality score	2.99	4.2	4.7	5.2
Popularity score	102	84	141	91
Number of subscriptions	2.7	4.2	4.8	4.7

METHODOLOGY AND RESULTS

We first investigate the sample of 118 open source projects developing Internet technology. We want to know in the area of Internet technology whether innovative efforts are allocated towards the projects using nonrestrictive licenses, controlling for age, current popularity, and intended audience of the projects.

To test the relation between programmer efforts and license choice, we estimate the following equation:

$$Vitality = \beta_0 + \beta_1 Age + \beta_2 Popularity + \beta_3 SA + \beta_4 EU + \beta_5 DE + \beta_6 License, \quad (1)$$

where Age is the days between the date of the first publication of the project and August 1, 2009 and Popularity is the score reflecting the number of hits and subscriptions. SA, EU, and DE represent three types of intended audience: System Administrator, End User, and Developer. License is equal to one if the project uses a restrictive license (GPL) and zero otherwise. The vitality score, which reflects the frequency of new releases, is a proxy for the programmer efforts devoted to the project. The vitality score for a project is calculated as:

$$\text{vitality score} = \frac{\text{number of releases} * \text{age}}{\text{days since last release}}$$

Table 2 lists the results of three regressions. Regression 1 in Table 2 shows the results of the regression of vitality score against age and popularity score. The estimated coefficient of Popularity is 0.02 (significant at the 1% level), indicating that the vitality of a project is positively related to its popularity. This suggests that more effort is devoted to the more popular projects. Therefore innovative effort is distributed efficiently towards widely used software.

Table 2
REGRESSION OF PROGRAMMER EFFORT AGAINST LICENSE TYPE [a]

	Regression 1	Std Error	Regression 2	Std Error	Regression 3	Std Error
Intercept	-0.19	(1.05)	-1.08	(1.13)	-0.11	(1.25)
Age	0.003*	(0.0009)	0.003*	(0.0009)	0.003*	(0.0009)
Popularity	0.02*	(0.001)	0.02*	(0.005)	0.02*	(0.005)
System Admin			3.59**	(1.62)	3.64**	(1.60)
End User			1.28	(1.06)	1.54	(1.06)
Developer			1.05	(1.46)	0.87	(1.45)
License					-1.59***	(0.90)

R^2	0.18	0.22	0.25
Adjusted R^2	0.17	0.19	0.21

*Significant at the 1% level **Significant at the 5% level ***Significant at the 10% level

a. These regressions use the subsample of 118 projects, for which the topic is Internet. The dependent variable is vitality score; standard errors are reported in parentheses.

Regression 2 in Table 2 includes three intended audience dummies: System Administrator, End User, and Developer to check if there is a difference in the effort devoted to projects geared toward different audiences among all Internet projects. The estimated coefficient of System Administrator is 3.59 (significant at the 5% level), indicating that there are more releases if the Internet project is aimed at system administrators. Programmers developing Internet technology publish more releases to system administrators than to audience in the baseline group, which includes advanced end users, quality engineers, and other audiences.

Regression 3 in Table 2 includes the license dummy to check the relationship between license type (equal to one if restrictive) and programmer effort. By the standardization hypothesis, there should be a negative relationship between license type and vitality. Contrarily, by the commercialization hypothesis, the relationship should be positive. In Regression 3 the estimated coefficient of the license dummy is significant and negative (-1.59). The results lend support to the standardization hypothesis. More effort is allocated to Internet projects under nonrestrictive licenses. This indicates that getting a larger number of users might be more important for these projects, even if there are risks of being "hijacked" by the private firms. For projects developing Internet technology, getting market acceptance is important for future standardization.

Next we use the whole sample of 16,442 open source projects to investigate the relation between various project topic and license choice. By the standardization hypothesis, projects with the topic of Internet tend to use nonrestrictive licenses. We use logistic regressions to test the hypothesis, where the dependent variable is the license dummy that is equal to one if the project is under a restrictive license (GPL), and zero otherwise. Table 3 lists the regression results.

Table 3
REGRESSION OF LICENSE TYPE AGAINST TOPIC AND INTENDED AUDIENCE [a]

	Regression 1	Std Error	Regression 2	Std Error	Regression 3	Std Error
Intercept	0.58*	(0.04)	0.46*	(0.04)	0.63*	(0.04)
Age	0.0003*	(0.00004)	0.0007*	(0.00003)	0.0003*	(0.00004)
End User	0.92*	(0.05)			0.96*	(0.05)
Developer	-1.11*	(0.06)			-1.17*	(0.06)
System admin	0.03	(0.09)			0.01	(0.09)
Desktop			-0.68*	(0.17)	-1.07*	(0.22)
Internet			-0.52*	(0.19)	-0.48***	(0.26)
Utility			0.07	(0.11)	0.23	(0.20)
Software			-1.27*	(0.12)	-1.53*	(0.37)
EU*Desk					0.07	(0.35)
EU*Int					-0.41	(0.47)
EU*Uti					-1.07*	(0.24)
Dev*Desk					1.35	(1.43)

Dev*Int		0.68	(0.62)
Dev*Uti		0.64	(0.51)
Dev*Soft		1.78*	(0.39)
SA*Int		0.06	(0.70)
SA* Uti		-0.18	(0.47)
*Significant at the 1% level **Significant at the 5% level ***Significant at the 10% level			
a. The regression uses the full sample of 16,442 projects. The dependent variable is a dummy that is equal to one if the project is under a restrictive license (GPL), and zero otherwise; standard errors are reported in the parentheses.			

Regression 1 in Table 3 reports the results of a logistic regression of license type against three Intended Audience dummies: System Administrator, End User, and Developer. The estimated coefficients of End User and Developer are 0.92 and -1.11, respectively (both significant at the 1% level), showing that projects geared towards end user tend to use restrictive licenses, while projects geared towards developer tend to use nonrestrictive licenses. This indicates that commercialization might be a more important goal for owners of open source projects aimed at end users, while network effects might be stronger for projects aimed at developers.

Regression 2 in Table 3 shows the results of a logistic regression of license type against four topic dummies: Desktop Environment, Internet, Utility, and Software Development. By the standardization hypothesis, there should be a negative relationship between license type and the topic of Internet. By the commercialization hypothesis, the relationship should be positive. In Table 3 Regression 2 the estimated coefficient of the Internet dummy is significant and negative (-0.52), providing support to the standardization hypothesis. Compared to projects in the baseline group with topics such as communications, multimedia, and others, projects with the topic of Internet are less likely to use restrictive licenses. The estimated coefficients of the Desktop dummy and the Software dummy are also significant and negative (-0.68 and -1.27, respectively), indicating that projects with topics of desktop environment and software development tend to use nonrestrictive licenses as well.

Regression 3 in Table 3 shows the results of a logistic regression of license type against intended audience, topic, and the interaction terms between them. The estimated coefficient of the topic of Internet is significant and negative (-0.48), indicating that projects with the topic of Internet is more likely to choose nonrestrictive licenses.

We summarize the results of Regression 3 in Table 3 to show the total effect of each variable on license choice. We get -0.97 for an Internet project aimed at developers by adding the coefficients of three variables: Internet (-0.48), Developer (-1.17), and the interaction term between Internet and Developer (0.68). Similarly, we get -0.41 for an Internet project aimed at system administrators, and 0.07 for an Internet project aimed at end users. This indicates that projects developing Internet technology tend to use nonrestrictive licenses when the intended audience is developer or system administrator. This finding is consistent with the standardization hypothesis. Internet projects tend to use restrictive licenses only when the intended audience is end user. This might be because projects aimed at end users have higher probability of future commercialization and will try to prevent the source code from being “hi-jacked” by private firms.

CONCLUSION

This study finds that for open source projects developing Internet technology, programmers devote more efforts to projects using nonrestrictive licenses. It also finds that projects with the topic of Internet are more likely to use a nonrestrictive license, especially when the intended audience is developer or system administrator. Both findings support network effects theory and the standardization hypothesis.

The main contribution of this research is in empirically testing the theory of the impact of open standards on open source license choice. It also complements earlier studies by analyzing a sample of open source projects focusing on Internet technology. It further uses logistic regressions to examine a larger sample of open source projects with various topics.

There are several limitations in this research that should be addressed in the future work. First, there are alternate theories to explain the license choice of open source projects, for example, the theory of signaling effects, i.e., programmers may get peer recognition and future job offers by working on open source projects (Lerner & Tirole, 2002). The regression results show that projects aimed at developers tend to use nonrestrictive licenses. This might indicate the existence of signaling effects. However, it is difficult to distinguish these effects using current data. Second, to understand the motivations behind programmers' decisions to devote their effort to a certain open source project, future research may need to collect subjective data. Third, future research need to better understand the mechanism for the emergence and establishment of new standards and the interactions between standards institutions and open source communities.

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MOBILE TELEPHONY: WHAT ARE THE INFLUENCING FACTORS OF USING A MOBILE PHONE IN CAMEROON?

