JOURNAL OF MANAGEMENT AND ENGINEERING INTEGRATION

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* It is with great sadness that we announce the passing of our dear friend Dr. Ralph Janaro. His contributions to the IEMS Conference and the JMEI will be missed.

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Operating Performance Comparisons between Laser Doppler Velocimetry and Time of Flight Techniques

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Abstract

Characterizing the aerodynamic diameter of aerosol particles in the atmosphere or generated from the respiratory drug delivery devices has been subject of research for a long time. This study presents the operating performance comparisons between two aerosol particle sizing instruments which incorporate real time characterization of both atmospheric and respiratory drug aerosols. The instruments were: the single particle aerodynamic relaxation time (ESPART) analyzer and the aerodynamic particle sizer (APS) spectrometer. The ESPART operates on the principle of laser-doppler-velocimetry, whereas the APS operates on the principle of time-of-flight technique. They are a class of instruments that measure the aerodynamic diameter of individual particles following a controlled acceleration in a well-defined flow field. Both instruments are capable of sizing several thousand particles in a second. The tested aerosols were generated from several commercially available respiratory drug delivery inhalers, nebulizers, and blow-off cup aerosol generators. They were 1) Qvar Metered Dose Inhaler (MDI), 2) Albuterol MDI, 3) Ventolin MDI, 4) PARI-LC Plus Nebulizer and NaCl solution (7mg/ml), 5) PARI-LC Plus Nebulizer and Polymer Microsphere solution in water, 6) Blow-off cup and Lactose Monohydrate submicronized powder, and 7) Blow-off cup and Mannitol powder. The results showed that both instruments demonstrated similar performance within ± 0.5% variation for the aerosols with count median aerodynamic diameter (CMAD) > 3.0 μm and mass median aerodynamic diameter (MMAD) > 4.0 μm. However, both instruments showed some different performances within ± 4% variation for the aerosols with CMAD and MMAD less than 3.0 μm and 4.0 μm, respectively. The ESPART was providing electrical charge and polarity of aerosols in addition to particle's aerodynamic diameter information.

1. Introduction

In the aerosol research community, various techniques are routinely employed in real-time particle count, aerodynamic size, and electrostatic charge spectrometry. Most common among these are laser-doppler-velocimetry (LDV), and time-of-flight (TOF). Each of these techniques has scientific evidences of robustness and they are widely adopted in aerosol studies. During recent two decades various commercial organizations and academic laboratories developed powerful equipments employing these techniques. Furthermore, there has been tremendous amount of interests and successes in real-time analysis of aerosols upon generation.

The major physical properties of any kind of aerosols are its inborn suspended particle's size (diameter), shape, diffusivity, density, and electrostatic charge [1]. In order to use them for industrial or therapeutic purposes, understanding and controlling these physical properties are

topics of much current interest. In fact, aerosol particle's size influences rest of the other physical properties. The gravitational force, terminal settling velocity, inertia force and electrostatic force that act on a particle are approximately proportional to the square of the particle diameter [2]. Therefore, one of the most commonly used terminologies in aerosol science and technology is the aerodynamic diameter (d_a) to represent the size of a particle. This is defined, for a particular particle, as the diameter of the spherical particle with density of 1000 kg/m^3 (the density of a water droplet) that has the same settling velocity as the particle. Mathematically it was derived from Stoke's Law and is defined by:

$$d_a = (\rho_p / \rho_0)^{0.5} d_p$$

where d_p is the particle diameter, ρ_p is particle density, and ρ_0 is the standard particle density 1000 kg/m^3. The aerodynamic diameter can be imagined of as the diameter of a water droplet having the same aerodynamic behaviors as the particle [3]. If a particle has an aerodynamic diameter of 1 μm, it behaves in an aerodynamic sense like a 1 μm water droplet regardless of its shape, density, or physical size. The aerodynamic diameter is the key property of a particle to characterize its deposition, Coulombic attraction/repulsion force, diffusivity, and velocity while airborne and suspended in the aerosol.

In addition, particles also acquire electrostatic charges during generation by the diffusion of ions in aerosol streams which is caused by the collisions resulted from Brownian motion of the ions and particles [3]. Acquisition of charges by a particle as a function of time and the charge state of the particle can be calculated in a simplified and dimensionless form with the following equation [4,5].

$$q = \frac{n e^2}{2\pi \varepsilon d_p k T} \quad (1)$$

where q is called the particle charge, n is the number of elementary charge units, e is the electronic charge (1.6 x 10^{-19} Coulomb), ε is the permittivity of air, d_p is the particle diameter, k is the Boltzmann's constant, and T is the absolute temperature. If we know the density of particle, ρ, then the charge on an individual particle can be described in terms of its average charge-to-mass ratio, q/m, which can be calculated by the following equation.

$$\frac{q}{m} = \frac{3 n e^2}{\pi^2 \varepsilon \rho d_p^4 k T} \quad (2)$$

There are numerous instruments to characterize both aerodynamic size and electrostatic charge of aerosols. This study compares the aerosol characterizing performances of two widely used aerosol particle analyzer instruments. One is called the Electronic Single Particle Aerodynamic Relaxation Time (ESPART) analyzer (US Patent 4633714 of the University of Arkansas at Little Rock, Arkansas, USA), and the other is called the Aerodynamic Particle Sizer Spectrometer (APS) (TSI Incorporated, Shoreview, Minnesota, USA) [6,7].

The ESPART incorporates the methodology of LDV principle, which measures simultaneously both aerodynamic diameter of and electrostatic charge (magnitude and polarity) of aerosol particles generated by various aerosol generation methods [8]. The LDV method characterizes each aerosol particle in real time. Opto-electronic measurements including LDV are non-intrusive, fast response times, and high data measurements accuracy [9].

The APS adopts the TOF measurement technique to determine aerodynamic diameter of individual aerosol particle measured in an accelerating flow field with a single, high-speed timing processor; coincidence detection achieved using a patented, double crest optical system; particle size binning based on internally stored calibration curve [10,11]. The present investigation had two specific objectives, which were the characterizations and comparisons of aerodynamic properties of aerosols generated by several different methods.

2. Materials and Methods

The tested aerosols were generated from several commercially available respiratory drug delivery inhalers, nebulizers, and blow-off cup aerosol generators. They were 1) Qvar Metered Dose Inhaler (MDI) (3M, Northridge, California, USA), 2) Albuterol MDI (Warrick Pharmaceuticals, Reno, Nevada, USA), 3) Ventolin MDI (Allen and Hanburys Respiratory Care, Victoria, Australia), 4) PARI-LC Plus Nebulizer (PARI, Midlothian, Virginia, USA) and sodium chloride solution (7mg/ml), 5) PARI-LC Plus Nebulizer and Polymer Microsphere solution in water (Duke Scientific, Freemont, California, USA), 6) Blow-off cup and Lactose Monohydrate submicronized powder (Gallade Chemical Inc., Santa Ana, California, USA), and 7) Blow-off cup and Mannitol powder (Aceto Corp., Lake Success, New York, USA).

2.1. ESPART Analyzer Instrument

The Electronic Single Particle Aerodynamic Relaxation Time (ESPART) analyzer measures aerodynamic size and electrostatic charge every single particle in real time [8]. It was designed and developed in the Aerosol Drug Delivery Research Lab of the University of Arkansas at Little Rock, Little Rock, Arkansas, USA [6]. Figure 1 illustrates its working principle. The suction pump of the ESPART draws aerosol at the rate of 1 L/min. The flow is directed downwards through a sensing volume of focused beams of laser radiation. During sampling each particle traverses through converging laser beams. It also experiences AC electric excitation which makes it oscillate horizontally. The photomultiplier is used to measure the intensity of the scattered light generates by each particle as it passes through the sensing volume. The electronic signal and data processor analyzes the phase lag of the particle motion with respect to the AC electric field driving the particle. The aerodynamic diameter is derived from the phase lag value. The direction and amplitude of the electrical migration velocity of the particle with respect to the electric field provides the polarity and magnitude of its electrostatic charge.

The ESPART analyzer operates in two modes. In mode 1, it measures the aerodynamic diameter of each particle whether the particle is charged or uncharged. Acquired aerosol data in this mode represents total (charged and uncharged) particles. In mode 2, it measures the aerodynamic diameter and the electrostatic charge of each charged particle. In mode 2, it ignores the uncharged particles purposely (i.e., by design). In this study mode 1 and mode 2 data were obtained in completely separate experimental runs.

The ESPART collects and stores raw data by using LabView™ application software (National Instruments, Austin, Texas, USA). Acquired data can be analyzed and mined by the Aerosol Particle Data Analyzer (APDA) software (developed in C Language at the Aerosol Drug Delivery Research Lab of the University of Arkansas at Little Rock, Little Rock, Arkansas, USA). APDA data can be cleaned and transferred to spreadsheets (Excel) which allows generating graphs and tables.

2.2. APS Spectrometer Instrument

The Aerodynamic Particle Sizer (APS) Spectrometer accelerates the aerosol sample flow (1 L/min) through an accelerating orifice. The aerodynamic size of a particle determines its rate of acceleration, with larger particles accelerating more slowly due to increased inertia. As particles exit the nozzle, they cross through two partially overlapping laser beams in the detection area. Light is scattered as each particle crosses through the overlapping beams. An elliptical mirror, placed at 90 degrees to the laser beam axis, collects the light and focuses it onto an avalanche photo detector (APD). The APD then converts the light pulses into electrical pulses. The configuration of the detection area improves particle detection and minimizes Mie scattering oscillations in the light-scattering-intensity measurements. Figure 2 illustrates working principle of the APS.

The use of two partially overlapping laser beams results in each particle generating a single two-crested signal. Peak-to-peak time-of-flight is measured with 4-nanosecond resolution for aerodynamic sizing. The amplitude of the signal is logged for light-scattering intensity. The smallest particles may have only one detectable crest and are binned separately. In uncorrelated mode, these particles are displayed in the smallest size channel (less than 0.523 micrometer). Particles with more than two crests, indicative of coincidence, are also binned separately but are not used to build aerodynamic-size or light-scattering distributions.

The APS uses the Aerosol Instrument Manager software, a 32-bit program designed for use with Windows operating systems. The Aerosol Instrument Manager Software controls instrument operation, plus it provides file management capabilities and numerous choices for data display. Graphs and tables allow viewing channel data as well as raw data, giving the highest resolution possible. One can view all data types—time-of-flight, light-scattering, or correlated data—with the Aerosol Instrument Manager software. An export function allows easy transport of data files to spreadsheet or other applications for customized data handling.

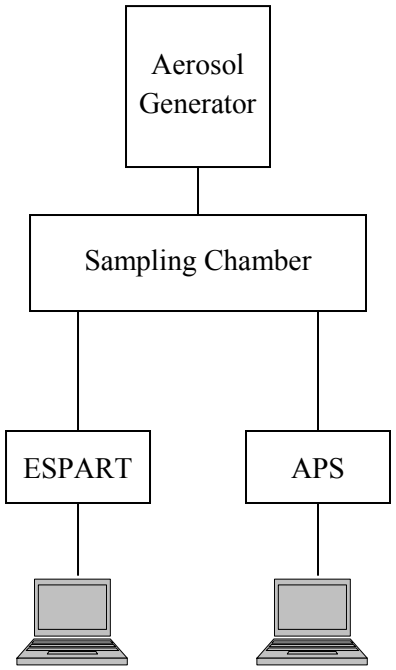

Figure 3: The Simplified Schematic of the Experimental Setup.

A simplified schematic of the experimental setup is shown in Figure 3. During each experiment, the aerosol sampling chamber was cleaned and evacuated before each run of the experiment. Aerosols were generated and filled the sampling chamber before starting the simultaneous characterization by the ESPART and the APS. Both instruments measured aerosols for five minutes continuously. Thus it was unlikely that variation of aerosol quantity generated by each individual method affected the measurements, and comparisons. The procedure was repeated for ten consecutive runs. The aerodynamic size data was acquired for both instruments, and the charge-to-mass ratio data

was measured for the ESPART only since the APS does not support measurement of this property.

3. Results and Discussion

It is necessary to point out that for some aerosol characterization methods other than LDV and TOF, sample preparation of the atomizing solution is required. For example, compendial methods that are based on either the multistage liquid impinger or cascade impactor require preparation of ultraviolet spectrophotometer detectable concentration of sample solution which takes repetitive dilution of the tested samples. Such solution preparation procedure takes long time. Nevertheless laboratory experimentalists need a relatively simple and fast measurement method, which both the ESPART and APS instruments are capable to perform.

Table 1 summarizes the aerodynamic diameters (count median aerodynamic diameter and mass median aerodynamic diameter), and electrostatic charge statistics of all tested aerosols determined by the LDV technique (ESPART Analyzer).

Table 2 summarizes the aerodynamic diameters (count median aerodynamic diameter and mass median aerodynamic diameter) statistics of all tested aerosols determined by the TOF technique (APS Spectrometer).

Figures 4 and 5 present the count median aerodynamic diameter (CMAD) and mass median aerodynamic diameter (MMAD) of aerosols generated by various methods.

It was observed that the CMAD and MMAD in the generated aerosols are consistent with findings that were reported by other investigators [12, 13]. The results showed that both instruments demonstrated similar performance within ± 0.5% variation for the aerosols with count median aerodynamic diameter (CMAD) > 3.0 μm and mass median aerodynamic diameter (MMAD) > 4.0 μm. However, both instruments showed some different performances within ± 4% variation for the aerosols with CMAD and MMAD less than 3.0 μm and 4.0 μm, respectively.

Figure 6 presents the net electrostatic charge or charge-to-mass ratio and polarity of generated aerosols measured by the ESPART. However, the APS does not support measurement of this property by design.

In this study, it was logical to recognize certain limitations. The data obtained from LDV or TOF method should be used with caution, however. Most notable issue is the lack of direct relationship with the mass of drug substance present and the vulnerability of the measurements to coincidence effects when sampling concentrated aerosols, may severely limit the significance of data from some aerosol drug delivery systems such as metered dose inhaler. Moreover when measuring particles smaller than 0.5 μm or larger than 20 μm, data accuracy has to be compromised to a great extent due the design constraints, therefore present study purposely avoided investigating the behavior of particles outside the size range of 0.5 to 20 μm.

4. Conclusions

This study evaluated the performance in characterizing aerosol particles' aerodynamic diameters of two real-time measurement techniques. Both the LDV-ESPART and TOF-APS are powerful instruments which are capable of providing quantitative and aerodynamic information on laboratory generated aerosols. Former also provides the real-time electrical properties. Since there is no lengthy sample preparation involved in techniques employed by these instruments, they are very user friendly

tools in situations where aerosol properties data and quick determination of results are essential.

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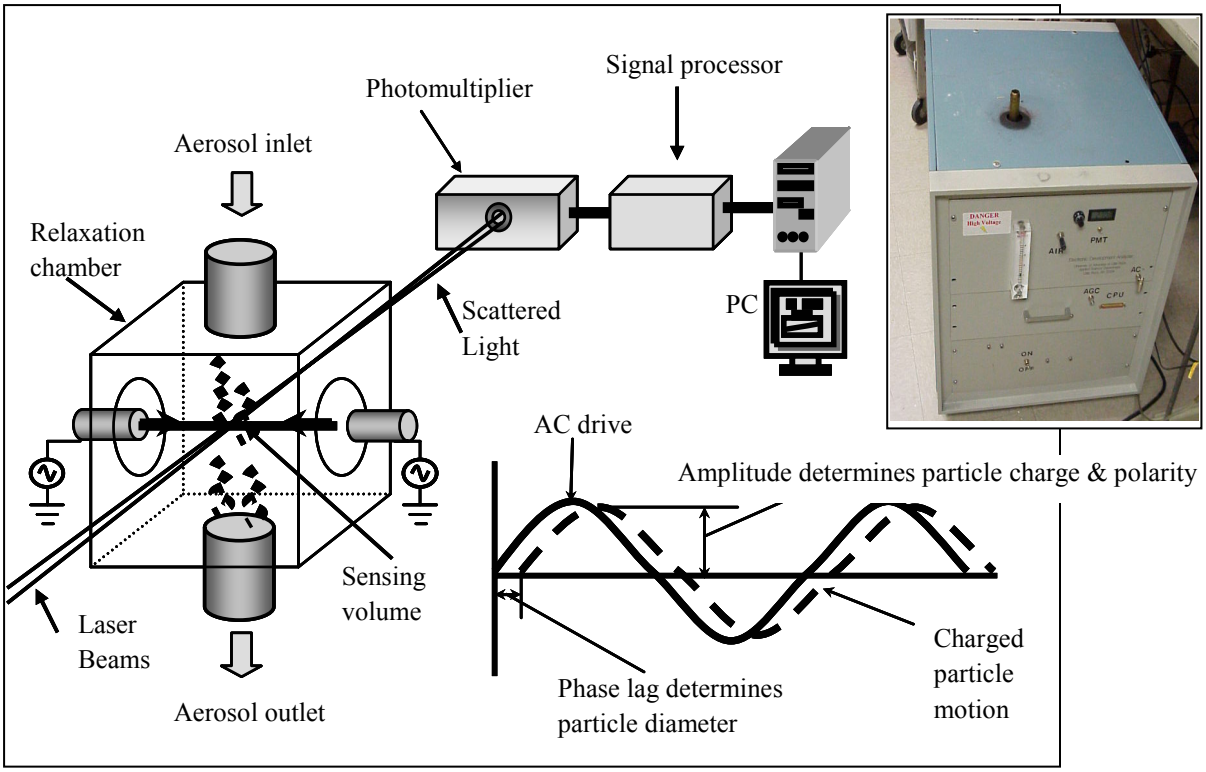


Figure 1: Operation of the Electronic Single Particle Aerodynamic Relaxation Time (ESPART) Analyzer. Inset shows the ESPART unit. (Reference 8).

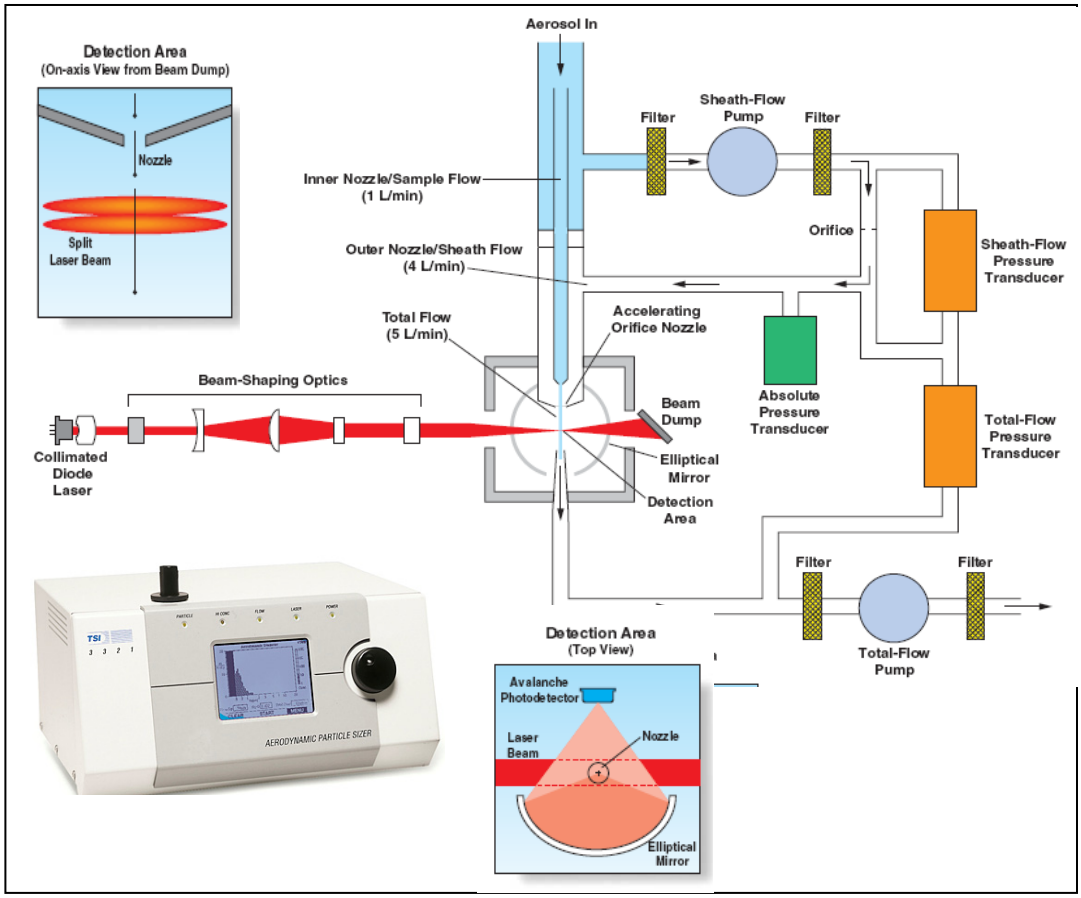


Figure 2: Operation of the Aerodynamic Particle Sizer (APS) Spectrometer Unit. Inset shows the APS unit. (Reference 7).

Table 1. Summary of the Tested Aerosols' Aerodynamic Size and Electrostatic Charge Properties Determined by the Lased Doppler Velocimetry Technique (ESPART Analyzer).

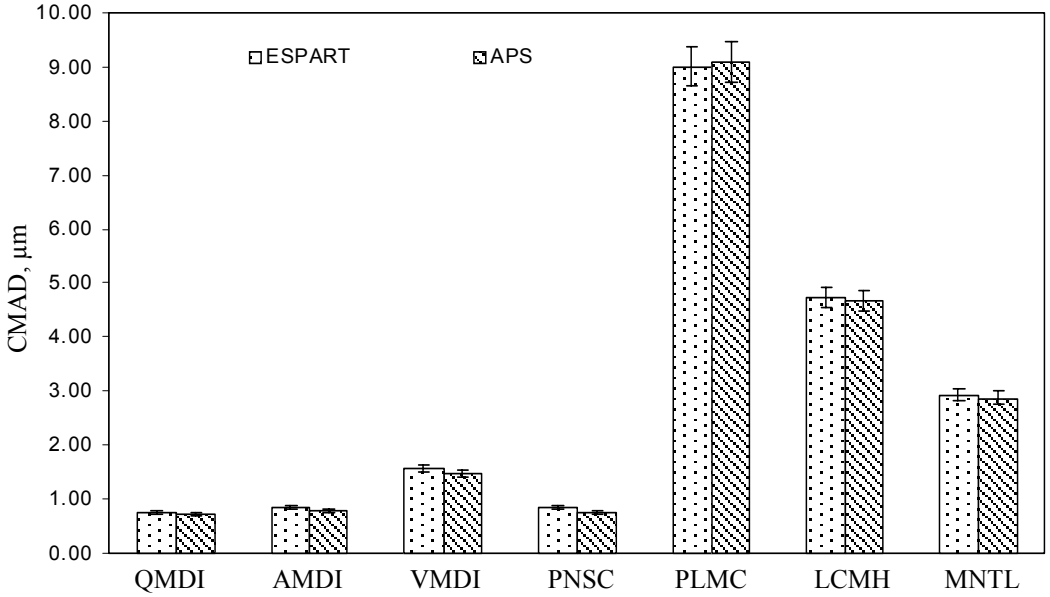
Aerosol	Total (charged & uncharged) Particles (St. Dev.)	Charged Particle (St. Dev.)	CMAD (μm) (St. Dev.)	MMAD (μm) (St. Dev.)	Net Charge to mass ratio (μC/g)
QMDI	6764 (8)	360 (4)	0.75 (0.01)	1.67 (0.04)	- 2.829 ± 0.07
AMDI	6514 (18)	1856 (16)	0.83 (0.03)	3.90 (0.06)	+ 4.072 ± 0.06
VMDI	5905 (5)	2971 (3)	1.56 (0.01)	2.71 (0.04)	+ 3.492 ± 0.05
PNSC	2238 (10)	301 (4)	0.83 (0.01)	1.51 (0.02)	- 0.774 ± 0.02
PLMC	2058 (11)	369 (2)	9.00 (0.04)	9.71 (0.02)	- 1.329 ± 0.04
LCMH	2032 (25)	1928 (6)	4.72 (0.06)	5.62 (0.07)	+ 3.265 ± 0.03
MNTL	1923 (13)	276 (11)	2.92 (0.01)	5.68 (0.09)	+ 2.503 ± 0.06

QMDI - Qvar Metered Dose inhaler, AMDI - Albuterol Sulphate Metered Dose Inhaler,
VMDI - Ventolin Metered Dose Inhaler, PNSC - PARI-LC Plus Nebulizer Sodium Chloride
PLMC - Polymer Microsphere, LCMH - Lactose Monohydrate, MNTL – Mannitol
CMAD - Count median aerodynamic diameter, MMAD - Mass median aerodynamic diameter

Table 2. Summary of the Tested Aerosols' Aerodynamic Size Properties Determined by the Time of Flight Technique (APS Spectrometer).

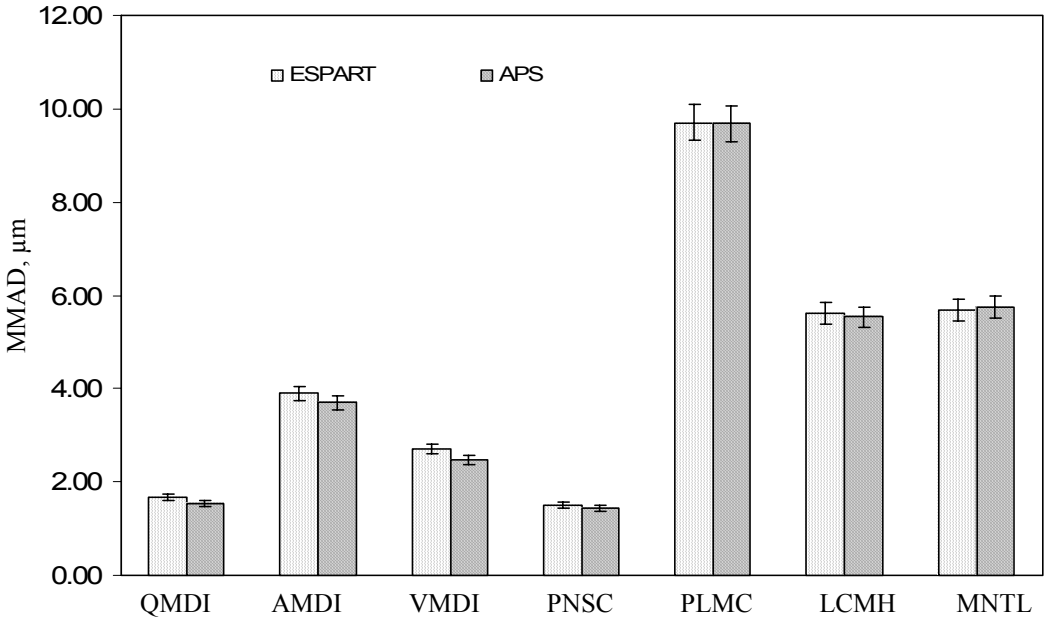
Aerosol	Total (charged & uncharged) Particles (St. Dev.)	CMAD (μm) (St. Dev.)	MMAD (μm) (St. Dev.)
QMDI	6928 (9)	0.72 (0.01)	1.54 (0.04)
AMDI	6636 (8)	0.78 (0.01)	3.71 (0.02)
VMDI	6249 (13)	1.48 (0.02)	2.49 (0.05)
PNSC	2463 (8)	0.76 (0.03)	1.51 (0.02)
PLMC	2456 (6)	9.10 (0.04)	9.69 (0.01)
LCMH	2299 (17)	4.67 (0.05)	5.54 (0.10)
MNTL	2272 (9)	2.88 (0.04)	5.76 (0.08)

QMDI - Qvar Metered Dose inhaler, AMDI - Albuterol Sulphate Metered Dose Inhaler,
VMDI - Ventolin Metered Dose Inhaler, PNSC - PARI-LC Plus Nebulizer Sodium Chloride
PLMC - Polymer Microsphere, LCMH - Lactose Monohydrate, MNTL – Mannitol
CMAD - Count median aerodynamic diameter, MMAD - Mass median aerodynamic diameter



QMDI - Qvar Metered Dose inhaler, AMDI - Albuterol Sulphate Metered Dose Inhaler, VMDI - Ventolin Metered Dose Inhaler, PNSC - PARI-LC Plus Nebulizer Sodium Chloride PLMC - Polymer Microsphere, LCMH - Lactose Monohydrate, MNTL - Mannitol

Figure 4: Analyzed results of tested aerosols' count median aerodynamic diameter (CMAD), which were measured simultaneously by the Electronic Single Particle Aerodynamic Relaxation Time (ESPART) Analyzer and the Aerodynamic Particle Sizer (APS) Spectrometer.



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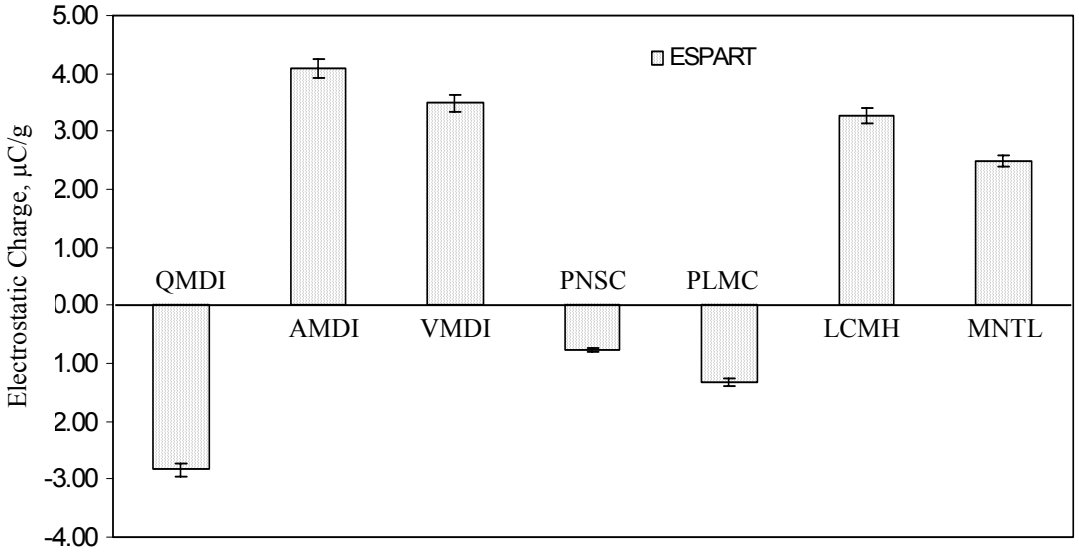
VMDI - Ventolin Metered Dose Inhaler, PNSC - PARI-LC Plus Nebulizer Sodium Chloride
PLMC - Polymer Microsphere, LCMH - Lactose Monohydrate, MNTL - Mannitol

Figure 5: Analyzed results of tested aerosols' mass median aerodynamic diameter (MMAD), which were measured simultaneously by the Electronic Single Particle Aerodynamic Relaxation Time (ESPART) Analyzer and the Aerodynamic Particle Sizer (APS) Spectrometer.