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ABSTRACT

Individual adoption of technology has been studied extensively in the workplace (Brown & Venkatesh, 2005). But far less attention has been paid to adoption of technology in the household (Brown & Venkatesh, 2005). Obviously, mobile phone is now integrated into our daily life. Indeed, according to a forecast from International Data Corporation (IDC), the market was supposed to grow from 26% to reach 1.288 billion mobile phones sold in the world in 2014 (ZDNet, 2015). But the carriers made better than the IDC's forecast with 1.3 billion mobile phones delivered in the world in 2014, that is, an annual growing of 27.6% (ZDNet, 2015). In 2013, the carriers delivered more than one billion mobile phones in the world, representing a 38.2% growth comparatively to 2012 (725.8 millions) (ZDNet, 2015). In addition, according to Cisco, one of the greatest global networking companies, there will be 5.2 billion mobile phone users in the world by 2017 while the population will be reaching 7.6 billion people (Ferland, 2013). The purpose of this study is then to pursue the investigation on the determining factors that make such people around the world are so using the mobile phone. On the basis of the moderator-type research model developed by Brown and Venkatesh (2005) to verify the determining factors in intention to adopt a computer in household by American people, this study examines the determining factors in the use of mobile phone in household by Cameroonian people. Data were randomly gathered from 505 Cameroonian people (from Yaounde and Douala; the two more important cities in Cameroon) who own a mobile phone. Data analysis was performed using the structural equation modeling software Partial Least Squares (PLS). The results revealed, among others, that half of the variables examined in the study showed to be determining factors in the use of mobile phone by Cameroonian people.

INTRODUCTION

Since numerous years, mobile phone is used for different professional purposes, particularly by senior managers in the workplace. And this technology is more and more used in the workplace since mobile applications have been integrated to enterprise business strategies. Individual adoption of technology has been studied extensively in the workplace (Brown & Venkatesh, 2005). But far less attention has been paid to adoption of technology in the household (Brown & Venkatesh, 2005). Obviously, mobile phone is now integrated into our daily life. Indeed, according to a forecast from International Data Corporation (IDC), the market was supposed to grow from 26% to reach 1.288 billion mobile phones sold in the world in 2014 (ZDNet, 2015). But the carriers made better than the IDC's forecast with 1.3 billion mobile phones delivered in the world in 2014, that is, an annual growing of 27.6% (ZDNet, 2015). In 2013, the carriers delivered more than one billion mobile phones in the world, representing a 38.2% growth comparatively to 2012 (725.8 millions) (ZDNet, 2015). In addition, according to Cisco, one of the greatest global networking companies, there will be 5.2 billion mobile phone

users in the world by 2017 while the population will be reaching 7.6 billion people (Ferland, 2013). So about 70% people worldwide will be using a mobile phone by 2017.

Few studies have been conducted until now which investigate the intention to adopt a mobile phone by people in household (in the case of those who do not yet own a mobile phone) or the use of mobile phone in the everyday life of people in household (in the case of those who own a mobile phone). Yet we can easily see that mobile phone is actually completely transforming the ways of communication of people around the world. It is therefore crucial to more deeply investigate the determining factors in the use of mobile phone by people in household. The purpose of this study is then to pursue this investigation of the determining factors that make such people around the world are so using the mobile phone. The related literature on the actual research area of mobile phone is summarized in Table 1.

Table 1
RELATED LITERATURE SURVEY
(ADAPTED FROM ISIKLAR AND BÜYÜKÖZHAN, 2007, P. 267; AND UPDATED)

Research Areas	***References***
Mobile phone diffusion and its impacts on people's daily life.	LaRose (1989) Kwon & Chidambaram (2000) Botelho &nd Costa Pinto (2004) Funk (2005) Andonova (2006) Centrone et al. (2007) Ehlen & Ehlen (2007) Fillion & Berthelot (2007) Fillion & Le Dinh (2008) Kurniawan (2008) Abu & Tsuji (2010) Sripalawat et al. (2011) Abdul-Karim et al. (2010) Fillion & Booto Ekionea (2010) Glajchen (2011) Kuznekoff & Titsworth (2013) Kwun et al. (2013) De Matos et al. (2014) Suyinn et al. (2014) Takao (2014) Velmurugan & Velmurugan. (2014) Paul et al. (2015)
Mobile phone ownership and usage.	LaRose (1989) Kwon & Chidambaram (2000) Palen et al. (2000) Aoki & Downes (2003) Selwyn (2003) Davie et al. (2004) Mazzoni et al. (2007) Peters et al. (2007) Tucker et al. (2007) Sohn & Kim (2008) Wessels & Drennan (2010) Chong et al. (2010) Fillion & Booto Ekionea (2010) Gebauer et al. (2010) Wesolowski et al. (2012)

	Kwun et al. (2013) De Matos et al. (2014) Kim & Park (2014) Saaksjarvi et al. (2014) Suyinn et al. (2014) Takao (2014) Velmurugan & Velmurugan (2014) Paul et al. (2015)
Mobile phone ownership and usage from a behavioral and psychological perspective.	Karjaluoto et al. (2003) Wilska (2003) Davie et al. (2004) Liljander et al. (2007) White et al. (2007) Butt & Phillips (2008) Abu & Tsuji (2010) Kimiloglu et al. (2010) Lane & Manner (2011) Kim & Park (2014) Suyinn et al. (2014) Takao (2014)
Effects on human health and daily activities.	Repacholi (2001) Salvucci & Macuga (2002) Weinberger & Richter (2002) Sullman & Baas (2004) Treffner & Barrett (2004) Westerman & Hocking (2004) Balik et al. (2005) Balikci et al. (2005) Eby et al. (2006) Rosenbloom (2006) Törnros & Bolling (2006) Cocosila & Archer (2010) Kuznekoff & Titsworth (2013) Suyinn et al. (2014) Paul et al. (2015)
Evaluation and design of mobile phone features for user interface and user satisfaction.	Chuang et al. (2001) Chen et al. (2003) Han & Wong (2003) Chae & Kim (2004) Han et al. (2004) Lee et al. (2006) Kimiloglu et al. (2010) Haverila (2011) Saaksjarvi et al. (2014)
Analytical evaluations of mobile phone-related observations.	Tam & Tummala (2001) Campbelland Russo (2003) Han & Wong (2003) Wang & Sung (2003) Lai et al. (2006) Haque et al. (2010) Liu (2010)
Comparative analysis on the use of mobile phone according to the cultures.	Zhang & Maruping (2008) Lee & Lee (2010) Wesolowski et al. (2012) Kim & Park (2014)

	Takao (2014) Velmurugan & Velmurugan (2014)
New mobile phone generation on the form of mobile computer and virtual life.	Brown (2008) Hurlburt et al. (2011) Murugesan (2011) Kwun et al. (2013) De Matos et al. (2014)

In addition to the summary of literature on the actual research area of mobile phone presented in Table 1, other researchers have identified some factors which may increase the use of mobile phone by people in household. For example, in a large study conducted in 43 countries of the world, Kauffman and Techatassanasoontorn (2005) noted a faster increase in the use of mobile phone in countries having a more developed telecommunications infrastructure, being more competitive on the wireless market, and having lower wireless network access costs and less standards regarding the wireless technology. Another study involving 208 users by Wei (2007) showed that different motivations predict diverse uses of mobile phone. According to the Wei's findings, mobile phone establishes a bridge between interpersonal communication and mass communication. A large study conducted by Abu and Tsuji (2010) in 51 countries classified by the *Banque Mondiale* revealed that, in general, income is a very important factor to adopt a mobile phone in the countries having a fix telephone infrastructure. And, in a study examining the effect of peer influence in the diffusion of the iPhone 3G across a number of communities sampled from a large dataset provided by a major European Mobile carrier in one country, De Matos et al. (2014) found that, during a period of 11 months, 14% of the iPhone 3Gs sold by this carrier were due to peer influence.

As we can see in the summary of literature related to mobile phone presented above, few studies until now examined the determining factors in the use of mobile phone by people in household. Thus, the present study brings an important contribution to fill this gap as it allows a better understanding of the impacts of mobile phone usage into people's daily life. It focuses on the following research question: What are the determining factors in the use of mobile phone by people in household?

The paper builds on the conduct of hypothetico-deductive scientific research in organizational sciences (see Fillion, 2004) and it is structured as follows: first, the theoretical approach which guides the study is developed; second, the methodology followed to conduct the study is described; finally, the data analysis and the results of the study are presented and discussed.

THEORETICAL DEVELOPMENT

This study is based on the theoretical foundations developed by Venkatesh and Brown (2001) to investigate the factors driving personal computer adoption in American homes as well as those developed by Brown and Venkatesh (2005) to verify the determining factors in intention to adopt a personal computer in household by American people. In fact, Brown and Venkatesh (2005) performed the first quantitative test of the recently developed model of adoption of technology in households (MATH) and they proposed and tested a theoretical extension of MATH integrating some demographic characteristics varying across different life cycle stages as moderating variables. With the exception of behavioral intention (we included user satisfaction instead given people investigated in this study already own a mobile phone), all the variables

proposed and tested by Brown and Venkatesh (2005) are used in this study. And we added two new variables in order to verify whether people are using mobile phone for matters of security and mobility. The resulting theoretical research model is depicted in Figure 1.