QMDI - Qvar Metered Dose inhaler, AMDI - Albuterol Sulphate Metered Dose Inhaler, VMDI - Ventolin Metered Dose Inhaler, PNSC - PARI-LC Plus Nebulizer Sodium Chloride PLMC - Polymer Microsphere, LCMH - Lactose Monohydrate, MNTL - Mannitol

Figure 6: Analyzed results of tested aerosols' net electrostatic charge (charge-to-mass ratio) in micro-coulomb per gram measured by the Electronic Single Particle Aerodynamic Relaxation Time (ESPART) Analyzer. Aerodynamic Particle Sizer Spectrometer does not support characterization of this property by design.

Effectiveness of Resource Buffers for the Stochastic Task Insertion Problem

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Abstract

This paper describes the development and testing of a new predictive scheduling technique for the Stochastic Resource Constrained Project Scheduling Problem (SRCPSP) with Stochastic Task Insertion (STI). This technique uses information about overall project and individual task resource usage to determine appropriate buffers sizes in the initial baseline schedule.

1. SRCPSP--STI

The area of focus for this research is the Stochastic Resource Constrained Project Scheduling Problem (SRCPSP) with Stochastic Task Insertion (STI). Selim [28] defined the STI problem as one in which some project activities may or may not occur with a certain probability and a known duration, and termed these activities as "unplanned". Thus, the STI problem is a specific form of the SRCPSP where a the duration of the unplanned activities are characterized by a Bernoulli distribution with outcomes equal to 0 and d_i .

The initial interest in this problem was motivated by Pet-Armacost's analysis of unplanned work in NASA's Orbiter Processing Facility at Kennedy Space Center. The STI problem occurs in many project planning applications where there are inspection tasks that may require additional work depending on the results of the inspection. Obvious industrial applications include any kind of repair and maintenance facility as well as major construction projects with periodic inspections.

1.1. SRCPSP--STI Formulation

The SRCPSP with stochastic task durations, including STI problems, can be formulated as a multi-stage stochastic programming problem as described by Fernandez [9] and may be written as:

Find a policy $\beta^*(\Psi g)$ that

Minimizes $E(\max_i s_i + d_i)$

Subject to

$s_i \geq s_j + d_j$, $\forall_i \in I, \forall_j \in H_i, i \notin C_g, i \notin S_g$ (precedence constraints)

$$\sum_{i \in A_g} r_{ik} \leq b_k^{\,g} \;, \forall g, \forall k$$ (resource constraints)

$\beta^*(\Psi g) \in n(\Psi g)$, $\forall g$ (nonanticipativity)

where,

$E(\bullet)$ = expected value of a random variable

r_{ik} = amount of resource type k required by activity i

b_{kg} = total availability of resource type k at decision stage g

I = set of indices for the project tasks{1,2, N}

N = total number of tasks in the project

A_g = set of activities on-going immediately after the decision d_g at stage g

C_g = set of completed tasks decision stage g

S_g = set of on-going at decision stage g

k = number of resource types

d_i = duration of activity i, a random variable

The resulting policy typically includes the development of a predictive or baseline

schedule and some defined actions to be taken when a stochastic event is realized.

2. Predictive Scheduling

Predictive or proactive scheduling techniques allow a project manager to develop a baseline schedule that protects the project against the effects of uncertainty. Analytical approaches and techniques for developing robust proactive schedules have been extensively studied ([3], [16], [25], [34]). Approaches include redundancy-based techniques that allow for extra time in each activity, or scheduling extra resources and robust machine scheduling techniques to develop schedules that minimize the consequences of the worst case scenario.

2.1. Predictive Scheduling for SRCPSP

Robust project scheduling includes mathematical programming models for the generation of stable baseline schedules under the assumption that the proper amount of resources can be acquired if booked in advance based on the pre-schedule and that a single activity disruption (duration increase) may occur during schedule execution [15]. The same authors have also used a resource flow network resource allocation model that protects a given baseline schedule against activity duration variability [21].

Stochastic task duration can be approached as a multi-stage decision process that uses so-called "scheduling policies" [30]. Explicit scheduling policies have been employed to minimize the expected project duration by developing multi-stage stochastic programming problems ([10], [11], [26]). Branch and bound methods have also been applied [18], [30], [31].

Al-Fawzan and Haouari [1] developed a tabu search algorithm to generate a baseline schedule to minimize makespan while maximizing robustness. Kobylanski and Kuchta [20] provided alternative definitions and methods of determining a robust schedule. Azaron, Perkgoz, et al. [4] evaluated the time-cost trade off with a multi-objective genetic algorithm that allocates resources while optimizing project cost, mean completion time, and the probability that duration exceeds a threshold.

Ballestin [5] evaluated when heuristic algorithms should be used to solve problems with stochastic task durations instead of working with the deterministic problem and provided heuristics to develop the baseline schedule. He used regret-based biased random sampling and a priority rule to calculate its possibility of being selected, and a second approach based on Hartmann's [13] genetic algorithm for the stochastic RCPSP. Ballestin and Leus' [6] work continued in the development of a Greedy Randomized Adaptive Search Procedure heuristic to develop baseline schedules for minimizing expected project makespan.

Deblaere, Demeulemeester, et al. [7] used three integer programming-based heuristics and one constructive procedure to develop a baseline schedule and resource allocation plan for the RCPSP with activity duration variability to maximize stability. Other approaches include Long and Ohsato [23] who used a genetic algorithm so optimal project duration is minimized while Shih [29] developed a greedy method for resource allocation to reduce completion time.

2.2. SRCPSP Approach: Critical Path and Buffering Methods

Grey [12] provided a detailed overview of Critical Chain Buffer Management and its application for the RCPSP, and included a discussion of critiques of the method. One concern is that the technique generates a baseline schedule by solving the

deterministic RCPSP and subsequently inserts buffers for robustness, instead of solving a stochastic RCPSP [14], which may be an oversimplification of the problem [17].

Grey found that most of the research on the use of buffers for project scheduling is in the job shop or machine scheduling literature [12]. There are limited results for the SRCPSP. Rabbani, Fatemi Ghomi, et al. [27] developed a new heuristic for the RCPSP with stochastic task durations by using concepts from critical chain to determine the finish time of activities at certain decision points. Van de Vonder, Demeulemeester, et al. [33] proposed a heuristic algorithm to protect the starting times of intermediate activities when multiple activity disruptions occur by adding intermediate buffers to a minimal duration RCPSP.

Kim and De La Garza [19] developed the resource constrained critical path method (RCPM), that allows for the identification of alternative schedules by identifying the critical path and float data. Liu, Song, et al. [22] proposed a multi-objective model for the RCPSP and used a critical chain scheduling approach to insert feeding and project buffers into the approximate optimal project schedule to enhance stability. Grey [12] suggested the possibility of using feeding and project buffers for the Stochastic Task Insertion (STI) case.

Tukel, et al. [32] introduced two new buffering methods for determining feeding buffer sizes in critical chain project scheduling for the SRCPSP with stochastic task durations. One method uses resource utilization and the other uses network complexity.

2.3. Research on the STI Problem

Selim [28] focused on developing appropriate metrics for assessing alternative approaches for the STI problem. In addition to makespan, she developed a set of robustness (stability) metrics to evaluate predictive scheduling techniques. She applied those metrics to the "optimistic" project (no stochastic tasks occurred—0% buffer) and the "pessimistic" project (all of the stochastic tasks occurred—100% buffer). Grey [12] expanded the research with two new robustness metrics and developed a new partial buffering strategy. Grey found the partial buffering strategy to be more effective than Selim's "extreme" buffering approach for most of the makespan and robustness metrics.

The Selim and Grey metrics compared the sequence of tasks and the durations of the project schedule at different stages. The initial schedule provided at the start of a project before work begins is referred to as the **initial base (IB)** [28], and **infeasible base** or **baseline** [12] schedule. The **modified base (MB)** [28] schedule is also referred to the **as-run** [12] schedule and represents the reported schedule after project completion. The perfect knowledge (PK) schedule refers to the schedule containing the optimal task order (minimized makespan) if all uncertainty was known at the beginning of the project.

Note that the as-run schedule requires that the original activity start times in the baseline schedule need to be adjusted whenever a buffered activity occurs or does not occur. Both Selim and Grey employed a "right-shift" or "left-shift" repair heuristic depending on whether the stochastic task did or did not occur.

If resource usage is important to project managers, then a set of metrics that describes changes to the resource flow is important to measure the differences between the initial baseline predictive schedule and the final "as-run" schedule. In this research, two new sets of resource metrics are defined that are

based on resource utilization and resource flow. Using these new metrics, as well as the Selim/Grey metrics, a new buffering approach was developed that used resource information to size the buffers.

3. New Resource Buffers for the SRCPSP with STI

Evidence in the literature suggests the need for the development of new predictive procedures to assist project managers in developing robust initial baseline schedules using resource information as a buffer sizing strategy. The four new resource buffering techniques (labeled as BR1 – BR4 below) allocate a larger buffer size to tasks with higher levels of resource utilization. This assumes that the stochastic nature of a task with high resource utilization has a more significant impact on its surrounding tasks than those with low resource utilization. Note that the buffer is a time buffer based on a percentage of the task duration (if it occurs.)

BR1 = Average ($\%R_1$, $\%R_2$, .., $\%R_N$) where R_N = number of units of resource type N required by that task divided by the total number of resource N units available. For example, task four uses 2 units of resource type one. If there are 10 units of resource one available, BR1 for task four is equal to 2/10 = 20%. If task four required more than one resource, each resource percentage would be calculated separately and averaged.

BR2 = max(BR1,50% buffer) where 50% buffer is half the duration of the stochastic task.

BR3 = Average ($\%PU_1$, $\%PU_2$, .., $\%PU_N$) where PU_N is equal to the project level utilization of resource type N at the start time of that task in the pessimistic schedule. For example, if task four uses 2 units of resource type one and is scheduled to start at time one in the pessimistic schedule. Also scheduled at time period one in the pessimistic schedule are 3 resources used by another task. If there are 10 units of resource one available, PU_1 for task four is equal to (3+2)/10 = 50%. Similar to BR1, this is calculated for each resource type and averaged.

BR4 = 70% buffer for networks with high resource parameters, 30% for networks with low resource parameters. High and low resource parameters were defined by Selim.

In each of these resource buffering strategies, the buffer is in terms of the percent of task duration. For example, a 50% buffer applied to a task with duration of 10 will schedule that task for duration of 5 in the initial baseline (IB) schedule. During schedule eventuation, the actual task may occur with duration of 10, or will not occur at all, and the surrounding tasks will be shifted to the left or right to repair the schedule in "real time" to create the modified base (MB).

3.1. Experimental Problem Set

The experimental process followed by Selim [28] was used to first develop a set of testing networks. The problems that were selected for study had 32 tasks and 2 types of renewable resources, with 10 units available of each. The RanGen software [8] was used to generate the test problems. RanGen accepted the network order strength and complexity index as well as resource factor and constrainedness as input parameters. Once RanGen produced 30 networks of each type, Selim selected 5 for study for each combination of input parameters.

3.2. Factors for Study

The RanGen network generator [8] generates networks for various settings for network and resource parameters. Resource parameters consist of **resource factors**,

defined as the average number of resource types requested by each activity and **resource constrainedness**, defined as resource availability divided by the available number of that resource. Network parameters include **order strength (OS)**, defined as the number of precedence relations divided by the theoretical maximum number of precedence relations [24] and **complexity index (CI)**, defined as: "the minimum number of node reductions sufficient (along with series and parallel reductions) to reduce a two-terminal acyclic network to a single edge"[8]. A full-factorial design with two setting for the two parameters was used to create the networks.

10xx = Low Resource, Low Network
11xx = High Resource, Low Network
12xx = Low Resource, High Network
13xx = High Resource, High Network

These network characteristics were then combined with the location of the stochastic occurrence in the network (early or late), and the number of stochastically occurring tasks (high or low) to form four sets of networks with each type of characteristics:

- Early, low: four stochastic tasks occur in the first half of the network
- Late, low: four stochastic tasks occur in the last half of the network
- Early, high: eight stochastic tasks occur in the first half of the network
- Late, high: eight stochastic tasks occur in the last half of the network

3.3. Problem Set-Up:

Selim computed a "Stochastic Number" (SN) that combined duration and resource characteristics that was then used to identify which activities would be identified as STI activities. The same procedure was used by Grey and is used here to create the problem set of 20 problems (with 32 tasks and 2 resource types.

Step 1: Calculate for each task m:

$SN = 0.5(d) + 0.25\left(\sum_{i=1}^{n} r_n\right)$ where:

SN = stochastic number.
d = duration of activity.
r_n = total utilization of resource type n.
n = the number of resource types.

Step 2: Identify the first half (early tasks) and second half (late tasks) using task start time and breaking ties using lowest activity number.

Step 3: Within the first and second half set of the schedule, identify the tasks with the highest 4 (low stochasticity) SN values and highest 8 (high stochasticity) SN values, breaking ties with start time (i.e., sort by timing (early/late), S_N, start time).

3.4. Analysis:

The analysis of the networks was conducted using Base SAS® and SAS PROC CPM which were used iteratively to solve a network, perform the right-shift/left-shift repair, and repeat the process until all tasks had been considered. See [2] for details.

Fifteen metrics were used to evaluate the effectiveness of the resource buffers. Six are due to Selim [28], two duration-related measures that compare duration of a modified base schedule to the perfect knowledge schedule and the original baseline schedule and four re-sequencing measures that evaluate changed task start times, additional and changed predecessors, and a combination of the two. Two measures from Grey [12] account for changes in task start time by calculating the absolute value of differences between the corresponding start times of the comparison schedules and using the average coefficient of variation of these differences as a performance metric. Additionally, seven metrics due to Archer [2]

compare the resource utilization and resource flow of the initial baseline to the final modified baseline.

These metrics were used to compare the results of developing the initial baseline schedules using the four new resource buffer sizing techniques to using a 50% buffer sizing strategy. The 50% buffer size was chosen as a comparison since it was demonstrated by Grey [12] to be more effective than the optimistic (0% buffer) and pessimistic (100% buffer) of Selim.

Initial analysis pointed to areas where resource buffer sizing techniques demonstrate the potential for improvement in robustness (Mx) and resource (RMx) metrics. Further statistical testing of the data was then used to first look for interaction effects, significant factors, and any areas of significant improvement.

	High stochasticity		Low stochasticity	
	Early	*Late*	*Early*	*Late*
10xx		B41/M1 BR3/M2 BR3/M7 BR3/RM3 BR1/RM4a	BR3/M2 BR4/RM2	BR1/M5 BR1/RM1
11xx	BR3/M5		BR4/M5	
12xx				BR1/RM4a BR1/RM4b
13xx	BR1/M8 BR4/M3 BR4/M5 BR4/M6			

3.5. Results

A general linear model (GLM) was constructed to investigate significant factors and interaction effects that explain the variance in the metric values. Method (50% of resource buffers) and two-way interactions with method have entered the model for most of the metrics. If a project manager can determine resource parameters, network parameters, stochasticity and location of stochastic events in a project that is to be scheduled, this information can help point the project manager to when it is most important to consider the method of developing the initial baseline schedule. Based on the results of the GLM model, there was clear that for the existing robustness metrics and newly developed resource metrics, interaction effects exist among the buffering methods, network parameters, resource parameters, level of stochasticity, and location (timing) of stochastic tasks.

With the initial GLM model revealing significant interactions with the buffering method used on the value of many metrics, a series of ANOVA tables were constructed for each set of networks with the same factor settings, and for each significant ANOVA result, Tukey's test for multiple comparisons was used to determine where the means are significantly different. The results did not provide any significant evidence that there exist instances when improvement may be made in rescheduling metrics by employing resource information to size buffers as compared to a flat application of a 50% buffer sizing technique.

Although there were significant interactions as indicated above, it was not possible to generalize the results. However, it does provide a basis for concluding that using a 50% buffer over a 0% (optimistic) or 100% (pessimistic) buffer will produce positive results for resource metrics.

3.6. Conclusions

If resources are important to a project manager dealing with the resource constrained project scheduling problem with stochastic task insertion (STI), it was hypothesized that this resource information

may be used to create a new buffer sizing technique. However, no evidence exists that resource buffers provide project managers with a better way to size buffers. While experimenting to uncover improvements made by resource buffers, the conclusions of Grey's analysis involving interactions with network characteristics for the 50% buffer have been expanded upon using multiple comparison ANOVAs and Tukey's procedure. The newly developed resource metrics were used, in addition to the Selim [28] and Grey [12] robustness metrics. While improvements using the resource buffers were not discovered, the conclusions do describe for project managers the interactions that exist and provide recommendations for using the 50% buffering method depending on (1) what is important to the project manager (duration, stability, resource utilization or flow) and (2) what information is available about the network (resource and network parameters, stochasticity level and location) at hand.

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"Say on Pay": A Focus on Performance

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Abstract

Current "say on pay" measures are considered by some stakeholders to be at the heart of corporate governance efforts to reward long-term performance.This paper presents an analysis of "say on pay" proxy resolutions for executive compensation and implications for tough economic times.

1. Introduction

With the new Obama administration have come fast moving changes in the "say on pay" movement. This paper examines data from corporate proxy proposal results to understand what the "say on pay" movement is and where it is headed.

2. History

The "say on pay" movement is really a continuation of the public view that executive compensation is out of line with performance. Say on pay has existed in Europe for years, but these efforts have recently been promoted in the U.S. What the movement supports is the right of corporate shareholders to hold a nonbinding vote on their board's compensation report. Included as part of the process, shareholders supply input and evaluation about the rationale for paying the CEO and top management. In doing this they hope that their "say" regarding identification of questionable compensation package practices will result in a second look at the matters by the board.

Interestingly, shareholders in the United Kingdom and some other European countries, have held these kinds of votes for several years (Elstein, 2008). In fact, within the United Kingdom, Australia, Netherlands and Sweden, company shareholders are allowed to cast advisory votes on executive compensation. Specifically, UK law has served as a model since 2002 for institutional investors and international funds groups in their appeals to the Securities and Exchange Commission in the U.S. Research on the UK efforts have been presented as benefitting longer-term performance targets in compensation plans, restrained growth of executive compensation packages, and significant movement of CEO salaries to performance-based pay (Odell, 2007).

Within the U.S., the trend toward greater accountability has been accelerated by enhanced disclosure and information to boards and stockholders about levels of compensation. These efforts are part of relatively new SEC disclosure rules that apply to annual reports and proxy statements, beginning with reports for fiscal years ending on or after December 15, 2006. (Cross, Salhus, Wolfman, and Zepralka, 2006).

Within the U.S. Congressional arena, the "say on pay" movement was promoted as legislation in April 2007 by Barney Frank (D-Massachusetts) to require public companies to let investors weigh in on executive compensation. This bill was passed by a 2-1 margin in the House of Representatives. In 2008, U.S. Sen. Barack Obama (D-Illinois) introduced similar legislation before the Senate Banking Committee that would require companies to allow nonbinding shareholder votes on executive compensation packages, but not cap or limit

CEO pay (McCann, 2008). Interestingly, his presidential opponent, John McCain (R-Arizona) publicly endorsed the measure in a June 10, 2008 speech, where he promised to force companies to seek shareholder approval for their executive-pay schemes if he won in November (Salzman, 2008).

Table 1 presents both sides of the debate. Those in favor of "say on pay" typically see it as a way to increase accountability, provide greater communication with shareholders, and emphasize rewards for long-term performance. Those against it are concerned with shareholder micro-management, leading to problems with the company's decision-making process. Critics also argue that shareholders already wield the authority to approve all equity-based compensation plans in a binding vote for any company listed on the New York Stock Exchange. In many cases, shareholders are already able to vote on incentive plans/annual bonuses, because of IRS rule 162M (a requirement that allows companies to claim tax deductions on an executive's compensation above $1 million) (McCann, 2008).

3. Analysis

The "say on pay" movement in the U.S. began with seven proposals in 2006. Since then, the number of "say on pay" proxy resolutions has increased from 50 in 2007 to more than 90 in 2008 (Gordon, 2008). In this study, the trends between 2007 and 2008 were analyzed for all companies supplying data regarding the vote in their proxies. Fifty-two companies were analyzed over the two year period.

As Tables 2-4 indicate, support for "say on pay" proposals changed little – from in 2007 to 2008. The average percent increase in support over the period was only 2.6 percent, as compared to the average percent decrease in support of 4.2 percent for the same period. Support for these proposals did not achieve a majority in approximately 73 percent of companies over both years. Similarly, while the average approval was less than 50 percent both years, 35.3 percent of companies saw increased support for the proposals, if they considered them both years. However 64.7 percent of companies with subsequent consideration for the "say on pay" option actually lost support in 2008.

Anecdotally, it is unclear how many companies, like Waddell & Reed Financial, almost achieved a majority in 2007 and took the public position of avoiding any further consideration in 2008.

4. What is in store for the future?

Both Mary Schapiro, the new SEC chairman, and Elisse Walter, the new SEC Commissioner, have come out in favor of giving shareholders an advisory vote on executive pay. In concert with this position stated at Ms. Shapiro's Senate confirmation hearings and Ms. Walter's presentation at a corporate governance forum in New York on February 18, it was announced on February 26 that recipients of the Troubled Asset Relief Program (or TARP) must now comply with "say on pay" measures. Prior to this announcement during the first six weeks of 2009, there were more companies that signaled their intention to consider "say on pay" initiatives in 2009 than there were in total for 2008. Table 5 provides this pre-announcement group.

After the announcement, it was estimated that this regulation will affect an additional 400 companies who have already received bailout money. Also, as a result of the regulation, any proxies filed after February 17, 2009 (the date the stimulus bill was signed) must comply. This means that things will likely be chaotic with

many companies scrambling to draft and print proxies in line with the new regulation. For both investors and management significant education and consulting opportunities exist as both groups try to figure out how to best analyze and vote on the measures. While most of the currently committed companies are financial institutions, House Financial Services Chairman, Barney Franks, predicts that there will be a bill passed in Congress this year to require all listed companies to adopt "say on pay."

5. Future Research

Future research efforts will build on this exploratory analysis to focus on the timing issues, related to voting, which until mandated, will likely be fraught with delays and postponements. For example, Directorship Magazine reported on July 23, 2008, that of the companies achieving a majority, only about two-thirds adopted the vote. It is unclear at this point what direction the idea of the non-binding vote will take in this recessionary environment.

Table 1: The debate: Arguments "For" VS. "Against" on "Say on Pay"

For	Against
"Say on pay" improves the level of communication between directors, management, and shareowners on a regular basis. (Per the British model, "say on pay" has created a pattern of soliciting feedback from large institutional shareholders in advance of the vote.)	"Say on pay" measures are really about shareholders managing companies--shifting power about compensation decisions (and eventually other decisions) away from executives and directors and giving it to a small group of shareholders.
"Say on pay" measures allow stakeholders to take advantage of a company's compensation process as a way to develop internal talent and reward long-term performance.	Corporate power will be shifted to a small number of shareholders whose interests do not necessarily align with the broader shareholder class.
Non-binding votes or the threat of negative votes can help maximize constructive input about compensation that is shared with a firm by very sophisticated investors from institutions, pension funds, and mutual funds.	Shareholder votes on pay are more likely to be based on emotions than facts, because many shareholders, particularly smaller ones, may only read part or possibly none of the CD&A in the proxy.
"Say on pay" enhances the accountability of the board. Since the non-binding vote avoids a nuclear option of shareholders voting with their feet (by selling stock) or losing talented board members (who are booted out over a single pay issue), it is comparable to a vote of confidence.	An up or down vote on pay cannot explain which action should be taken or which element of the pay package is in contention. Is it the mix of cash and equity or perks that is objectionable? Is it the performance metrics? Or is the whole corporate philosophy about compensation unacceptable?
"Say on pay" is politically correct, because it exhibits a process of transparency.	Support or nonsupport for a pay package does not provide a cure for poor oversight.
Adopting a voluntary "say on pay" measure may be more flexible than legislation forced upon companies.	Compensation issues are very difficult for experienced compensation committees to handle, let alone shareholders.
"Say on pay" has been shown in the U.K. to slow the rate of increase in executive pay.	"Say on pay" really does not keep executive pay from rising, as seen in the U.K.
Pay is more equitably distributed among executive officers under this scrutiny.	Shareholders have alternatives other than "say on pay." For example, they can vote directors out.
"Say on pay" allows stockholders who own shares through indexes (commitments for buying and holding the stock unless they sell their index shares or the stock is dropped from the index), to have some say about endorsing or rejecting the compensation discussion and analysis (CD&A).	Micromanaging the firm with respect to pay would restrict overall decision making. This additional constrictive feedback loop would limit board decisions.
"Say on pay" eliminates conflicts of interest where consultants design pay policies. In fact, this has been a focus of Congress' probe regarding relationships of consultants who structure pay packages to enrich executives, who in turn contract with the consultant for employee-benefits and risk-management services. "Say on pay" transparency will encourage negotiation of agreeable company packages over pay long before the company meeting, because consultants don't want a "no" vote from stockholders as part of their resumes.	"Say on pay" is a waste of time. Since voting power for many shares lies with mutual funds and investment firms that manage money for others AND those firms want to win contracts with corporate management for pension and investment banking business, these block votes would not vote against executives' interests, despite the interests of their smaller clients.
In countries where "say on pay" is used, no negative credit implications or executive recruitment and retention problems have occurred due to a shift in pay decisions.	

Table 2

Companies with Say on Pay Proposal	For 2007	For 2008
Shareholder Majority Achieved	26.9%	27.0%
Majority Not Achieved	73.1%	73.0%

Table 3

	2007	2008
Average Approval Percentage	46.2%	47.6%
Lowest Percentage	30.4%	30.0%
Highest Percentage	69.6%	93%

Table 4

Companies with Say on Pay Proposals for both 2007 and 2008	
Increased Support	35.3%
Decreased Support	64.7%
Average Percentage Increase	2.6%
Average Percentage Decrease	4.2%

Table 5 – Among the Companies Receiving "Say on Pay" Shareholder Proposals in 2009:

Abbott Laboratories (ABT)
Alaska Air (ALK)
Allegheny Energy (AYE)
Allstate (ALL)
Altria Group (MO)
American Express (AXP) *
American International Group (AIG)
Ameriprise Financial, Inc.
Apple Computer (APL)
AT&T (T)
Bank of America (BAC)
Bank of New York Mellon (BK)
Boeing (BA)
Bristol Myers Squibb (BMY)
Burlington Northern Santa Fe (BNI)
Capital One Financial (COF)
CenturyTel (CTL)
Charming Shoppes *
Chevron
Citigroup (C)
Citizens Communications (CZN)
Coca-Cola Company (KO)
Colgate-Palmolive (CL)
Comcast (CMCSA)
ConocoPhillips (COP)
CVS / Caremark (CVS)
Dominion Resources (D)
Dupont (E.I. du Pont de Nemours) (DD)
Edison International (EIX)
Electronic Data Systems (EDS)
Eli Lilly (LLY)
Embarq (EQ)
EMC (EMC)
Entergy (ETR)
Exxon Mobil (XOM)
Ford (F)
Freeport-McMoRan Cooper & Gold (FCX)
General Electric (GE)
General Motors (GM)
Goldman Sachs (GS)
Hain Celestial Group (HAIN)
Hewlett-Packard (HPQ) *
Honeywell (HON)
Huntington Bancshares (HBAN)
Intel (INTC) *
International Business Machines (IBM)
Johnson & Johnson (JNJ)
Jones Apparel Group (JNY)
Lexmark International (LXK)
Lockheed Martin (LMT)
Marathon Oil (MRO)
McDonald's (MCD)
Merck (MRK)
Morgan Stanley (MS)
Northrop Grumman (NOC)
Occidental Petroleum (OXY) *
Oracle
PepsiCo (PEP)

Pfizer (PFE)
PG&E (PCG)
Procter & Gamble
Prudential (PRU)
Pulte Homes (PHM)
Qwest (Q)
Raytheon (RTN)
Rite Aid (RAD)
Schering-Plough (SGP)
Schlumberger Limited (SLB)
Sempra Energy (SRE)
South Financial Group (TSFG)
State Street (STT)
Target (TGT)
Time Warner (TWX)
Tupperware Brands (TUP)
UnitedHealth (UNH)
Valero Energy (VLO)
Wachovia (WB)
Waddell & Reed Financial (WDR)
Wal-Mart Stores (WMT)
Walt Disney Company (DIS)
Wells Fargo & Company (WFC)
XTO
Yahoo (YHOO)
YUM! Brands (YUM)
Zions Bancorporation (ZION)

* - *resolution withdrawn in light of agreement*

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Factors that Influence the Use of Social Networking Sites: A Study of Midwestern U.S. College Students

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Abstract

One of the hallmarks of the current use of information technology in the U.S., and increasingly in other countries around the world, is the widespread use of social networking sites such as Facebook. This study uses survey data of college-age individuals in the Midwestern U.S. to note patterns in usage of such sites, and includes analysis by gender, Web experience, perceived privacy, trust and as key variables. The results suggest that levels of trust in social network sites influence social network usage, and that gender influences levels of Web experience and perceived privacy and trust in social network sites.

1. Introduction

In the information age, the rapid development of information technology (IT) is playing an increasingly important role in the lives of people. The Internet and telecommunications have brought great changes to people's daily lives, learning, and work. The remarkable growth in Internet access has created a phenomenal growth in the number of users. In 2000, global Internet use was at 1.3 billion; the latest usage statistics from December 2008 indicates a increase in use to 1.5 trillion users. The growth in Internet usage in the past 8 years has been a phenomenal 305.5 percent [18]. The new and improved Web, Web 2.0, has created a sophisticated user base that thrives on the new functionality and tools now accessible online such as blogs, wiki's, online social networking, higher interactive and collaboration.

Various niche groups on social networks online provide individuals with similar professions or interest to pursue causes and share information that would benefit group members. From a business standpoint, knowing who uses social networking sites and their motivations would facilitate appropriate and efficient marketing of products and services. Increasingly, the growth and enhancements to the Web has made it an essential tool for business, education, government, and entertainment all of which provides great convenience and value to users.

Given that online social networking is still a growing phenomenon, academic research in this realm is still in its infancy [16]. While some initial research has been done, there is still much to be known about the nature of the social network user. While there are a few recent studies that provide basic descriptive demographic data on social network users, there is meager research conducted in a rigorous quantifiable manner that describes the influence of demographic data and other factors that could influence social network usage such as Web experience and perceived trust. Given the state of the research and literature in this arena, this study was motivated by the need to better understand social networking usage.

The rest of the paper presents the following. First, it identifies how social networks are currently used by various demographic groups. This is followed by a brief discussion on factors that could influence social networking. Next, the methodology used is described. Finally, the paper concludes with presentation of the results of the data analysis and implications for future research.

1.1. Web 2.0 and the Social Networking Revolution

Today, the Web is no longer seen as merely another display mode to publish information. The Web is in the forefront of a revolution of greater user collaboration and sharing online that enhances almost all aspects of life to every demographic in the population. Web 2.0 has enhanced its functionality to present interactive features and applications to users [1]. Web 2.0 has become a catchall buzzword that people use to describe a new generation of Internet that is emerging to form the "participatory Web." What seems clear is that Web 2.0 brings people together in a more dynamic way, and social networking is a key characteristic of the Web 2.0 world.

An online social networking site is described as online space that an individual can create a profile to establish or maintain connections with others [10]. These Web sites are often seen as relationship facilitators. In the past five years, these sites have grown from catering to activities of college students into a phenomenon that engages tens of millions of Internet users. While there are many social networking Web sites, the most common ones are facebook.com and myspace.com. Since February 2007, Facebook was the sixth most visited Web site in the United States as measured by average visits [6] with an active user count of over 140 million members that continues to grow at 250,000 users per day [17].