Figure 1
Theoretical Research Model

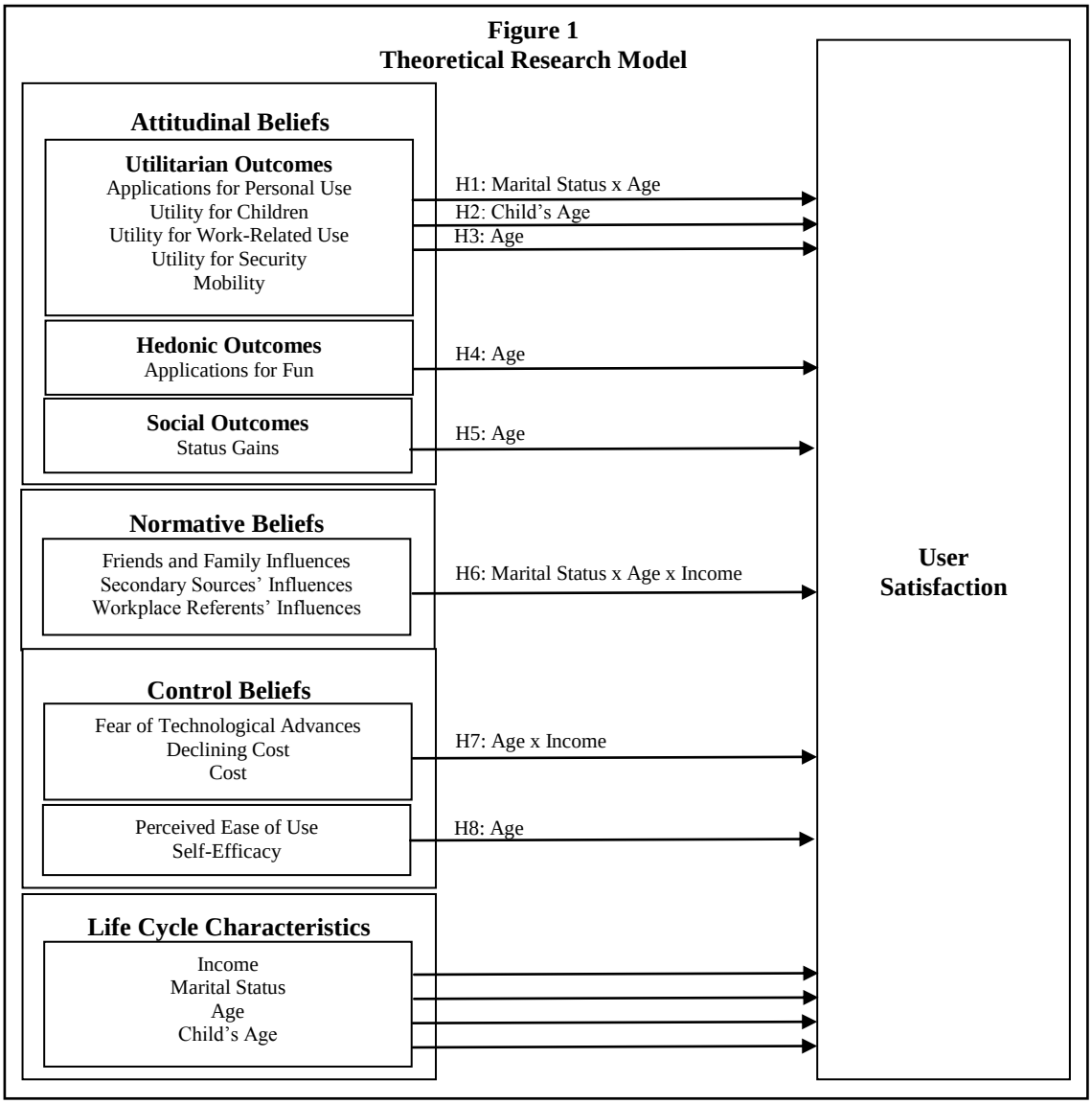

Figure 1 shows that Brown and Venkatesh (2005) integrated MATH and Household Life Cycle in the following way. MATH presents five attitudinal beliefs grouped into three sets of outcomes: *utilitarian*, *hedonic*, and *social*. Utilitarian beliefs are most consistent with those found in the workplace and can be divided into beliefs related to *personal use*, *children*, and *work* (we added beliefs related to *security* and *mobility*). The extension of MATH suggested and tested by Brown and Venkatesh (2005) presents three normative beliefs: *influence of friends and family*, *secondary sources*, and *workplace referents*. As for control beliefs, they are represented in MATH by five factors: *fear of technological advances*, *declining cost*, *cost*, *perceived ease of use*, and *self-efficacy*. And, according to Brown and Venkatesh (2005), integrating MATH with a life cycle view, including *income*, *age*, *child's age*, and *marital status*, allows to provide a richer

explanation of household personal computer (PC) adoption (household mobile phone usage in this study) than those provided by MATH alone. Finally, as shown in Figure 1, the dependant variable of the theoretical research model developed is related to *user satisfaction* (satisfaction in the use of mobile phone by people in household). All the variables integrated into the theoretical research model depicted in Figure 1 are defined in Table 2.

We can see in Table 2 that the definitions of MATH variables integrated into the theoretical research model proposed in Figure 1 are, in the whole, adapted from the theoretical foundations developed by Venkatesh and Brown (2001) to investigate the factors driving personal computer adoption in American homes. As for the definitions of the variables related to the household life cycle, they were taken from Danko and Schaninger (1990) as well as Wagner and Hanna (1983), respectively. And the definitions of the two new independent variables that we added to the model are from Fillion and Berthelot (2007).

In the reminder of the section, we develop eight research hypotheses (H1-H8) related to the theoretical research model suggested in Figure 1. It is important here to note that these eight research hypotheses are adapted from the Brown and Venkatesh (2005) paper. In fact, in the present study, we test the same research hypotheses than Brown and Venkatesh (2005) did in their study, but using a different technology (mobile phone instead of personal computer), a different dependent variable (user satisfaction instead of behavioral intention), a different methodology (an in-person randomized survey instead of a nationwide survey with the assistance of a market research firm and an electronics retail store), and a different sample (African people instead of American people).

As mentioned previously, MATH presents five attitudinal beliefs grouped into three sets of outcomes: *utilitarian*, *hedonic*, and *social*. Utilitarian beliefs are most consistent with those found in the workplace and can be divided into beliefs related to *personal use*, *children*, and *work*. Personal use related to mobile phone can include tasks such as personal calls, Internet browsing, files, videos, or photos sharing or downloading, discussions on social media (Facebook, Twitter…), and so on. A focus on household utility is suggestive of a more well-established, responsible household. Brown and Venkatesh (2005) showed that marital status moderates the relationship between applications for personal use and intention to adopt a PC for household use. Another study by Fillion and Booto Ekionea (2010) revealed that marital status has an influence on the relationship between applications for personal use and satisfaction of using a mobile phone by people in household. So we would expect to see also an influence of the marital status on the relationship between applications for personal use and household satisfaction of using a mobile phone in the present study.

Table 2
VARIABLES AND DEFINITIONS

Beliefs and Characteristics	***Variables***	***Definitions***
Attitudinal Beliefs (independent variables)	Applications for Personal Use	The extent to which using a mobile phone enhances the effectiveness of household activities (adapted from Venkatesh & Brown, 2001).
	Utility for Children	The extent to which using a mobile phone enhances the children's effectiveness in their activities (adapted from Venkatesh & Brown, 2001).
	Utility for Work-Related Use	The extent to which using a mobile phone enhances the effectiveness of performing work-related activities (adapted from Venkatesh & Brown, 2001).

	Utility for Security	The extent to which using a mobile phone increases the security of its user and his/her family (Fillion & Berthelot, 2007).
	Mobility	The extent to which a mobile phone allows to use only this telephone to perform all personal and professional activities (Fillion & Berthelot, 2007).
	Applications for Fun	The pleasure derived from mobile phone use (adapted from Venkatesh and Brown, 2001). These are specific to mobile phone usage, rather than general traits (adapted from Brown & Venkatesh, 2005; see Webster & Martocchio, 1992, 1993).
	Status Gains	The increase in prestige that coincides with the purchase of a mobile phone for home use (adapted from Venkatesh & Brown, 2001).
Normative Beliefs (independent variables)	Friends and Family Influences	"The extent to which the members of a social network influence one another's behavior" (Venkatesh & Brown, 2001, p. 82). In this case, the members are friends and family (Brown & Venkatesh, 2005).
	Secondary Sources' Influences	The extent to which information from TV, newspaper, and other secondary sources influences behavior (Venkatesh & Brown, 2001).
	Workplace Referents' Influences	The extent to which coworkers influence behavior (Brown & Venkatesh, 2005; see Taylor & Todd, 1995).
Control Beliefs (independent variables)	Fear of Technological Advances	The extent to which rapidly changing technology is associated with fear of obsolescence or apprehension regarding a mobile phone purchase (adapted from Venkatesh & Brown, 2001).
	Declining Cost	The extent to which the cost of a mobile phone is decreasing in such a way that it inhibits adoption (adapted from Venkatesh & Brown, 2001).
	Cost	The extent to which the current cost of a mobile phone is too high (adapted from Venkatesh & Brown, 2001).
	Perceived Ease of Use	The degree to which using the mobile phone is free from effort (Davis, 1989; also adapted from Venkatesh & Brown, 2001).
	Self-Efficacy (or Requisite Knowledge)	The individual's belief that he/she has the knowledge necessary to use a mobile phone. This is closely tied to computer self-efficacy (Compeau & Higgins, 1995a, 1995b; see also Venkatesh & Brown, 2001).
Life Cycle Characteristics (moderator variables)	Income	The individual's year gross income (see Wagner & Hanna, 1983).
	Marital Status	The individual's family status (married, single, divorced, widowed, etc.) (see Danko & Schaninger, 1990).
	Age	The individual's age (see Danko & Schaninger, 1990). In this case, age is calculated from the individual's birth date.
	Child's Age	The age of the individual's youngest child (see Danko & Schaninger, 1990). In this case, age is represented by a numeral.