According to a study on Facebook users, the average user spends around 45 minutes on the site each day. More than 70% of social networking activity occurs in the evening, with 37% of participants visit daily and 41% visit a few times per week. Photos, diaries, and music are the preferred content to put on user's own pages, and personal experiences, movies, family, and travel are what people want to see most on their friends' profiles. These users often cite keeping in touch with real life friends and acquaintances and passing the time or avoiding boredom as the key reasons for their use [5]. Far fewer people reported using the site as a means for developing romantic relationships, finding companionship, relieving loneliness, or meeting more interesting people than they knew in real life. Recent research also indicates educational benefits as the reason for logging on to social networking sites [23].

These online social networking sites are still especially popular among the 18 to 25 year old age group who are mostly college students. While these young, early adopters have acted as the initial catalyst for social networks, use among older populations is increasing rapidly. [14]. Studies cite that these new demographics will gain a wide range of benefits from social networking Web sites such as the ability to keep in touch with friends, to establishing new relationships with others, and to feeling a sense of community within the social network to which they belong.

Organizations are also beginning to discover real value from social networking online. New research shows that an increasing number of organizations are informally experimenting with and benefiting from the use of Web 2.0 tools such as communities of practice/groups and chat/instant messaging (IM), with other popular applications including corporate social networks (49%) and blogs and/or wikis (39%) [8]. Many major corporations are planning to use social networking tools to build better communication with employees and to replace outdated intranet systems [1]. Additionally, companies are finding ways to increase revenue through these sites, since it may be significantly cheaper to employ online social networking strategies than to pay for advertising [20]. Using social networks, organizations are able to prescreen potential customers and connect with prospects on a personal level that would build trust and credibility, and adopting social networking services as a way to increase differentiation and retain customers [15].

Online social networking is a fast growing IT phenomenon. It is connecting ordinary Internet users from various demographics, providing niche group interactions for employees and has revealed a new potential target market for businesses. As social networking sites grow 47% annually, reaching 45% of Web users, society, individuals, and businesses have a lot to

gain by understanding what influences social network usage [2].

1.2. Factors that Influence Social Networking

Although offline social networking behavior has been extensively studied, online social networking, as a relatively recent phenomenon, is much less understood. Most of the popular press concerning social networking sites has been negative in focus [6]. Thus, while its popularity keeps growing at a remarkable pace, social networking sites are not without their issues. Controversy surrounds the use of these sites, specifically in terms of privacy, safety, and attitudes toward revealing personal information to the world.

Academic researchers are now beginning to show much interest in this area, yet there is a lack of empirical research on social networking sites and what influences and hinders its usage. Existing sparse academic research has given many valuable insights into how and why social networking is used, particularly by college students. However, most of the previous research has been descriptive studies, often qualitative in nature, that provide findings from data found in user profiles, profile pictures and user surveys [4,10,22].

A study conducted by Acquisti and Gross (2006) focusing on social networking membership, information sharing, and privacy issues of college students revealed that members' privacy concerns did not necessarily coincide with their usage and behaviors on social networks. However, no information on the empirical validation of the survey instrument used was provided. The same researchers conducted another study into privacy issues by analyzing Facebook profiles [13]. The findings indicated that 99% of user did not change the default privacy settings to limit information sharing and many provided large amounts of personal information online.

Another study examined how privacy and trust influence social interactions by comparing the two popular social networking sites, Facebook and MySpace [9]. The study revealed that online relationships can develop in sites where perceived trust and privacy safeguards are weak. However, the researchers conclude that the interaction of trust and privacy concern in social networking sites is not yet sufficiently understood to provide an accurate understanding of usage. Given the popular media hype on privacy invasion and social networking as well as on news releases describing criminal liability as well as college suspensions resulting from usage and behavior on social networks, privacy and trust may have a distinct influence on social networking usage [12].

In addition to perceived privacy and trust, previous studies have also examined the impact of basic demographic data on social networking usage. A survey conducted by Ellison, Steinfield and Lampe (2006) revealed that age and year in school were significant predictors of usage and membership, with younger students and undergraduate students being more likely to belong to social networking sites such as Facebook.

1.2.1. Gender, IT, and Social Networking Sites:

Gender is another factor that has received some attention in the past. A Pew survey of teenage social network users found gender differences that indicated that boys use these sites more frequently than girls in order to engage in flirting [23]. The academic literature is rich with studies that look at the impact of gender on Internet use (e.g., Chen 2007, Odell 2000, Richard 2007). According to researchers, still much concern exists that gender differences influence Web based learning and Internet usage patterns. It is widely asserted that female usage of the Internet is limited by their negative attitudes towards computers and new technology due to their less overall experience with the Internet when compared to men [21].

The tendency of men and boys to have access to, adopt, and use IT ahead of and in greater numbers than women and girls has been widely attributed to the existence of many gender-related barriers. However, in addition to these significant barriers faced by women in the U.S. and around the world (such as are literacy, education and language; mobility and location;

time, money and skills; and socio-cultural attitudes and practices), scholars have noted that IT has the potential to empower women around the world economically, socially and politically, including giving women more upward mobility in the labor market and increased motivation for and access to education. It has also been noted that higher levels of information technology education (ITE) for women may help to avoid elements of what is seen as the downside of IT, such as the deskilling of jobs and the increase in tedious, dead-end jobs [3].

Much less is known of the impact of gender and Internet experience on online social network usage and behavior. As society and the lives of individuals continue to be deeply affected by evolving gender roles, and as businesses begin to use gender as a major demographic characteristic to market to social network users, the influence of gender and Web experience on social networking becomes an important factor worthy of analysis. Therefore, the relationship between gender and the explosion of social networking is also of interest in this regard.

Based on the past literature, perceived privacy, trust, gender and Web experience were chosen as the four major factors that influence social networking usage. Consequently, the main hypothesis investigated in this exploratory study was that gender, perceived privacy, trust, and Web experience influence online social network usage. Figure 1 presents the research model developed to test the hypothesis.

2. Methodology

In order to understand what influences social network usage and behavior, an online survey was created and administered to students at a university in the Midwest. The participants were queried on their social network usage patterns, as well as on what influences their usage. Students were given modest incentives in the form of extra credit to complete the survey, and encouraged by their professors to take their time and answer questions as accurately as possible. Thus a favorable response rate was achieved, with 114 total responses out of 130 students offered the opportunity.

In order to reduce the challenge of accurately capturing and measuring social entities under investigation in positivist quantitative research, many researchers use existing items when possible. However, existing research measures often do not apply to a researcher's current project and it is necessary to exercise caution when adopting existing measures. As such, we used existing measures as a starting point in operationalizing variables of interest. Existing survey questions from prior studies were modified to capture perceived privacy, trust and Web experience. The survey also gathered background data and attempted to elicit responses to open ended questions on individual beliefs and feelings involved with online social networking.

3. Results of Data Analysis

Data gathered from 114 survey participants were analyzed using SPSS 17.0 to conduct a number of different tests. The survey participants were undergraduate students from a variety of majors (participating students received an extra credit point for completing the online survey). Of the 114, 3 were incomplete unusable responses leaving 111 data points for data analysis. The characteristics of the respondents are summarized in Table 1. Overall, about 38% of the respondents were female and 62% male. The respondents spent an average of almost 6 hours per week on social networking Websites (with Facebook as the most common site used), and they logged on 3.35 times on average each day to a social network.

In order to assess the unidimensionality of the items and constructs used, an exploratory factor analysis (EFA) was conducted using principal components analysis with a promax rotation. The EFA included all the items with the number of factors specified to be the number of latent constructs. The initial factor matrix indicated that all items loaded above 0.60 [7] on the intended factor except for two items from perceived privacy.

Cronbach alpha values were used to assess the reliability of the items associated with the latent constructs. According to Gefen et al (2000), Cronbach alphas for constructs in

exploratory studies should exceed 0.60, and in confirmatory studies they should exceed 0.70. Other authorities suggest that a reliability of at least 0.6 suffices for early stages of research [19]. The internal consistency of constructs in this study surpassed the suggested guidelines for exploratory studies. The factor loadings as well as the reliability measures for each construct are presented in Table 2.

3.1. General Linear Regression Analysis

Regression analysis was conducted to examine the main hypothesis of the research study in which use of online social network, measured as time spent on online social networks per week, serve as the dependent variable. The predictor variables are gender, perceived privacy, trust, and Web experience. Table 3 provides the collinearity statistics, and coefficient estimates for the regression analysis. The high tolerance and low variance inflation factors (VIF) indicate that collinearity is not an issue for this regression.

Trust was the only statistically significant variable that had an impact on usage of online social networks in this sample. Each standardized value represents the amount of change in the use of social networking, given a standard deviation unit change in X (where X is gender, perceived privacy, trust, and Web experience). For example, the use of social networks changes by .298 with a standard deviation unit change in trust in online social networks. The interpretation of the parameters also can use unstandardized coefficient estimates. In this case, each unstandardized value represents the amount of change in use of online social networks, given a single raw score unit change in X (where X again is gender, perceived privacy, trust, and Web experience. This sample therefore implies that users' use of online social networks is related in a statistically significant way to their level of trust in online social networks.

3.2. MANOVA and ANOVA Analysis

In order to further analyze the question of what influences time spent on social networking each week, both MANOVA (multivariate analysis of variance) and ANOVA (analysis of variance) were conducted.

Specifically, MANOVA was conducted to examine if gender helps differentiate perceptions of trust, privacy or Web experience with regard to social networking. The overall multivariate test of the MANOVA indicated that there is a difference in the means of the factors that influence online social networking for gender. Specifically, Wilks' lambda, the most common traditional test for MANOVA, was significant at an 0.05 alpha level.

The ANOVA (univariate analysis of variance) tests assessing the impact of gender on each of the factors that influence online social network use indicate that gender significantly influenced perceived privacy, Web experience and trust (See Table 4).

4. Conclusion

Web 2.0 and the growing use of social networking sites such as Facebook constitute one of the latest developments in the growing impact of the Internet and IT on people's daily lives, learning and work. The remarkable growth in the number of users of online social networking means that many constituencies are interested in finding out more about this phenomenon, as it affects the individuals, learning, business/commerce, and society.

In examining factors that influence social network usage, perceived privacy and trust in the site, as well as Web experience and gender, have been discussed as important potential influences. A model was developed whereby perceived privacy, trust, Web experience, and gender are hypothesized to influence online social network use.

Through an online survey taken by 114 Midwestern U.S. college students, data was collected on these variables and analyzed using linear regression, MANOVA and ANOVA. Results indicate that levels of trust in social network sites are a statistically significant influence on social network usage, and further, that gender influences levels of Web experience and perceived privacy and trust in social network sites.

These results suggest the need for further research on factors influencing social network usage, especially in light of the increasing importance of online social networking in society as a whole, to individual users' lives, and to businesses and entrepreneurs seeking new customer bases and new ventures. This study is seen as a first step towards building a more complex model. The factors chosen for this investigation (perceived privacy, trust, Web experience, and gender) were based on a survey of past literature. The current study suggests that additional variables could also be considered as possible influences on social network usage, and might explain more of the variance. Accordingly, an open-ended survey could be conducted to explore reasons why individuals use or do not use social networking media. Another important step in future research would be to see if studies in other locales replicate these results.

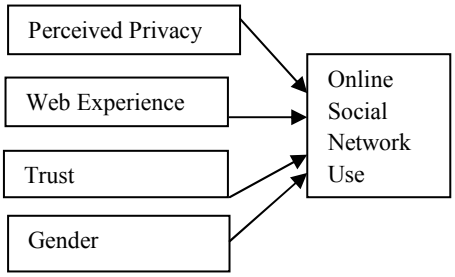

Figure 1 – Theoretical Model of Factors that influence social network usage

Table 1: Characteristics of Respondent Students

Characteristic		Percent	Average
Gender	Male	62.0	N/A
	Female	38.0	
Age	<20	33.3	20.02
	20-25	64.8	
	>25	1.8	
Work experience	Yes	78.4	N/A
	No	21.6	
Years of web experience	<6	16.5	8.66
	6-10	59.5	
	<10	24	
Membership social networking	Facebook	95.5	N/A
	MySpace	15.2	
	LinkedIn	1.8	
	Other	1.8	
Hours per week social networking	<5	51.3	5.98
	5-10	29.7	
	>10	18.9	
Times per day social networking	1-3	64	3.35
	4-6	28	
	>7	8	
Introduced to social networking site by	Friends	82.6	N/A
	Family	10.1	
	Web Ad	4.6	
	Faculty	2.7	
Use of social networking for school work	Yes	55	N/A
	No	45	

Table 2: Validated Questionnaire Items

Factor	Loading
Trust : Cronbach's alpha = 0.822	
Trusting someone or something is not difficult.	.782
I feel that people or Websites are generally reliable.	.867
The personal information that I provide on this web site is secure	.851
Web Experience : Cronbach's alpha = 0.911	
I feel I am an experienced user of the Internet.	.914
I am very confident in using the web based technologies	.933
Perceived Privacy : People seem very willing to divulge private information about themselves to others	

Table 3: Regression Results

Model	Unstandardized Estimates		Stdized Est's	T	*p*-level	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
Intercept	1.255	3.766		.333	.740		
Trust	*1.320	.475	.298	2.778	.007	.773	1.320
Web Exper.	.261	.522	.054	.499	.619	.762	1.261
Gender	.365	.991	.037	.368	.714	.861	1.365
Perceived Privacy	.301	.356	.083	.845	.400	.929	1.301

* $p < .05$

Table 4: Analysis of Variance Results

	Sum of Squares	DF	Mean Square	F value	Signif.*
Perceived Privacy	8.929	1.00	8.929	5.616	.020
Trust	5.741	1.00	5.741	5.234	.024
Web Experience	6.372	1.00	6.372	7.172	.009

*p=0.05

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The Implementation of Engineering Tools and Methodology to Identify Solutions to the Declining Oyster Industry in the Chesapeake Bay

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Abstract

Over the years, oyster abundance has declined to record lows, particularly on the eastern coast of USA. With a focus on Maryland's Chesapeake Bay, state-wide harvests which exceeded 15 million bushels in the late 1800's and sustained an average of 2 to 3 million bushels through much of the mid 20th century, dropped to 26,495 bushels in 2004. This decline has been attributed to many factors, including fishing pressure, habitat destruction and water quality [1]. Ecologically, oysters are three-dimensional creatures; they are a primary contributor to the Bay's filtration system, they provide a critical habitat for many species, and they serve as food for other sea creatures in the food chain. Economically, oysters have traditionally supported a large commercial fishery industry of harvesters and entrepreneurs, and an estimated annual dockside value at its peak in the early 1900's, in excess of $20 million. Our goal is to investigate and apply engineering methods and technologies that may impact the survivability of oysters and restore their production, and develop a new business model for watermen to compete. This project uses Object Oriented Analysis and Development to enhance our simulation model of the oyster industry created using STELLA simulation software. Inefficiencies within the oyster production industry can be identified and will be considered when developing our Oyster Hatchery Optimization Model and Cost-Benefit Analysis; a solution that is germane to new business practices that benefit watermen and promote entrepreneurship.

1. Introduction

For over 200 years the harvesting of the *Crassostrea Virginica* (the eastern oyster) in the Chesapeake Bay of Maryland has been a traditional past time and has lead to a lucrative oyster industry. However, there has been a sharp decline in the number of oyster bushels harvested which is directly due to a decline in the oyster population.

The oyster itself is a cornerstone species that supports the delicate estuarine environment in many ways. In addition to filtering algae and particulates from the water column, the Eastern oyster forms three-dimensional reefs that provide habitat for other species in the bay [1]. Therefore the absence of the species not only has social and economic impact but a very important environmental one as well.