Further, research as shown that age is significantly positively associated with a greater emphasis on *utilitarian outcomes*, while *income* is not (Morris & Venkatesh, 2000). The study from Brown and Venkatesh (2005) concluded that age moderates the relationship between applications for personal use and intention to adopt a PC for household use. And the study conducted by Fillion and Booto Ekionea (2010) showed that age has an influence on the relationship between applications for personal use and satisfaction of using a mobile phone by people in household. Thus, as for marital status, we expect that applications for personal use will also interact with age to impact household satisfaction of using a mobile phone.

HYPOTHESIS 1 (H1). *Marital status and age will moderate the relationship between applications for personal use and satisfaction of using a mobile phone at home.*

Children's needs differ from those of adults and will likely change as children age. For products that are important to them and about which they have knowledge, children can exert significant influence on the purchase decisions (Foxman et al., 1989). Further, child's age is positively correlated with the degree of influence in purchase decisions (Atkin, 1978; Mangleburg, 1990; Nelson, 1978; Ward & Wackman, 1972). Likewise, as children enter school and progress through their education, their needs change. In their study, Brown and Venkkatesh (2005) found child's age as a moderator of the relationship between utility for children and intention to adopt a PC for household use. So, we expect that utility for children will also interact with child's age to impact household satisfaction of using a mobile phone.

HYPOTHESIS 2 (H2). *Child's age will moderate the relationship between utility for children and satisfaction of using a mobile phone at home.*

Generally, as people age their position within the organization tends to raise (Schaninger & Danko, 1993; Wells & Gubar, 1966). A by-product of the rising organizational position is increased e-mail use (Rice & Shook, 1988). Increasingly, these work-related tasks are performed at home (Feldman & Gainey, 1997; Morrow, 1999; Venkatesh & Vitalari, 1992), whether using a PC or a mobile phone. The study conducted by Brown and Venkatesh (2005) indicated that age moderates the relationship between utility for work-related use and intention to adopt a PC for household use. Further, the study performed by Fillion and Booto Ekionea (2010) showed that the moderator variable age has an influence on the relationship between utility for work-related use and satisfaction of using a mobile phone by people in household. Thus, in the present study, we expect that utility for work-related use will also interact with age to impact household satisfaction of using a mobile phone.

HYPOTHESIS 3 (H3). *Age will moderate the relationship between utility for work-related use and satisfaction of using a mobile phone at home.*

Beyond utilitarian applications, as for household PC use, mobile phone use could be for *hedonic purposes*. The role of fun has received some concern in the technology adoption literature via constructs such as enjoyment (Davis et al., 1992; Venkatesh, 2000) and playfulness (Webster & Martocchio, 1992). Although in workplace settings the role of fun has been downplayed, applications for fun (*hedonic outcomes*) have been shown to be particularly relevant in the context of household PC adoption (Malone, 1981; Venkatesh & Brown, 2001). As mentioned by Brown and Venkatesh (2005), age is expected to moderate this relationship given the evidence that younger people tend to be likely using technology as an end in itself (Assael, 1981; Brancheau & Wetherbe, 1990) when compared to older people who evaluate utility more closely (Morris & Venkatesh, 2000). Using technology for its own sake is an indication that an individual is intrinsically motivated to use the technology (Davis et al., 1992). The tendency to use technology for its own sake ties closely to the affective components which are the essence of enjoyment and fun. So, in their study, Brown and Venkatesh (2005) found age as a moderator of the relationship between applications for fun and intention to adopt a PC for household use. Therefore, we expect that it will be the same regarding the relationship between applications for fun and satisfaction of using a mobile phone at home.

HYPOTHESIS 4 (H4). *Age will moderate the relationship between applications for fun and satisfaction of using a mobile phone at home.*

As pointed out by Brown and Venkatesh (2005), while results have been mixed, earlier technology adopters are generally younger than later adopters (Brancheau & Wetherbe, 1990; Rogers, 1995). According to Rogers (1995), innovators are more strongly influenced by *status outcomes* than are later adopters. So this assertion from Rogers take a great importance in the present study given, as mentioned earlier, according to Cisco, one of the greatest global networking companies, there will be 5.2 billion mobile phone users in the world by 2017 while the population will be reaching 7.6 billion people (Ferland, 2013). In their study, Brown and Venkatesh (2005) found an opposite direction to those predicted in their hypothesis, that is, the observed relationship was such that the influence of status gains on intention to adopt a PC in household increased with age. And, contrary to their expectations, the moderator variable age had not an influence on the relationship between status gains and satisfaction of using a mobile phone by people in household in the study conducted by Fillion and Booto Ekionea (2010). But, as these studies have been performed with American and Canadian people, respectively, we expect that it will be different with African people so that the independent variable status gains will interact with the moderator variable age to impact their satisfaction of using a mobile phone at home.

HYPOTHESIS 5 (H5). *Age will moderate the relationship between status gains and satisfaction of using a mobile phone at home.*

The extension of MATH, such as proposed by Brown and Venkatesh (2005), presents three normative beliefs: *influence of friends and family*, *secondary sources*, and *workplace referents*. Childers and Rao (1992) suggest that socially proximal referents are important for the consumption of luxury goods. Since luxury goods are those not commonly owned or necessary (Childers & Rao, 1992), and only about half of the households own a PC (Venkatesh & Brown, 2001) [it is important to note that the percentage of households owning a PC is a lot higher actually, probably near from 100%, given household people are more and more active on the Internet (Facebook, Twitter, YouTube, Skype, e-mail, buying goods and services, and so on), and the PC cost has dramatically decreased since few years], Brown and Venkatesh (2005) classify PCs as luxuries. For these reasons, we think that PCs can no longer be classified today as luxuries. On the other hand, in our view, mobile phones can be classified as luxuries given their costs are higher than PCs and their monthly operation costs are also very expensive. But, it is a different scenario regarding African people (people which are investigated in the present study). Indeed, as the fix telephone infrastructure is very bad in Africa, African people must own a mobile phone. It is absolutely necessary to communicate with their families, friends, and other people. So, it is why more and more, if not all, African people have a mobile phone. Hence, although it can be considered as luxury, African people must own a mobile phone to communicate.

Thus, influence of friends and family members should be important in satisfaction of using a mobile phone at home. Secondary sources are thought to play a role throughout the adoption and diffusion process (Rogers, 1995). We think that it will be the same regarding workplace referents. In terms of the life cycle variables, age, marital status, and child's age have

each moderate the impact of social referents on intention to purchase a PC for home use (Brown & Venkatesh, 2005). In our view, it will be the same regarding the mobile phone. We also think that income will moderate the impact of social referents on satisfaction of using a mobile phone at home. The study performed by Brown and Venkatesh (2005) showed that age, marital status, and income moderated the relationship between friends and family influences and secondary sources' influences, and intention of American people to adopt a PC for household use. And those conducted by Fillion and Booto Ekionea (2010) concluded that age, marital status, and income moderated the relationship between secondary sources' influences and workplace referents' influences, and satisfaction of using a mobile phone at home by Canadian people. So, we expect that it will be the same in the present study involving the mobile phone household use by African people.

HYPOTHESIS 6 (H6). *Age, marital status, and income will moderate the relationship between the normative beliefs ((a) friends and family influences; (b) secondary sources' influences; and (c) workplace referents' influences) and satisfaction of using a mobile phone at home.*

Control beliefs are represented in MATH by five factors: *fear of technological advances*, *declining cost*, *cost*, *perceived ease of use*, and *requisite knowledge*. Control beliefs include external and internal factors depending on whether they are constraints tied to the environment or cognitive/ability effort (Venkatesh, 2000). The first three factors (*fear of technological advances*, *declining cost*, and *cost*) are external, and the latter two (*perceived ease of use* and *requisite knowledge*) are internal. The external constraints reflect the reactions to technology change and cost characteristics and are, in essence, characteristics of the PC (or mobile phone) and its environment. Overall, we would expect that income has an impact on the cost-related issues due to the price sensitivity and overall price/deal consciousness (Vakratsas, 1998). Age also plays a role on issues of obsolescence due to heightened price sensitivity. Brown and Venkatesh (2005) found in their study that age and income moderated the relationship between fear of technological advances, declining cost and cost, and intention to adopt a PC for household use by American people. Surprisingly, the study conducted by Fillion and Booto Ekionea (2010) showed no significant moderating effect of age and income on the relationship between fear of technological advances, declining cost and cost, and satisfaction of using a mobile phone at home by Canadian people. So, we expect that it will be different in the present study involving African people.