2. The Biology of the Oyster

Oysters are bivalve mollusks; mollusks, are any of numerous chiefly marine invertebrates of the phylum Mollusca, typically having a soft un-segmented body, a mantle, and a protective calcareous shell and including the edible shellfish and the snails [2]. The oyster is biologically constructed of two hard keratin-based shells connected to each other by a

ligament that allows the creature to seal shut. This halved shell exterior defines the oyster as a "bivalve mollusk". The shape of the shell is typically dictated by environmental constraints, and these oysters are capable of growing over and around adjacent objects including other oysters [1].

The Chesapeake oyster or eastern oyster resides in the estuaries of the Chesapeake Bay (Figure 1) where they feed on the plankton and nutrients in the water. They do so using their gills to filter microalgae and probably bacteria [1]. Hence, oysters increase light penetration in the water column. Improved water clarity promotes the growth of underwater grasses, which benefit blue crabs and many other aquatic organisms [3]. Ideally oysters thrive in these nutrient rich waters where the bottom is relatively firm and stable, salinities are from 10 to 30 ppt (15 to 18 ppt is considered optimal) [4]. Oysters that reside in the Chesapeake Bay tolerate wide fluctuations in temperature, salinity and turbidity. However, oysters themselves cannot regulate their body temperature or the salinity of their body fluids; the oyster's condition is dictated by pre-existing environmental conditions [1].

The Chesapeake Bay has proven to be an ideal environment for the Eastern oyster. Consequently, in the late 19th and early 20th century the eastern oyster population flourished, which in turn gave rise to a prodigious oyster harvesting industry.

3. Benefits of the Oyster Industry

In recent years the total U.S. harvest of oysters has been 30 million pounds of meats; about 75 percent of the total is the eastern oyster. About 18 million pounds of total oyster production (all species) is by cultivation [4]. The Chesapeake oyster industry has birthed many industry related occupations which are tied to harvesting equipment, shucking houses/companies, leased-bottom real estate, oyster hatchery equipment and algae producers (companies). Not only does the oyster industry create employment, but because of the labor-intensive oyster harvesting that originated in small estuary communities, it created a culture as well.

Scientists believe that the Chesapeake Bay's once-flourishing oyster populations historically filtered the estuary's entire water volume of excess nutrients every three or four days [5]. It was estimated that prior to 1870 the eastern oyster was in peak abundance [1] but today the eastern oyster population in the Chesapeake Bay is estimated at only 1% of its original abundance due to over- harvest, habitat destruction, and disease- mediated mortality [6].

4. The Decline of the Species and Historical Management

Although over-harvesting is the prime cause of the depleted oyster population in the Chesapeake Bay, there have been other key contributors as well; these factors include reduced water quality, habitat destruction, diseases, and interaction among factors. In the late 1800s the Chesapeake Bay was inhabited by an abundant supply of oysters [7], after over sixty years the population has dropped by over 80% (Figure 2).

Oysters were traditionally harvested by hand tongs and rakes specially designed for this purpose. Now, more efficient mechanized apparatus are used and the result is a quicker dissemination of the oyster species during harvesting and destruction of the sea bed. Additionally, the resulting sand and silt from shoreline development run off into the Bay literally stifling the oysters to their death. The already declining species was further in peril when the disease MSX (caused by protozoan parasite *Haplosporidium nelsoni*) spread to oyster populations in 1959; and when the protozoan parasite, *Perkinsus marinus*, which

causes the disease Dermo, became a major problem in the mid-1980s [1].

5. Restoration Methods

The US government (National Oceanic and Atmospheric Association) and other organizations of concern have implemented many restoration efforts to revive the diminishing oyster population. These methods included: Sea bottom enhancement, shell planting, seed planting, disease research and creating oyster sanctuaries, oyster reserves, oyster aquacultures, harvesting regulations based on season and quantity and oyster restoration research and development. This diverse approach incorporated legislative, engineering, economic and ecological fields of study and research. The primary reason for failure of these efforts after successful implementation is Maryland's "common property" regulation. It is important to establish at the outset that Maryland's oyster fishery is not a "pure" common-property resource, as this would imply that exploitation was completely uncontrolled [8], but the freedom for the harvester to ply his trade in open water has lead to uncontrolled reaping of this natural resource which conteracts the achievements of the resotration efforts.

The proposed method of restoration uses engineering, ecological and economic analysis tools. The expected result would be an engineering business model that contributes to repletion efforts by increasing the oyster population and addresses the economic strife local oyster harvesters (watermen) are facing by providing entrepreneurial opportunites and more control of their craft; therefore creating a more sustainable, stable oyster industry.

6. Methodology

The aquaculture industry has proven to be very valuable to many fishery industries. Aquaculture provides an alternative source of fishery product to its industry while simultaneously providing employment and reducing harvesting pressure; the Chesapeake Bay oyster industry is no stranger to this phenomenon. The problem with this oyster industry is that there are only three hatcheries, two of which are relatively small privately owned hatcheries and one large-scaled government owned hatchery only producing oysters for restoration, Horn Point Laboratories (University of Maryland). There is a definite void for privately owned aquaculture. The project directive is to demonstrate the economic viability and entrepreneurial opportunity of incorporating micro oyster hatcheries in the Chesapeake Bay.

In order to demonstrate the stability of this micro-hatchery deployment the Chesapeake Oyster industry will be modeled and analyzed using STELLA 8.0 simulation software. An economic cost-benefit analysis of owning and running an oyster hatchery is constructed to compliment the results of the simulation model.

7. Model Structure and Analysis

7.1. General Structure

A flow diagram of the oyster industry will be developed using Object Oriented Techniques and serve as the skeletal structure of the simulation model being developed. Unfortunately, harvest and harvest effort data used for the model are based on incomplete reporting by oyster buyers and has been the victim of poor data management, harvest costs are variable and difficult to estimate, disease mortality is difficult to measure and accurate estimates of oyster stocks over time do not exist [8].

The STELLA model depicts two processes in one concurrent event. The model represents the harvesting and sale of oysters in one season (one year) and the oyster growth process modeled to occur in 3-3.5 years. The growth

process will be simulated first; the results will then be used to initialize the harvesting and market aspect of the model that is modeled as a 12 month process. The growth rate and mortality of oysters are primarily dependent on the salinity, turbidity, disease prevalence and nutrient level of the estuaries in which they reside. To accurately represent these environmental factors their effects were incorporated into the functional responses for mortality and growth rate (as an assumption). Parameter values and functional responses were obtained from previous research projects and literature. The model used fourth order Runga-Kutta numerical methods at a time step of one week to solve all the differential equations. The simulation duration is from 1986 to 2009, which is derived from the time frame of the harvest bushels data.

The system being modeled is the oyster industry of the Chesapeake Bay where the model currency is the oyster. The three main components in this model are the natural environment, public and private hatcheries (micro-hatcheries), and the oyster retail market (Figure 3).

7.2. Public Oyster Hatchery Compartment

It is often theorized that a sustainable oyster industry is largely dependent on the efforts of oyster restoration. Now, because the operations of the public hatchery are not of value to the project goal, the intricacies of processes in the public hatchery can be ignored. Instead the oyster commodity outcome of the public hatchery is modeled (Figure 4). In this case the public hatchery is Horn Point Laboratory University of Maryland. It is the only, government –owned (public hatchery) in Maryland and the largest contributor of oyster spat for restoration efforts. Because the growth rate is overall reflective of the salinity, temperature and nutrient availability [1], there is no need to model these factors unless they are being specifically examined. The oyster larvae are within a partially controlled environment within the Horn point facility where temperature is controlled and kept at an adequate value.

This compartment was modeled from the larval to spat stage because of the availability of the yearly data. The statistical data for mortality rates and lengths of growth processes was obtained from direct interviews with Ecological Technicians at the facility; the data provided was also based on a trend. The input on this compartment is the larvae production per year, represented in a model connector as a step-wise graph from times 1986 to 2009. The facility was not operational until 1994 (or at least indicated by the data received) therefore the larval production prior to that date was 0. The production for 2009 was assumed to be the same as 2008 in order to predict the 2009 influence on the market. The oyster larval mortality rate and spat production was also obtained and modeled accordingly. From that data the larval mortality rate was calculated and represented by the following functional response:

Larvae_mortality_rate =
1-(spat_production/Oyster_Larvae)

When spat are grown out of the Horn Point hatchery they are placed in reserves and sanctuaries in the Chesapeake Bay. There is no certainty of how much of the harvest from the Chesapeake actually came from oysters placed in reserves by Horn point Laboratory; so to accommodate this the model is set up to represent this portion by a functional response.

HPL_percentage_harvested =
*min(reserveadults,harvest_bushels*reserveprop)*

This function, the percentage harvested from Horn point hatchery (HPL percentage harvested) is determined by choosing the minimal value between the oysters supplied to the Bay by Horn Point hatchery (reserve_adults) and the actual harvest multiplied by the reserve proportion (harvest_bushels*reserve_prop). This Horn Point Laboratory portion of the

harvest can be whatever the model user chooses it to be because it does not affect the numerical outcome of the harvest. The reason for this is because the harvest is represented by actual data. This versatility allows the modeler to track the Horn point hatchery input for further studies. The entire oyster harvest is fed into the 'Oyster Processing for Retail' compartment and it should be noted that, the oyster growth process to adulthood is modeled as a random number between 3 to 3.5 years as in occurs in the natural environment.

7.3. Private Oyster Hatchery Compartment

This compartment is modeled from both the real-world micro-hatchery (Marinetics) (which produces roughly 1 to 1.5 million oysters in a year) and Horn Point Laboratory for operational similarities (Figure 5). For simplicity the grow-out process in the private hatchery is modeled from the larval stage/input. General parameters used include: the growth process of fertilized eggs to eyed larvae takes 14 days approximately; survivability of eggs to larvae is 50%; growth of eyed larvae to settled spat is 48-72 hours; the whole brood does not transition to spat altogether, because of the differing growth rates of the larvae, the entire growth process to spat may take from 2-4 weeks.

More specific parameters are defined as follows*: Spat Mortality, Mortality rate* - We shall assume that the same mortality rate for the public hatchery exists for private hatcheries. According to our model for the public hatchery, the mortality of larvae is approximately 94% for 2008. Interviews revealed that spat mortality can be from 98-99%. For this reason we shall use a random number generator for our mortality rate between 94-99%; According to Marinetics, their survival rate for the private hatchery is 0.924; *Commercial Adults*: to accommodate for poor growing seasons a random number generator of 3-3.5 years is used ; *Number of Hatcheries* - this is the driver in this component of the model; *Harvest to Shuck, Harvest to consumer* - these are direct flows dictated by the distribution percentage; *Egg2larv* - according to calculations in order to get a result of approximately 2.4 million oysters in one year, which is close to the amount produced by the two private hatcheries in Maryland, the model must be initiated with close to 4200000 oyster larvae; a pulse function of an input of 160000 oyster larvae every 2 weeks (0.04 years) is used as a result; *Larv mortality* - this is represented by leakage out of the conveyor module, 70-80% mortality; *Spat mortality* - this is 94-99% according to information from the Public Oyster Hatchery calculated mortality rate from documented data, in the public oyster hatchery component of the model; *Com Hatchery Harvest* - this distribution to the customer was split up to accommodate for future economic calculations of half-shell product vs. oyster meat only.

7.4. Oyster Retail Processing Compartment

Oysters are harvested, cleaned and processed for sale to the consumer. The consumers are the supermarkets, restaurants, etc. Oysters are either harvested from government owned restricted reserves or the free-public estuaries. These are combined with oysters from privately owned hatcheries to sum the total oysters being sold to the consumer (Figure 6). 'Oyster Harvest' in the model represents the total yearly harvest of oysters from both from reserves and the public Chesapeake Bay. There is variability of harvesting periods within a year; hence the simulation model only depicts yearly harvest rather than the monthly harvest. The shucking house is the place where oysters are cleaned, shucked and distributed to the consumer. Shucking houses either sell packaged oyster meat (without the shell) or oysters with shell (known as half-shell) to the consumer. In this model the Shucking house serves as the distributor the consumer. For the case of the private hatchery, they sometimes sell directly to

the customer and the remaining portion goes to the shucking house. This is represented by the following functional responses:

*Com_hatch2shuck= distr_percentage*com_hatchery_harvest*

Com_hatch2consum= com_hatchery_harvest(1-distr_percentage)*

Additional components defined in the model: *HPL percentage harvested* – a functional response to track the percentage of oysters harvest from Horn Point Laboratory; *Harvest Bushels* – Data acquired from Maryland DNR Report. This is the driver for this compartment in the model; *OysterHarvest2shuck* – The transit time for oysters from time of harvest to the shucking house is assumed to be zero. Oyster bushels were converted to oysters by multiplying by 10 since we generally there are approximately 10 oysters in a bushel. Also, approximately 7lb of oyster meat is equivalent to 1 bushel which was incorporated in calculations as well; *Shucking House* – Oysters are entering the shucking house from two sources; from the public hatchery and the private hatchery. Oysters leave the shucking house in an assumed zero time.

7.5. Oyster Retail Market Compartment

The purpose of this compartment is to incorporate the supply and demand relationship of oysters to the consumer (Figure 7). The measure of the impact of micro-hatcheries is determined by the value of the oyster to the customer. There are many factors such as competitive markets, transportation, inflation etc that go into calculating the cost of an oyster to the consumer. Therefore the holistic economic calculations necessary for oyster costs is a complicated model within itself. Because we would like to consider the cost of the oyster and hatchery effects on the local level, as well as keep our model as simple as possible, our calculations for cost to the consumer was based on a simple supply and demand functional response based on historical data obtained from NOAA.

In the model there is a converter that transforms the oyster commodity into money; therefore the end result of the model is the monetary value of the oyster and the price point to the consumer. Because the price point is based on a supply-demand relationship, the model is designed to track how the output of oysters harvested within a certain time period influences the price point. The model possesses a functional response that creates a 'conversion coefficient' based on the historical supply-demand relationship between oyster production and price sold. This conversion coefficient was then used to predict future oyster pricing based on the new micro-hatchery oyster supply to the industry. The functional response is given below.

*Conversioncoeff=Ches_nominal_price_per_lb/((harvest_bushels*10/7)+(com_hatch_contr/7))*

Other noted parameters include: *Com hatch contr* - An If Else statement is used to accommodate for the number of oysters produced by the two private hatcheries presently in the industry which is approximately 2.5 million total (approximately 1.3 million each). Even though we are focused on localized pricing we did not consider imports from other states; *Com hatch contr = IF (spat2ad <= 2500000) THEN spat2ad ELSE 0*; *Chesapeake nominal price per lb - Values* derived from historical data provided by NOAA.

8. Model Testing

The model was verified by its functionality and closeness of results to the real world scenario. To ensure this was not a coincidence, the dynamic model was then subjected to validation tests.

It should be noted that there are no fully valid models because all models are something less than the object, or system, being modeled [9]. Because models are designed to mimic the

real-world experience, there is a greater value placed on seeking the usefulness of the model rather than seeking its validity. Attempting to validate a model that functions by the use of valid data presents a conundrum; there is no valid data to compare the model with other than data from the future. Validations of Optimization Models, Decision Theory or Game Theory are often not questioned since the solution procedures are elegant and correct [10]. The model is designed to run simulations using already validated data, namely oyster harvests and private hatchery sales. Because f the unique structure of the model the conventional dynamic modeling tests cannot be applied. The series of tests applied were for model structure validation (figure something); and model behavior validation of which only the Parameter Sensitivity test, Extreme Policy Test, Boundary adequacy, Behavior Sensitivity test and Statistical tests were carried out .