HYPOTHESIS 7 (H7). *Age and income will moderate the relationship between the external control beliefs ((a) fear of technological advances; (b) declining cost; and (c) cost) and satisfaction of using a mobile phone at home.*

As noted earlier, perceived ease of use and requisite knowledge (or self-efficacy) are internal factors. Consistent with MATH (Venkatesh & Brown, 2001), perceived ease of use and self-efficacy reflect perceptions of the individual's relationship with the technology: Is it easy to use and do they know enough to use it well? The effects of perceived ease of use and self-efficacy on the intention to adopt a PC by American people have been moderated by age in the study performed by Brown and Venkatesh (2005). And, in the study conducted by Fillion and Booto Ekionea (2010), age moderated the relationship between self-efficacy and satisfaction of using a mobile phone by Canadian people. The theoretical rationale for the increasing

importance of perceived ease of use and self-efficacy with age is related to the difficulty of processing visual cues (Kline & Schieber, 1982) and functioning in complex information environments (Plude & Hoyer, 1985). So, as Brown and Venkatesh (2005) as well as Fillion and Booto Ekionea (2010), we expect that the last two control beliefs, that is, perceived ease of use and self-efficacy, will be moderated by age in the present study involving African people.

HYPOTHESIS 8 (H8). *Age will moderate the relationship between the internal control beliefs ((a) perceived ease of use; and (b) self-efficacy) and satisfaction of using a mobile phone at home.*

In the next section of the paper, we describe the methodology followed to conduct the study.

METHODOLOGY

This study was designed to gather information on mobile phone adoption decisions in Cameroonian households. Indeed, the focus of the study is on individuals who own a mobile phone. So we conducted in-person survey research with individuals of the two more important cities in Cameroon, Yaounde and Douala. In this section, we describe the instrument development and validation, the sample and data collection, as well as the data analysis process.

Instrument Development and Validation

To conduct the study, we used the survey instrument developed and validated by Brown and Venkatesh (2005) to which we added three new scales, the first two measuring other dimensions in satisfaction in the use of mobile phone by people in household, that is, utility for security and mobility, and the last one measuring user satisfaction as such. The survey instrument was then translated in French (a large part of the population in Cameroon is speaking French) and both the French and English versions were evaluated by peers. This review assessed face and content validity (see Straub, 1989). As a result, changes were made to reword items and, in some cases, to drop items that were possibly ambiguous, consistent with Moore and Benbasat's (1991) as well as DeVellis's (2003) recommendations for scale development. Subsequent to this, we distributed the survey instrument to a group of 25 MBA students for evaluation. Once again, minor wording changes were made. Finally, we performed some adjustments to the format and appearance of the instrument, as suggested by both peers and MBA students. As the instrument was already validated by Brown and Venkatesh (2005) and showed to be of a great reliability, that we used the scale developed by Hobbs and Osburn (1989) and validated in their study as well as in several other studies to measure user satisfaction, and that we added only few items to measure the new variables utility for security and mobility, then we have not performed a pilot-test with a small sample. The evaluations by both peers and MBA students were giving us some confidence that we could proceed with a large-scale data collection.

Sample and Data Collection

First, in this study, we chose surveying people in household over 18 years taken from the two more important cities in Cameroon Africa (Yaounde and Douala) who own a mobile phone. To do that, a graduate student studying at the Faculty of administration of the University of

Moncton, one of our colleagues from the University of Yaounde I, and a friend of our colleague in Yaounde were collecting data in-person. One at a time over a 3- to 4-hour period, the three responsible to collect data were soliciting people in-person to answer our survey. And, in order to get a diversified sample (e.g., students, retired people, people not working, people working at home, people working in enterprises, and so on), data were collected from 9 a.m. to 9 p.m. Monday through Friday over a 6-week period. People answering our survey were randomly selected in the streets, in the stores, and in the houses of the two Cameroonian cities chosen for the study by the three responsible to collect data. The sample in the present study is then a randomized sample, which is largely valued in the scientific world given the high level of generalization of the results got from such a sample. Once an individual had the necessary characteristics to answer the survey and was agreeing to answer it, a responsible was there to guide him/her to rate each item of the survey on a seven points Likert-type scale (1: strongly disagree… 7: strongly agree). In addition, the respondent was asked to answer some demographic questions. Finally, it is important here to mention that no incentive has been used in order to try increasing the response rate of the study. So, following this data collection process, 505 people in household answered our survey over a 6-week period.

Data Analysis Process

The data analysis of the study was performed using a structural equation modeling software, that is, Partial Least Squares (PLS-Graph 3.0). Using PLS, data have no need to follow a normal distribution and it can easily deal with small samples if the sample is at least 10 times greater than the number of items measuring the variable having the greatest weight in terms of items into the model (Barclay et al., 1995; Fornell & Bookstein, 1982). Recently, some authors (see Goodhue et al., 2012) tried to refute this evidence but, in our view, they did not succeed well. In addition, PLS is appropriate when the objective is a causal predictive test instead of the test of a whole theory (Barclay et al., 1995; Chin, 1998) as it is the case in this study. And, to ensure the stability of the model developed to test the research hypotheses, we used the PLS bootstrap resampling procedure (the interested reader is referred to a more detailed exposition of bootstrapping (see Chin 1998; Chin et al. 2003; Efron & Tibshirani, 1993)) with an iteration of 100 sub-sample extracted from the initial sample (505 Cameroonian people). Some analyses were also performed using the Statistical Package for the Social Sciences software (SPSS 13.5). The data analysis and the results follow.

DATA ANALYSIS AND RESULTS

In this section of the paper, the data analysis and the results of the study are presented. We begin to provide some characteristics of the participants. Then we validate the PLS model developed to test the research hypotheses. Finally, we describe the results got from PLS analyses to test the research hypotheses and we discuss about some implications.

Participants

The participants in this study were not relatively aged, with a mean of 30 years and a standard deviation of 11 years. More than half of the participants were male (54.2%). More than

80% of the participants were single (57.9%) or married (28.5%). The gross yearly income of the respondents in the study was in the range of $0 to $5 445 (0 to 2 750 000 CFA francs). Indeed, 78.9% of the respondents were winning between $0 and $1 979 (0 and 1 000 000 CFA francs), and, from this percentage, 67.6% were winning between $0 and $989 (0 and 500 000 CFA francs). And only 3% of the respondents in the study were winning between $4 950 and $5 445 (2 500 000 and 2 750 000 CFA francs). Concerning the level of education, 15.4% of the participants in the study got a high-school diploma, 11.1% had a college degree, 36.6% completed a baccalaureate, 23.6% got a master, and 5.7% got a doctorate. The percentage of participants having a doctorate is very surprising here since it is three times higher than in a similar previous study conducted in Canada (see Fillion & Booto Ekionea, 2010). Finally, the respondents were mainly students (36.4%), full-time employees (19.7%), self-employed (13.1%), unemployed (12.9%), part-time employees (10.5%), and volunteers (3%).

Validation of the PLS Model to Test Hypotheses

First, to ensure the reliability of a construct or a variable using PLS, one must verify the three following properties: individual item reliability, internal consistency, as well as discriminant validity (Yoo & Alavi 2001; see the paper for more details).

To verify individual item reliability, a confirmatory factor analysis (CFA) was performed on independent and dependent variables of the theoretical research model. A single iteration of the CFA was necessary given all loadings of the variables were superior to 0.50 and then none item was withdrawn nor transferred in another variable in which the loading would have been higher. Indeed, in the whole, items had high loadings, which suppose a high level of internal consistency of their corresponding variables. In addition, loadings of each variable were superior to cross-loadings with other variables of the model. Hence the first criterion of discriminant validity was satisfied.

And to get composite reliability indexes and average variance extracted (AVE) in order to satisfy the second criterion of discriminant validity and to verify internal consistency of the variables, we used PLS bootstrap resampling procedure with an iteration of 100 sub-sample extracted from the initial sample (505 Cameroonian people). The results are presented in Table 3.

Table 3
MEANS, STANDARD DEVIATIONS, COMPOSITE RELIABILITY INDEXES, CORRELATIONS, AND AVERAGE VARIANCE EXTRACTED OF VARIABLES

Variables	*M*	*SD*	*Relia-bility Indexes*	*Correlations and Average Variance Extracted*[d]																		
				1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
1. Applications for Personal Use	4.17	2.17	**0.85**	**0.81**																		
2. Utility for Children	4.21	2.10	**0.95**	.32	**0.93**																		
3. Utility for Work-Related Use	4.07	2.19	**0.86**	.45	.46	**0.82**																	
4. Utility for Security	4.71	2.03	**0.89**	.25	.23	.32	**0.86**																
5. Mobility	3.68	2.18	**0.93**	.36	.25	.29	.24	**0.90**															
6. Applications for Fun	4.75	2.03	**0.89**	.19	.08	.15	.23	.09	**0.82**														
7. Status Gains	2.87	2.07	**0.92**	.22	.25	.31	.35	.39	.20	**0.89**													
8. Friends and Family Influences	4.49	2.05	**0.93**	.25	,21	.25	.29	.28	.20	.33	**0.87**												
9. Secondary Sources' Influences	4.26	2.00	**0.93**	.26	.30	.30	.38	.33	.17	.31	.54	**0.90**											
10. Workplace Referents' Influences	4.65	2.06	**0.97**	.31	.33	.38	.23	.26	.10	.26	.53	.44	**0.97**										
11. Fear of Technological Advances	4.50	2.25	**0.89**	.19	.13	.22	.26	.24	.17	.28	.30	.30	.27	**0.89**									
12. Declining Cost	5.54	1.72	**0.86**	.18	.04	.09	.20	.16	.26	.05	.16	.12	.12	.18	**0.82**								
13. Cost	4.64	1.93	**0.66**	.18	.17	.20	.29	.24	.26	.16	.26	.34	.21	.24	.13	**0.66**							
14. Perceived Ease of Use	5.56	1.63	**0.88**	.16	.12	.19	.21	.16	.22	.03	.23	.13	.15	.13	.37	.20	**0.81**						
15. Self-Efficacy	5.82	1.61	**0.87**	.24	.15	.23	.25	.18	.21	.03	.29	.18	.20	.14	.35	.16	.64	**0.83**					
16. Income[a]	NA	NA	**NA**	.01	.22	.02	.05	.06	-.08	-.03	.07	.03	.11	.10	.03	.04	.10	.14	**NA**				
17. Marital Status[a]	NA	NA	**NA**	-.02	-.21	-.02	.04	.01	.17	-.04	-.07	-.05	-.15	-.01	.02	-.02	.04	-.01	-.02	**NA**			
18. Age[b]	30.13	10.63	**NA**	.06	-.01	.07	.05	.11	.14	.07	.17	.08	.06	.09	.05	.09	.06	.08	.04	-.02	**NA**		
19. Child's Age[c]	8.31	6.87	**NA**	0.0	.21	.03	.03	.03	-.11	.00	.13	.09	.10	.09	.00	.09	-.02	-.02	-.02	-.37	-.02	**NA**	
20. User Satisfaction	4.92	1.87	**0.88**	.29	.28	.31	.31	.40	.33	.29	.39	.39	.38	.28	.30	.30	.47	.46	.08	-.02	.08	.08	**0.73**

[a]This variable was coded as a nominal variable. It was measured in terms of non quantified distinct categories.
[b]This variable was coded as a continuous variable. It was measured using the respondents' birth date.
[c]This variable was coded using the age of the respondents' youngest child.
[d]Boldfaced elements on the diagonal of the correlation matrix represent the square root of the average variance extracted (AVE).
For an adequate discriminant validity, the elements in each row and column should be smaller than the boldfaced element in that row or column.

As shown in Table 3, PLS analysis shows that all square roots of AVE (boldfaced elements on the diagonal of the correlation matrix) are higher than the correlations with other variables of the model. In other words, each variable shares more variance with its measures than it shares with other variables in the model. As a result, discriminant validity is verified. Finally, as supposed previously, we can see in Table 3 that PLS analysis showed high composite

reliability indexes for all variables of the theoretical research model. The variables have therefore a high internal consistency, with composite reliability indexes ranging from 0.66 to 0.97.

Hypothesis Testing

first, to get the significant variables in the study and the percentage of variance explained (R^2 coefficient) by all the variables of the research model, we developed a PLS model similar to those of Fillion (2005), Fillion and Booto Ekionea (2010), Fillion et al. (2010), Limayem and DeSanctis (2000), and Yoo and Alavi (2001). And to ensure the stability of the model, we used the PLS bootstrap resampling procedure with an iteration of 100 sub-sample extracted from the initial sample (505 Cameroonian people). The PLS model is depicted in Figure 2.

Figure 2
PLS MODEL TO GET SIGNIFICANT VARIABLES AND PERCENTAGE OF VARIANCE EXPLAINED (ONE-TAILED TEST)

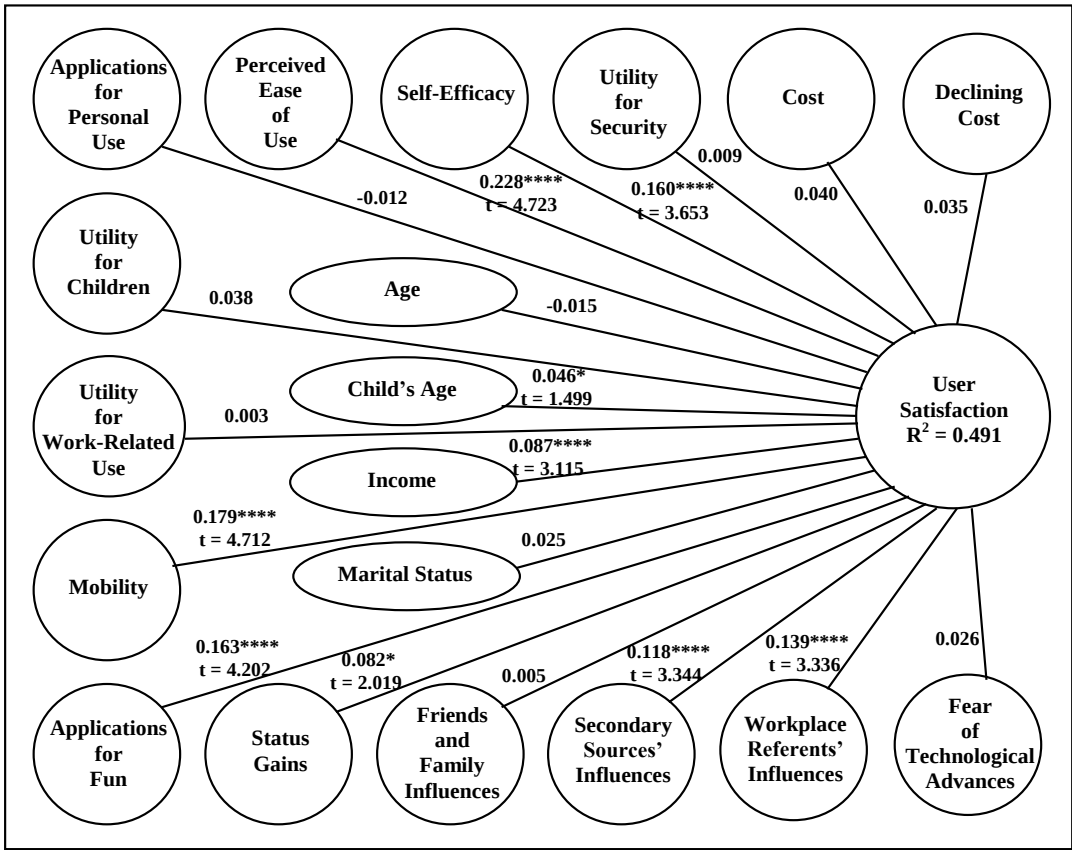

Figure 2 shows that all the variables of our theoretical research model, used as independent variables, are explaining 49.1% of the variance on the dependant variable user satisfaction. And half of these variables are significant, that is, they are determining factors in satisfaction of using a mobile phone by people in household. More specifically, the seven more significant variables are perceived ease of use ($t = 4.723$, beta = 0.228, $p < 0.001$), mobility ($t = 4.712$, beta = 0.179, $p < 0.001$), applications for fun ($t = 4.202$, beta = 0.163, $p < 0.001$), self-efficacy ($t = 3.653$, beta = 0.160, $p < 0.001$), secondary sources' influences ($t = 3.344$, beta =

0.118, $p < 0.001$), workplace referents' influences ($t = 3.336$, beta = 0.139, $p < 0.001$), and income ($t = 3.115$, beta = 0.087, $p < 0.001$). And two other variables are significant at the level of significance requested in this study, that is, $p \leq 0.05$. These are status gains ($t = 2.019$, beta = 0.082, $p < 0.05$) and child's age ($t = 1.499$, beta = 0.046, $p < 0.05$).

Finally, to measure interaction effect of moderator variables (e.g., the life cycle stage characteristics: income (I), marital status (MS), age (A), and child's age (CA)) in order to verify hypotheses 1 to 8, we used the PLS procedure proposed by Chin et al. (2003) (see the paper for more details). On the other hand, in a review of 26 papers assessing interaction effect of moderator variables published between 1991 and 2000 into information systems (IS) journals, Carte and Russell (2003) found nine errors frequently committed by researchers when they estimate such an effect, and provided solutions (see their paper for more details). So we tried to avoid these nine errors in applying their solutions to test hypotheses 1 to 8. Indeed, among others, in the verification of hypotheses 1 to 8 that follows, interaction effect of a moderator variable is significant if, and only if, the path between the latent variable (the multiplication of items of independent and moderator variables forming interaction effect) and the dependent variable is significant, as well as if the change in R^2 coefficient (the difference between the R^2 calculated before the addition of interaction effect and those calculated after the addition of interaction effect (ΔR^2, pronounced delta R^2)) is greater than 0.