9. Parameter Sensitivity

The method of parameter perturbation will be employed to calculate the parameter sensitivity. Each parameter is adjusted to a 5% increase and a 5% decrease and then compared with the results of a 0% adjustment. The residual sum of squares (RSS) will be calculated for each perturbation method, using Microsoft Excel, as the 5% increase and decrease is compared to that of the observed data. The parameters are analyzed one at a time; therefore while one parameter is being perturbed the others remain unadjusted. For this project there is only two variable parameters that are neither historical data or are a descendent of any preceding parameter in the simulation model, these are 'the number of hatcheries' and the 'eggs 2 larvae" input'. After the perturbation the parameters will be ranked according to their RSS values on which most sensitive. Please note that for this model, the number of hatcheries parameter can only be altered in increments of 1, therefore the perturbation for this parameter will be a 100% increase and a 100% decrease. The simulation is run from years 1986-2009. Because the simulation reconfigures on every time step it greatly increases the number of statistical data received. This method is also used as a tool for tweaking the most sensitive parameters so that the model results closely fit those of the real-world.

10. Results

The Micro-hatchery economic research showed that an initial investment of $290,905, inclusive of building, operation and maintenance costs. For the sensitivity analysis it was determined that the number of hatcheries caused a greater influence of change in the simulation model. This was expected because the 'eggs to larvae parameter' was tied to the number of hatcheries in the model design, and since the number of hatcheries carried a greater volume of oysters (essentially twice the eggs to larvae parameter) it was calculated to be more sensitive. According to the rankings on the magnitude of the error, it was determined that 1 hatchery in the model yielded the most difference.

It should also be considered however that the functional responses that are used to calculate price per lb may need to have a higher or lower threshold to accommodate for many hatcheries being added to the system; the model can only represent the impact of many hatcheries are added to the system while demand for oysters by the consumer remains the same.

In the as-is state of the industry, with only 2 micro-hatcheries, after the model was put through the simulation run of 1102 sequences the results showed that the Final calculated price of oyster per pound was $9.58 while the actual price was $9.73 per pound (Figure 8). Calculating the rate of return according to the

calculated price for a micro-hatchery producing roughly 1.2 million oysters per year gives us:
Assuming 10 oysters (1 bushel) = 7lb
1.2 million Oysters = 840,000 lb = $8,047,200
Now comparing this to an initial investment of $290,905 plus $100,000 due to inflationary prices it would seem that at the end of the year there is a quick and hefty return on the investment within 1 year. However, it should be noted that external costs such as transportation fees, leasing on land and equipment, permits, oyster processing fees, insurance, etc. was not added into this evaluation. I would estimate return on investment in at least 2 years if these costs are included.

Scenario1 – Rate of Return on Hatchery without Leased Bottom: Previously we demonstrated that the initial investment of a micro-hatchery is approximately $390,905 for the first year, with yearly maintenance and operational costs of $98,800/yr. This cost analysis is considering only the costs incurred for constructing and maintaining the hatchery. Assuming the price and successful oyster breeding is the same as indicated in the model for the first year and proceeding years there is an expected $8,047,200 profit. This translates into a full return on investment in the first year of operation with a profit of $8,047,200 - $390,905 = $7,656,295. It should be noted that facility equipment would need to be replaced within the first 2 years; this varies for certain equipment and this transition will deplete profits in the future.

Scenario 2 – Rate of Return on Hatchery without Leased Bottom: In this scenario we consider a more real world application where the cost for purchasing leased bottom equipment for growing the oysters is considered. The initial investment of $390,905 for the first year and $98,800 for the following years (this figure excludes parts replacement) remains the same. Additional equipment for growing the oysters to adulthood on the Bay (as with all hatcheries) is roughly $26,349 annually for off bottom cages and $33,244 annually if the entrepreneur uses floats instead (22).

If costs for land acquisition (and insurance), transportation of goods and costs for larvae and shell are ignored. The new profit margin for the first year is as follows:
$8,047,200 – ($390,905 + $26,349) = $7,629,946 (using off-bottom cages)
$8,047,200 – ($390,905 + $33,244) = $7,623,051 (using floats)

11. Discussion

In can be deduced from these results that the number of micro-hatcheries does not affect the demand for oysters or at the very least a number of over 32 micro-hatcheries will bring about change in demand. This supports earlier predictions that the oyster population is so low that it will require a very large amount of oysters being sold on the consumer market to affect the demand and price. This is another indicator of how much the industry in peril

For the as-is state of the industry, the entrepreneur must now consider what is his risk involved. Some facts are clear from the Micro-hatchery business model. This industry has little competition, and a large return on investment, however there is some uncertainty on success. But with the expert personnel and an adequate location this can be a fruitful investment. The results show that there s a very large return despite other external costs. This is a great investment with a limited supply

With increasing numbers of micro-hatcheries however the demand for oysters will fall but not enough to greatly affect profits. The reason for this is because the oyster natural supply is so low that it will take an astronomical increase in population to cause a great decrease in demand. Environmental interest groups and entrepreneurs should act on the window of opportunity to make a good return on an investment while, stabilizing the industry,

providing occupation for watermen, preserving the oyster harvesting culture and benefitting the environment.

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13. Figures

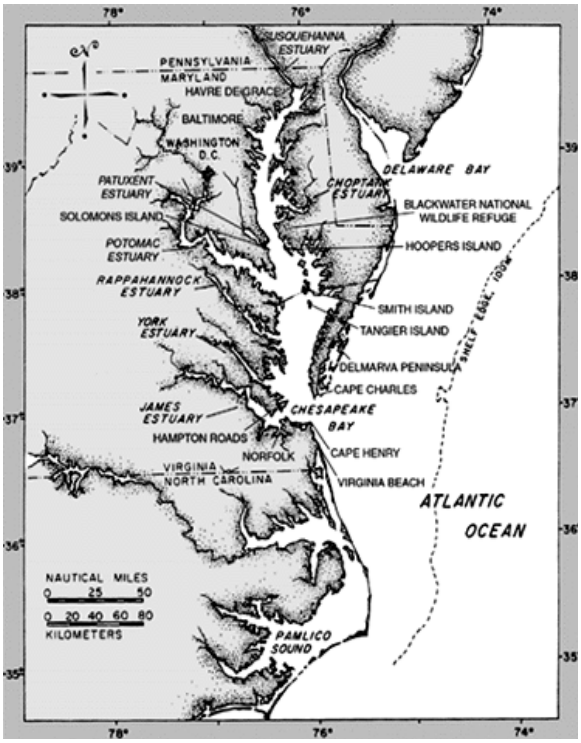

Figure 1. The Chesapeake Bay (Courtesy U.S. Geological Survey)

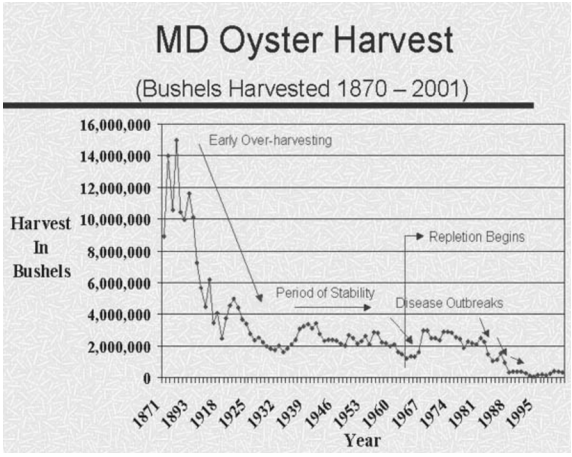

Figure 2. Maryland Oyster Harvest

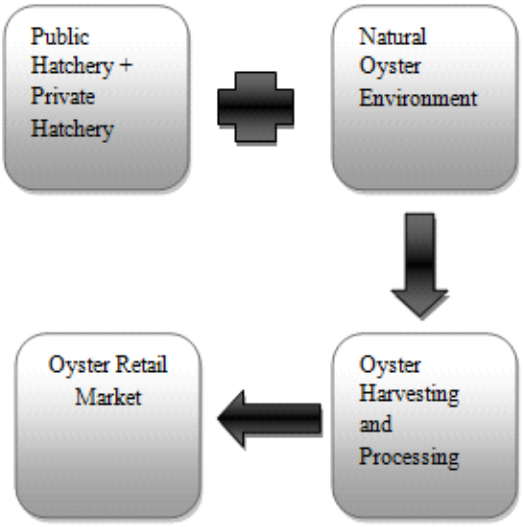

Figure 3. The Simplified Oyster Industry Model

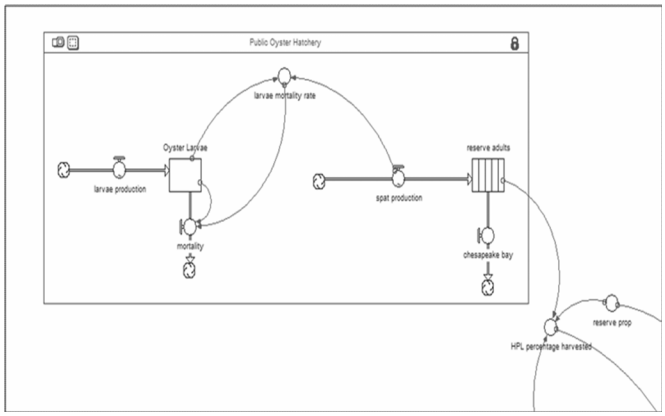

Figure 4. STELLA Model Public Oyster Hatchery

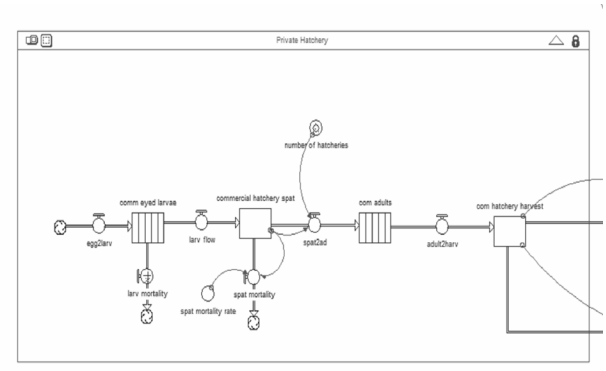

Figure 5. STELLA Private Oyster Hatchery

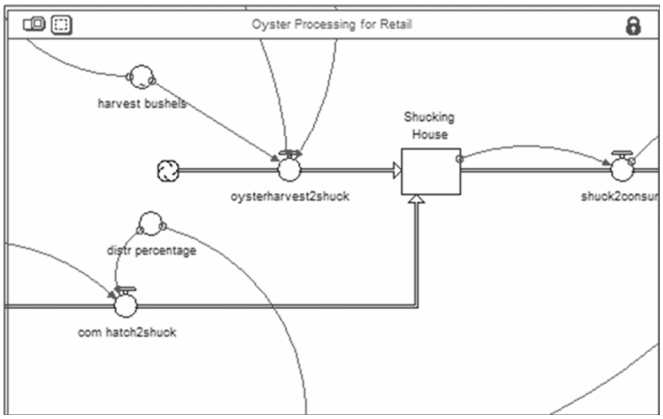

Figure 6. STELLA Oyster Processing for Retail

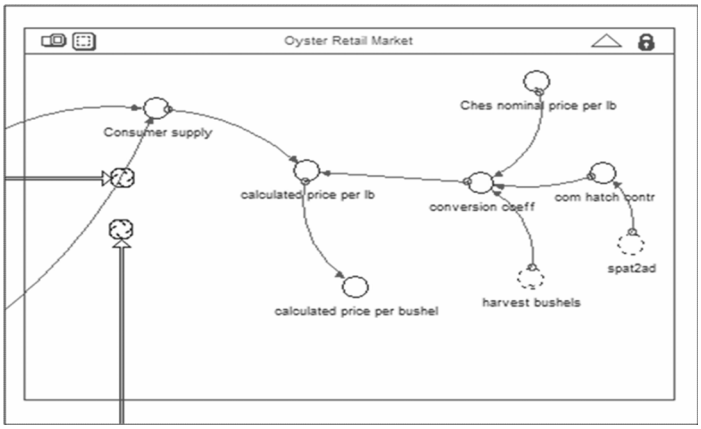

Figure 7. STELLA Oyster Retail Market

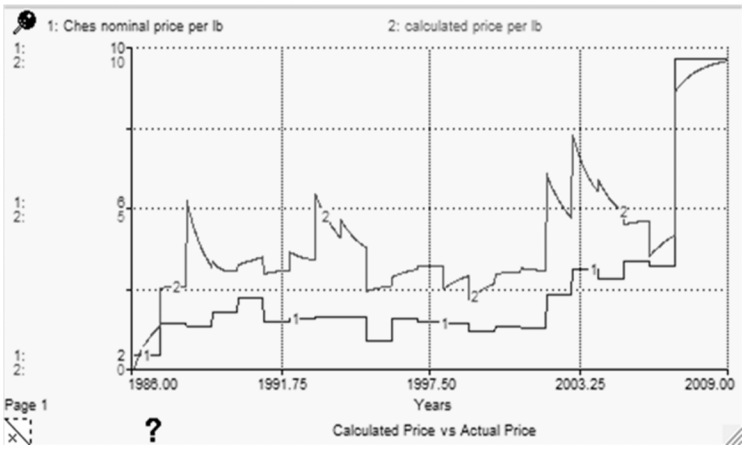

Figure 8. STELLA - Actual price vs. Calculated price

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A Modified Simulated Annealing Algorithm for Scheduling in an Agile Environment

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Abstract

In this paper, a modified simulated annealing algorithm is applied to the scheduling of an agile manufacturing system consisting of machining and assembly operations with the objective of minimizing the makespan. This problem has been addressed in the literature using heuristics and metaheuristics including simulated annealing. In addition, a lower bound has been developed.

The modified simulated annealing algorithm is applied to the problem in addition to other simulated annealing algorithms and performance comparisons, based on the deviation above the lower bound and the frequency of achieving the best solution, are performed. The results show that the modified algorithm outperforms all other algorithms on most of the studied cases. Factors affecting the performance of the presented algorithm are also investigated.

1. Introduction

The problem under investigation in this paper is the scheduling of an agile manufacturing system consisting of two stages: machining and assembly. The machining stage uses a single flexible machine designed to produce a wide variety of parts that are assembled in the second stage to produce a variety of final products. The second stage consists of two or more identical assembly stations. The scheduling objective is to minimize the makespan.

The described system fulfils the goals of agile manufacturing by allowing the manufacturing of a high variety of modular products in small batches at low costs through the machining of common parts that may be assembled at a second stage to make various products.

As an example, Figure 1 shows a table that may be produced by the system described above. Figure 1 also includes a diagraph describing the processing of the table in a notation that was developed by Kusiak [1]. The table in Figure 1 consists of four parts (P1-P4). A cutting/bending machine is used to prepare parts in the first stage, while all subsequent assembly operations are welding operations. Table 1 lists all operations and their time requirements. Parts P1, P2, P3, and P4 are modular parts that are used in several other products. Gaafar et al. [2] used the same parts (presented in Figure 1) to produce a chair. Each part consists of two tubes that are welded together in the following assembly operation (A1-A4). The results of A1 and A2 are assembled in A5 while the results of A3 and A4 are assembled in A6. A7 is the final assembly operation resulting in the final product. It is assumed that one machine and two identical assembly (welding) stations (AS1 and AS2) are available.

In this research, the problem is reduced to the scheduling of the machine in the first stage, while assembly operations are conducted on availability bases. This allows the problem to be represented as a string of unrepeated numbers from one to n depicting the sequence of the machining operations, where n is the number of part nodes on the diagraph. Representing the

problem in this way confines the search space to *n!*. As an example, Figure 2 shows the resulting schedule of the string '1342' with a makespan of 32.

The diagraph in Figure 1 has three assembly levels and according to the notation developed by Kusiak [1] it is a complex digraph because it contains at least two assembly nodes in at least one assembly level. A simple digraph, on the other hand, contains no more than one assembly node in any assembly level.