For a matter of space, given that the test of hypotheses 1 to 8 required the development of several PLS structural equation models (two models per hypothesis, that is, 16 models), we summarize PLS analyses to test each hypothesis. And, as for the PLS model developed to get the significant variables in the study and the percentage of variance explained by all the variables of the theoretical research model previously (see Figure 2), for each PLS model developed, we used the PLS bootstrap resampling procedure with an iteration of 100 sub-sample extracted from the initial sample (505 Cameroonian people) to ensure the stability of the model.

Concerning hypothesis 1 related to the independent variable applications for personal use (APU), the path from the latent variable APU*MS*A to the dependent variable user satisfaction is significant ($t = 1.808$, beta = 0.156, $p < 0.05$) and there is a change in R^2 ($\Delta R^2 = 0.015$). Thus, as we expected, the moderator variables marital status and age have an influence on the relationship between applications for personal use and satisfaction of using a mobile phone by people in household. Also hypothesis 1 is supported. The scenario is similar for hypothesis 2 related to the independent variable utility for children (UC). The path from the latent variable UC*CA to the dependent variable user satisfaction is very significant ($t = 2.836$, beta = 0.181, $p < 0.001$) and there is a substantial change in R^2 ($\Delta R^2 = 0.014$). So, as we formulated in the hypothesis, the moderator variable child's age has an influence on the relationship between utility for children and satisfaction of using a mobile phone by people in household. As a result, hypothesis 2 is supported. For hypothesis 3 related to the independent variable utility for work-related use (UWRU), the path from the latent variable UWRU*A to the dependent variable user satisfaction is significant ($t = 2.333$, beta = 0.180, $p < 0.01$) and there is a change in R^2 ($\Delta R^2 = 0.015$). Then, as we thought, the moderator variable age has an influence on the relationship between utility for work-related use and satisfaction of using a mobile phone by people in household. Hypothesis 3 is therefore also supported. Regarding hypothesis 4 related to the independent variable applications for fun (AF), the scenario is different. The path from the latent variable AF*A to the dependent variable user satisfaction is not significant ($t = 0.106$, beta = 0.010) but there is a small change in R^2 ($\Delta R^2 = 0.002$). Contrary to our expectations, the moderator variable age has not an influence on the relationship between applications for fun and

satisfaction of using a mobile phone by people in household. As a result, hypothesis 4 is not supported. And the scenario is similar for hypothesis 5 related to the independent variable status gains (SG). The path from the latent variable SG*A to the dependent variable user satisfaction is not significant (t = 0.148, beta = 0.149) but there is a change in R^2 ($\hat{}R^2$ = 0.012). Then, contrary to what we thought, the moderator variable age has not an influence on the relationship between status gains and satisfaction of using a mobile phone by people in household. Consequently, as hypothesis 4, hypothesis 5 is not supported.

In the case of hypothesis 6-a related to the independent variable friends and family influences (FFI), the path from the latent variable FFI*MS*A*I to the dependent variable user satisfaction is significant (t = 2.265, beta = 0.096, p < 0.01) and there is a substantial change in R^2 ($\hat{}R^2$ = 0.028). So, as we expected, the moderator variables marital status, age, and income have an influence on the relationship between friends and family influences and satisfaction of using a mobile phone by people in household. Hypothesis 6-a is then supported. Concerning hypothesis 6-b related to the independent variable secondary sources' influences (SSI), the path from the latent variable SSI*MS*A*I to the dependent variable user satisfaction is very significant (t = 2.843, beta = 0.090, p < 0.005) and there is a huge change in R^2 ($\hat{}R^2$ = 0.033). Thus, as we thought, the moderator variables marital status, age, and income have an influence on the relationship between secondary sources' influences and satisfaction of using a mobile phone by people in household. And hypothesis 6-b is also supported. But the scenario is different for hypothesis 6-c related to the independent variable workplace referents' influences (WRI). The path from the latent variable WRI*MS*A*I to the dependent variable user satisfaction is not significant (t = 0.035, beta = 0.002) but there is a substantial change in R^2 ($\hat{}R^2$ = 0.026). Then, contrary to what we formulated in the hypothesis, the moderator variables marital status, age, and income have not an influence on the relationship between workplace referents' influences and satisfaction of using a mobile phone by people in household. As a result, hypothesis 6-c is not supported.

Regarding hypothesis 7-a related to the independent variable fear of technological advances (FTA), the path from the latent variable FTA*A*I to the dependent variable user satisfaction is very significant (t = 3.364, beta = 0.186, p < 0.001) and there is a huge change in R^2 ($\hat{}R^2$ = 0.039). Thus, as we expected, the moderator variables age and income have an influence on the relationship between fear of technological advances and satisfaction of using a mobile phone by people in household. Hypothesis 7-a is therefore supported. And the scenario is similar for hypothesis 7-b related to the independent variable declining cost (DC). The path from the latent variable DC*A*I to the dependent variable user satisfaction is significant (t = 1.766, beta = 0.123, p < 0.05) and there is a substantial change in R^2 ($\hat{}R^2$ = 0.027). So, as we thought, the moderator variables age and income have an influence on the relationship between declining cost and satisfaction of using a mobile phone by people in household. Consequently, hypothesis 7-b is also supported. But the scenario is different for hypothesis 7-c related to the independent variable cost (C). The path from the latent variable C*A*I to the dependent variable user satisfaction is not significant (t = 0.795, beta = 0.040) but there is a substantial change in R^2 ($\hat{}R^2$ = 0.027). Thus, contrary to our expectations, the moderator variables age and income have not an influence on the relationship between cost and satisfaction of using a mobile phone by people in household. As a result, hypothesis 7-c is not supported.

Finally, concerning hypothesis 8-a related to the independent variable perceived ease of use (PEU), the path from the latent variable PEU*A to the dependent variable user satisfaction is significant (t = 1.635, beta = -0.098, p < 0.05) and there is a small change in R^2 ($\hat{}R^2$ = 0.003).

So, as we formulated in the hypothesis, the moderator variable age has an influence on the relationship between perceived ease of use and satisfaction of using a mobile phone by people in household. And hypothesis 8-a is then supported. The scenario is similar regarding hypothesis 8-b related to the independent variable self-efficacy (SE). The path from the latent variable SE*A to the dependent variable user satisfaction is significant ($t = 1.644$, beta = 0.137, $p < 0.05$) and there is a change in R^2 ($\hat{}R^2 = 0.004$). So, as we thought, the moderator variable age has an influence on the relationship between self-efficacy and satisfaction of using a mobile phone by people in household. Consequently, hypothesis 8-b is also supported. Table 4 below presents a summary of the test of hypotheses.

Table 4
SUMMARY OF THE TEST OF HYPOTHESES

Hypotheses	***Results***	***Software (beta sig.)***
H1- Marital status and age will moderate the relationship between applications for personal use and satisfaction of using a mobile phone at home.	Supported	PLS (0.156*)
H2- Child's age will moderate the relationship between utility for children and satisfaction of using a mobile phone at home.	Supported	PLS (0.181****)
H3- Age will moderate the relationship between utility for work-related use and satisfaction of using a mobile phone at home.	Supported	PLS (0.180**)
H4- Age will moderate the relationship between applications for fun and satisfaction of using a mobile phone at home.	Not supported	PLS (0.010)
H5- Age will moderate the relationship between status gains and satisfaction of using a mobile phone at home.	Not supported	PLS (0.149)
H6- Age, marital status, and income will moderate the relationship between the normative beliefs ((a) friends and family influences; (b) secondary sources' influences; and (c) workplace referents' influences) and satisfaction of using a mobile phone at home.	a- Supported b- Supported c- Not supported	PLS (0.096**) PLS (0.090***) PLS (0.002)
H7- Age and income will moderate the relationship between the external control beliefs ((a) fear of technological advances; (b) declining cost; and (c) cost) and satisfaction of using a mobile phone at home.	a- Supported b- Supported c- Not supported	PLS (0.186****) PLS (0.123*) PLS (0.040)
H8- Age will moderate the relationship between the internal control beliefs ((a) perceived ease of use; and (b) self-efficacy) and satisfaction of using a mobile phone at home.	a- Supported b- Supported	PLS (-0.098*) PLS (0.137*)

*p < 0.05; **p < 0.01; ***p < 0.005; ****p < 0.001 (one-tailed test).

In summary, as shown in Table 4, nine hypotheses (including sub-hypotheses) have been supported in our study, that is, H1, H2, H3, H6-a, H6-b, H7-a, H7-b, H8-a, and H8-b. Thus, the moderator variables (e.g., the household life cycle) age, marital status, income, and child's age had several moderating effects in this study since practically all hypotheses we formulated have been supported. On the other hand, the moderator variable age had not a significant moderating effect on the relationship between applications for fun and satisfaction of using a mobile phone at home, as well as between status gains and satisfaction of using a mobile phone at home. Hence hypotheses H4 and H5 were not supported.

In the next and last section of the paper, we discuss about some implications of the more important findings of the study.

DISCUSSION AND CONCLUSIONS

This last section is devoted to a discussion about the more important findings of the study and some conclusions. And, to support our discussion and conclusions, we provide the reader with a more detailed view of the PLS structural equation model developed to get the significant variables in the study, including the percentage of variance explained by each variable (see Table 5).

Table 5
BETA PATH COEFFICIENTS, T-VALUES, AND PERCENTAGES OF VARIANCE EXPLAINED OF VARIABLES

Variable	*Beta*	*t*	R^2
Applications for Personal Use	-0.012	0.237	0.001
Utility for Children	0.038	0.866	0.000
Utility for Work-Related Use	0.003	0.071	0.000
Utility for Security	0.009	0.263	0.000
Mobility	0.179****	4.712	0.024
Applications for Fun	0.163****	4.202	0.067
Status Gains	0.082*	2.019	0.088
Friends and Family Influences	0.005	0.113	0.025
Secondary Sources' Influences	0.118****	3.344	0.029
Workplace Referents' Influences	0.139****	3.336	0.020
Fear of Technological Advances	0.026	0.719	0.002
Declining Cost	0.035	0.943	0.002
Cost	0.040	1.003	0.003
Perceived Ease of Use	0.228****	4.723	0.175
Self-Efficacy	0.160****	3.653	0.024
Income	0.087****	3.115	0.008
Marital Status	0.025	0.672	0.015
Age	-0.015	0.540	0.000
Child's Age	0.046*	1.499	0.008

*$p < 0.05$; ****$p < 0.001$ (one-tailed test).

As shown in Table 5 (and Figure 2), the nineteen independent variables examined in the study explained 49.1 percent ($R^2 = 0.491$) of the variance in satisfaction in the use of mobile phone by people in household. And we can also see in Table 5 that the nine variables who showed to be significant (see also the significant beta path coefficients in Figure 2), that is, mobility, applications for fun, status gains, secondary source's influences, workplace referents' influences, perceived ease of use, self-efficacy, income, and child's age explained alone 44.3 percent of the variance in satisfaction of using a mobile phone by people in household. Thus, these nine variables are assuredly very important factors to take into account in future studies on the mobile phone and on the part of mobile phone providers, and more particularly perceived ease of use, status gains and applications for fun which explained alone 33 percent of this variance (see Table 5). It is very interesting to see here that one of the two new variables that we added to the Brown and Venkatesh's (2005) theoretical research model, that is mobility, showed to be very significant ($p < 0.001$) in satisfaction of using a mobile phone by people in household. Indeed, the present study showed that people are, to some extent, using a mobile phone for a matter of mobility (the mobile phone provides them with the possibility to use only this telephone to perform all their personal and professional activities). So here are a new variable that we can add to the integrated research model of MATH and household life cycle

characteristics suggested by Brown and Venkatesh (2005) to test in future studies. In addition, this new variable may be included in the sales marketing plan of mobile phone providers.

In the large-scale study in which Brown and Venkatesh (2005) integrated MATH and some household life cycle characteristics (as moderating variables), the integrated model explained 74 percent of the variance in intention to adopt a personal computer for home use, a substantial increase of 24 percent over baseline MATH that explained 50 percent of the variance. In the present study, we used the integrated model proposed by Brown and Venkatesh (2005). We also added two new independent variables to the model, that is, utility for security and mobility. And we used the household life cycle variables as moderating variables in the research model as did Brown and Venkatesh (2005). Finally, given that we investigated the perceptions of people already using a mobile phone instead of those having the intention to adopt a mobile phone, as did Brown and Venkatesh (2005) for the personal computer, we used the dependent variable user satisfaction instead of behavioral intention. And the model explained 49.1 percent of the variance in satisfaction of using a mobile phone by people in household (see Table 5 and Figure 2). As a result, in this study, our theoretical research model explained the same percentage of variance than those explained by MATH alone (without the household life cycle characteristics and using behavioral intention as dependent variable).

Further, in a previous study in which we investigated the intention to buy a mobile phone by people in household (see Fillion & Berthelot, 2007), we also used the theoretical research model suggested by Brown and Venkatesh (2005) to which we added the same two independent variables utility for security and mobility than we included in the present study in which we investigated satisfaction in the use of mobile phone by people in household. And our model explained 50 percent of the variance in intention to buy a mobile phone, exactly as in the present study where our model explained 50 percent of the variance in satisfaction of using a mobile phone. Of course, the dependent variable was different in the two studies. Indeed, we used behavioral intention in the previous study and user satisfaction in the present study. Hence we can conclude that the variable user satisfaction is as much appropriate as dependent variable in the theoretical research model suggested by Brown and Venkatesh (2005) than is behavioral intention. In addition, in the model we used in this study, more independent variables showed to be good predictors in satisfaction of using a mobile phone by people in household than did independent variables in the model we used in the previous study in intention to adopt a mobile phone for household use. Finally, in the present study, we found several interesting things to help advance knowledge in this new and exciting field of adoption and use of technology in households.

First, we found nine very important variables that seem to be good predictors in satisfaction of using a mobile phone by people in household, and more particularly perceived ease of use, status gains and applications for fun, as well as one of the two new variables that we added to the Brown and Venkatesh's (2005) model, mobility (see Table 5). These nine variables are also very important to take into account by mobile phone providers to design new mobile phones still better adapted to people's needs and to perform their sales marketing. Second, we found that people are, to some extent, using a mobile phone for a matter of mobility, given our new variable mobility showed to be very significant (see Table 5). Third, we found that it is as much appropriate to use the dependent variable user satisfaction than the dependent variable behavioral intention in the research model proposed by Brown and Venkatesh (2005), given the percentage of variance explained in intention to adopt a mobile phone for household use in our previous study is similar to those of using a mobile phone in household in this study. The

dependent variable *use behavior* proposed by Thompson et al. (1991) may also be tested in future studies. Also, we suggest the test of new independent variables that may explain a greater percentage of variance in satisfaction of using a mobile phone by people in household in future studies. To that end, we recommend three new independent variables in the next paragraph. Finally, the results of this study provided the evidence that it is far better to use the household life cycle variables as moderating variables in the research model, as did Brown and Venkatesh (2005), given the percentage of variance explained in intention to adopt a new technology in household by the model tested by these authors was significantly higher. Indeed, we used the household life cycle variables as moderating variables in the theoretical research model of this study instead of independent variables, as we have made in two previous study (see Fillion & Berthelot, 2007; Fillion & Le Dinh, 2008; Fillion & Booto Ekionea, 2010), and the percentage of variance explained by the model both in intention to adopt a mobile phone and in satisfaction of using a mobile phone by people in household has been each time higher (up to 4 percent higher).

It would be interesting in future studies to add some other new variables to the actual theoretical research model (those suggested by Brown and Venkatesh (2005) augmented with the two new variables we tested in several previous studies (see Fillion & Berthelot, 2007; Fillion & Le Dinh, 2008; Fillion & Booto Ekionea, 2010), depending on the technology examined naturally, in order to try to explain still more variance in satisfaction of using a new technology in household. For example, the variable *attention* may be added in social outcomes (a lot of people, particularly young and old people, are feeling to be alone in our actual stressing world, in which both men and women are working and get very busy, so the mobile phone may be an excellent way to communicate with other people every time and everywhere to get the feeling to be less alone), the variable *social norm* may also be added in social outcomes (who knows, people may be using a mobile phone just to do as everybody!), and the variable *control* may be added in utilitarian outcomes (some people may be using a mobile phone to control other people in their family or others; may be another kind of Big Brother!). It would be also interesting to test the actual theoretical research model in other situations and with other populations.

Regarding the limitations of this study, as pointed out by Brown and Venkatesh (2005), the primary limitation is the reliance on a single informant. It is possible that other members of the household would have provided different responses concerning the motivations to use a mobile phone at home. Future research in household use of technology should incorporate responses from multiple members of the household to truly assess the nature of household use. A second limitation of the study is that it was conducted in a limited area of Cameroon. If the study would have been carried out in the whole Cameroon, its results would be of a higher level of generalization. But the fact that the sample of the study was a randomized sample allows a high level of generalization of its results. Another limitation of the study is the administration of the survey instrument in-person by three different research assistants. Some respondents may have differently understood some items of the survey instrument depending on different explanations from the part of the three research assistants and then provided more or less precise ratings on these items, introducing the possibility of some response bias. But the method we privileged in this study to administer the survey instrument is not an exception to the rule. Each method has its strengths and its limitations.

To conclude, much more research will be needed on the use of technology in households in order to better understand its impacts on people's daily life. The research will allow, among others, at least to minimize, if not to remove, some negative impacts of technology in people's

daily life in the future and to develop new technologies still better adapted to people's needs. So we will continue to inquire into this very exciting field.

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