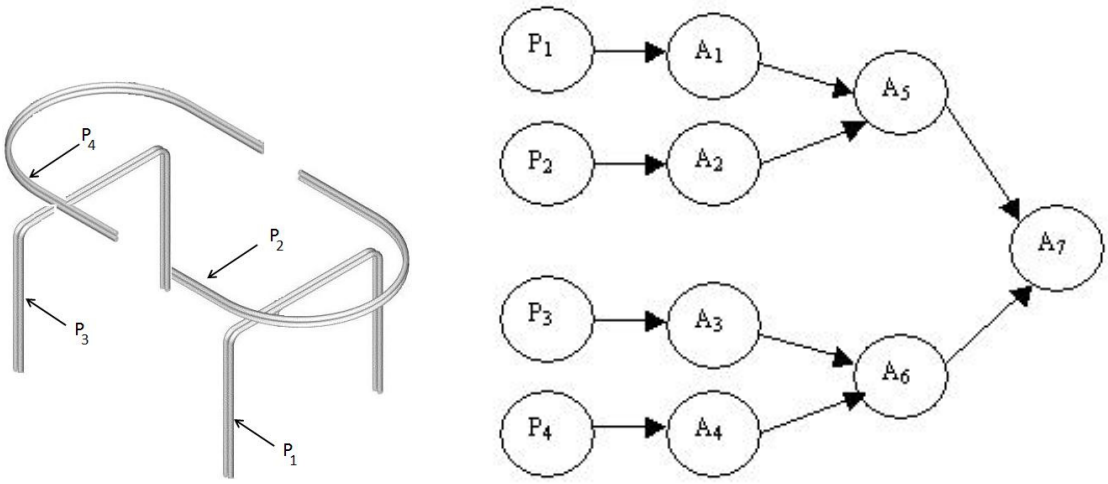


Figure 1. An example product and its standardized digraph.

Table 1. Machining and assembly time sets for the example product in Figure 1.

Part	P_1	P_2	P_3	P_4			
Time	5	3	5	3			
Assembly	A_1	A_2	A_3	A_4	A_5	A_6	A_7
Time	7	5	7	5	4	4	6

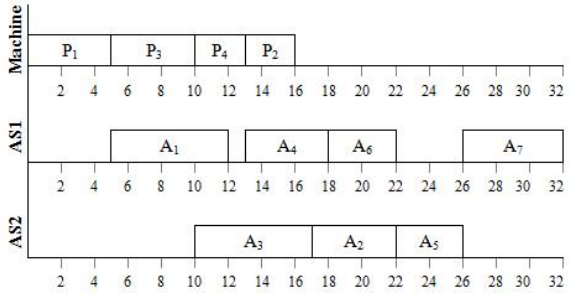


Figure 2. Schedule based on the string '1342'.

This paper addresses scheduling problems associated with complex digraphs with the following assumptions:

1. Operation times (machining and assembly) are deterministic;
2. Only one part is machined in the first stage at any instance of time;
3. A maximum of one assembly operation is allowed at any assembly station and a maximum of one assembly station may be assigned to any assembly operation at any instance of time;
4. Preemption of machining or assembly operations is not allowed;
5. Unlimited buffer capacity between the machining stage and the assembly stage, and between assembly stations; and
6. Setup times and handling times are included in the machining and assembly times.

The described problem has been investigated by He and Babayan [3] who developed a digraph standardization procedure, a mathematical formulation, a lower bound, and four heuristic algorithms to solve the problem. They also

presented computational results showing that their proposed heuristics result in optimal and near optimal solutions. Gaafar and Masoud [4] applied genetic algorithms and simulated annealing to the same scheduling problem and obtained significantly better results. SA provided better performance over GA. Liao and Liao [5] applied ant colony optimization to a similar problem. Gaafar et al. [2] introduced an enhancement to the GA based on particle swarm optimization (PSO) concepts. The modification enhanced the GA performance, but was still short of that of SA. This motivated the current research that explores the power of a new enhancement to SA to further post its performance. The presented algorithm builds on the work of AbdulRahman [6] who introduced two parallel SA algorithms and reported better results than those reported by Gaafar and Masoud [4]. The algorithm presented in this paper is simpler and achieves better results. Additionally, the current research investigates factors that significantly affect the performance of the various scheduling approaches under tighter conditions than was presented in earlier research.

In the remainder of this paper, Section 2 presents the various simulated annealing algorithms. Section 3 outlines the experimentation strategy for evaluating and comparing the performance of the various algorithms. Section 4 presents and discusses the results of the experiment. Finally, Section 5 provides the overall research conclusions.

2. The simulated annealing algorithms

This section introduces the general SA algorithm used by Gaafar and Masoud [4] followed by the proposed modifications to enhance its performance. The modified algorithm is named parallel simulated annealing (PSA).

The SA algorithm used by Gaafar and Masoud [4], starts with an initial solution (schedule) that is generated as a random string of unrepeated numbers from 1 to n. Assembly schedules are directly driven by the machine schedule. At every instant of time when there are vacant assembly stations, all assembly operations are scanned, the ones with satisfied precedence constraints are identified, and the ready assembly operations are assigned to vacant assembly stations accordingly. Assembly operations closer to the left end then to the top of the digraph are given higher priority. The makespan of this initial schedule is calculated before the algorithm moves to a new schedule. The next schedule (iteration) is generated by computing six different neighbor permutations using certain perturbation schemes [7] and then selecting the best schedule; the one with the least makespan. If the selected permutation (schedule) has a lower makespan than the current solution, it is accepted and it becomes the new solution. Otherwise, the selected permutation may still be accepted, as the new solution, according to a set probability. This means that SA may move to a worse solution, which allows it to get out of local optima. This probability is controlled by a parameter that is named temperature, where high temperatures relate to high probability of accepting a worse solution. The temperature parameter is usually decreased over time (similar to physical annealing processes) according to a cooling schedule that is controlled by a cooling parameter. The SA algorithm uses the cooling schedule published in Negenman [8], which forces the probability of accepting a worse solution to decrease over time, so that any gained proximity to the optimum is not lost. The SA algorithm terminates after 836 iterations (5016 evaluations of the objective function) or when a lower bound schedule is reached, whichever comes first. Parameters of the SA algorithm are listed in Table 2.

Table 2. Parameters of the SA algorithm.

Parameter	Value
Number of iterations	836
Number of perturbation schemes	6
Cooling schedule	Polynomial
Initial temperature	150
Cooling parameter	0.9

The parallel simulated annealing (PSA) algorithm developed in this research uses the same problem representation, random initial solution generation, and neighborhood perturbation schemes as the original SA. However, and as the name implies, PSA runs four SA algorithms in parallel. Analogous to the sowing of seeds to grow different plants, the number of the SA algorithms run in parallel is metaphorically referred to as the number of seeds. This notion of parallelism was motivated by the fact that the SA algorithm seldom reached the best solution by utilizing the full number of iterations.

Several authors have explored the concept of parallel simulated annealing for other applications (e.g., [9] and [10]). However, for the problem considered in this research, AbdulRahman [6] introduced a simple parallel SA algorithm that runs four SA algorithms in parallel and reports the best result of all four as the final solution. The author also presented a modification to this simple algorithm which was called parallel modified simulated annealing (PMSA) that produced better results than the simple parallel algorithm. The PSA presented in this research is a simplification of the PMSA and achieves better results.

In the PSA the best solution obtained by each seed is recorded to avoid losing good solutions. Also, PSA takes advantage of the multiple seeds by running two different cooling schedules: polynomial and logarithmic. The logarithmic cooling schedule was inspired by the works of Zolfaghari and Liang [11] who developed this cooling schedule for SA applied to a similar optimization problem of machine/part grouping.

The PSA generates the best schedules in two phases. In the first phase, the algorithm runs each of the four parallel SA algorithms for 189 iterations, but if a lower bound solution is reached inside any of the parallel seeds, the PSA algorithm is terminated. Otherwise, the best solution inside each seed is further processed in the second phase of the algorithm using two new perturbations. The two new perturbations modify one solution (the secondary parent) based on the characteristics of another solution (the primary parent) to produce a new solution. The modification is based on the distance between the locations of the various activities in the two parents. The activity with the largest difference in distance is selected for modification in two different perturbations: distance-swap and distance-insert mutations. In the distance-swap mutation, the selected activity in the secondary parent is swapped with the activity that is in the corresponding location in the primary parent. In the distance-insert mutation, the selected activity in the secondary parent is moved to the corresponding location in the primary parent while activities are slid from that location in the direction of the vacated location of the selected activity until it is filled. Figure 3 shows an example of both mutations.

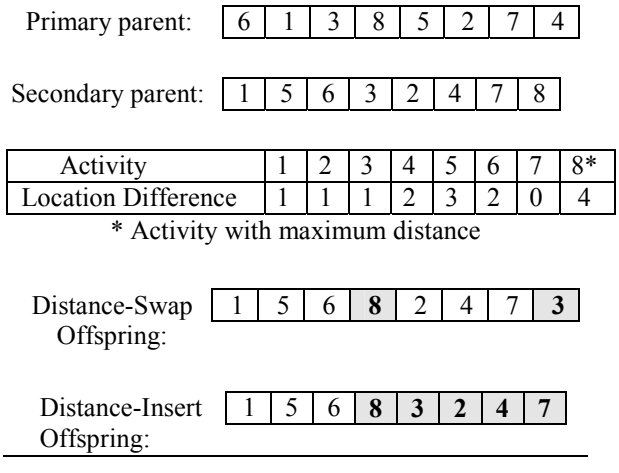


Figure 3. Distance-based mutation perturbations.

In Figure 3, activity '8' has the largest location distance in the two parents. In the distance-swap mutation, activity '8' in the secondary parent is moved from its current location (8th) to location 4 as in the primary parent. Accordingly, activity '3' is moved from its current location to the original location of activity '8.' In the distance-insert mutation, activity '8' is still moved to its corresponding location in the parent (4th), but all activities from that location are slid to the right to vacate location 4 for activity 8.

In the second phase of the PSA, the initial primary parents are the best solutions from each of the parallel SA algorithms in the first phase. For each primary parent, the other three parents act as secondary parents and the two distance-based mutation perturbations are applied to generate six new solutions that are compared to the primary parent and a new primary parent is selected for the next iteration in the same way as in the original SA algorithm. The second phase runs for 20 more iterations or until a lower bound solution is obtained, whichever comes first. The maximum number of objective function evaluations f the PSA algorithm is 5016; the same number used for the SA algorithm. Table 3 displays the main parameters of the PSA algorithm. Pilot runs were utilized to decide on the various parameters of the PSA.

The first phase of the presented PSA is similar to the PMSA, except that the PMSA uses 179 iterations only. PMSA, however, uses a cumbersome initiation scheme in the second phase that is described in details in AbdulRahman [6]. PMSA uses 30 iterations in the second phase.

Table 3. Key parameters of the PSA algorithm.

Parameter	Value
Number of seeds	4
Iterations per seed (first phase)	189
Iterations per seed (second phase)	20
No. of perturbations (first phase)	6
No. of perturbations (first phase)	2
Cooling schedule	Polynomial+ Logarithmic
Initial temperature	150
Cooling parameter	0.9

3. Experimentation strategy

A designed experiment is used to compare the performance of the three algorithms (SA, PMSA, and PSA). The experiment also investigates the effect of three factors on the performance of these algorithms: the number of part nodes in a digraph (A); the complexity of a digraph (B); and the ratio of average machining time per part to average subassembly time per subassembly operation (C). The fixed effects 2^3 factorial design replicated twice is chosen [12]. Two levels (low and high) are selected for every factor. Table 4 summarizes these levels. The levels of factors A and C are quantitative, while the levels of factor B are qualitative. Higher complexity is realized by three attributes: more subassembly nodes; more assembly levels; and loss of symmetry in the digraph. Choice of the factors and their levels was guided by the information in Gaafar and Masoud [4].

Performance evaluation is based on two responses: the percentage deviation from the lower bound (DLB) and the frequency of resulting in the best solution (FBS). Lower bounds were obtained using the procedure outlined in He and Babayan [3, p 2476]. Overall, six response values are recorded for every problem considered (DLB and FBS for each of the three algorithms). The 2^3 experiment requires eight runs, each representing a unique factorial combination. For each run, 100 instances of the scheduling problem were randomly generated for a total of 800 instances for the whole experiment. For the same run, each instance had its own machining and assembly time sets, which were initially generated from discrete uniform distributions in the ranges of (2, 25) and (1, 30), respectively.

These times were subsequently either scaled up or down to reach the desired level of factor C, 1/4 or 1/2. The 800 instances were solved three times using the three algorithms and the two responses (DLB and FBS) were computed for every algorithm.

For the statistical analysis of the results, two replicates of the DLB responses at each run of the experiment were obtained by dividing the 100 instances in each run into two groups of 50 each. The averages of the solutions of each group were used to calculate the DLB responses.

Table 4. Factor levels for the 2^3 factorial experiment.

Factor	Levels	
	Low	High
A: Part nodes	16	32
B: Digraph complexity	2 assembly levels	3-4 assembly levels
C: Machining to assembly time ratio	1/4	1/2

4. Results and analysis

Table 5 lists the average DLB and the FBS for the eight experimental runs. Cells containing the best values achieved in each run are shaded. Each response cell in the 'Average DLB' columns of Table 5 is the average of 100 instances. The FBS columns list the number of times an algorithm achieved the best solution in 100 instances. PMSA and SA results in Table 5 are consistent with those reported in the literature [4, 6]. It is clear that both PMSA and PSA outperform SA over both responses in all cases. Differences are more pronounced in the first four runs at the low level of factor C (C=1/4). PSA outperforms PMSA in the same way. For example, in Run 1 the average DLB falls from 0.69% (SA) to 0.62% (PMSA) to 0.43% (PSA). For the first four runs, the overall average DLB for SA, PMSA, and PSA are 1.11%, 1.01%, and 0.91%, respectively, while the total FBS are 306, 350, and 390, respectively. Overall, PSA is consistently the best performer, followed by PMSA. However, in some instances, SA still produced a better solution than both PMSA and PSA. A more comprehensive comparison is presented in Figure 4 that displays the improvement that each algorithm provides on the solutions obtained from another algorithm. .

Table 5. Results in averages and frequencies for 100 instances per run.

Run #	Factors			Responses					
				Average DLB			FBS		
	A	B	C	SA	PMSA	PSA	SA	PMSA	PSA
1	16	L	1/4	0.69	0.62	0.43	85	89	100
2	32	L	1/4	0.20	0.10	0.08	67	91	96
3	16	H	1/4	1.36	1.23	1.16	85	90	100
4	32	H	1/4	2.20	2.07	1.98	69	80	94
5	16	L	1/2	1.36	1.33	1.30	94	95	100
6	32	L	1/2	0.21	0.18	0.17	89	94	98
7	16	H	1/2	1.33	1.23	1.07	85	91	100
8	32	H	1/2	0.50	0.43	0.31	78	82	94

Two comparisons are depicted in Figure 4. Each curve in Figure 4 shows the various percentiles of the deviations of solutions obtained from one algorithm over another. For example, the line labeled PMSA-PSA shows the percentiles of the percentage deviations of solutions obtained from PMSA over those obtained from PSA. Figure 4 shows that in less than 4% of the cases, PMSA provided a better solution than that of PSA by a maximum reduction in the DLB of about 0.9%, while PSA provided a better solution 10% of the time with a maximum reduction in the DLB of about 5.1%. SA/PSA comparisons show that while SA provides a better solution with a maximum reduction in the DLB of about 0.5% in about 2% of the cases, PSA provides a better solution with a maximum reduction in the DLB of about 7.8% in 20% of the cases. The two algorithms provide the same results in the remaining 78% of the cases. These comparisons show that the use of PSA may result in significant time savings.

The two runs where SA produced better schedules than PSA in 6 instances are runs with a large number of part nodes and high diagraph complexity (runs 4 and 8). These are conditions where the SA algorithm seems to benefit from the large number of iterations to reach the best solution.

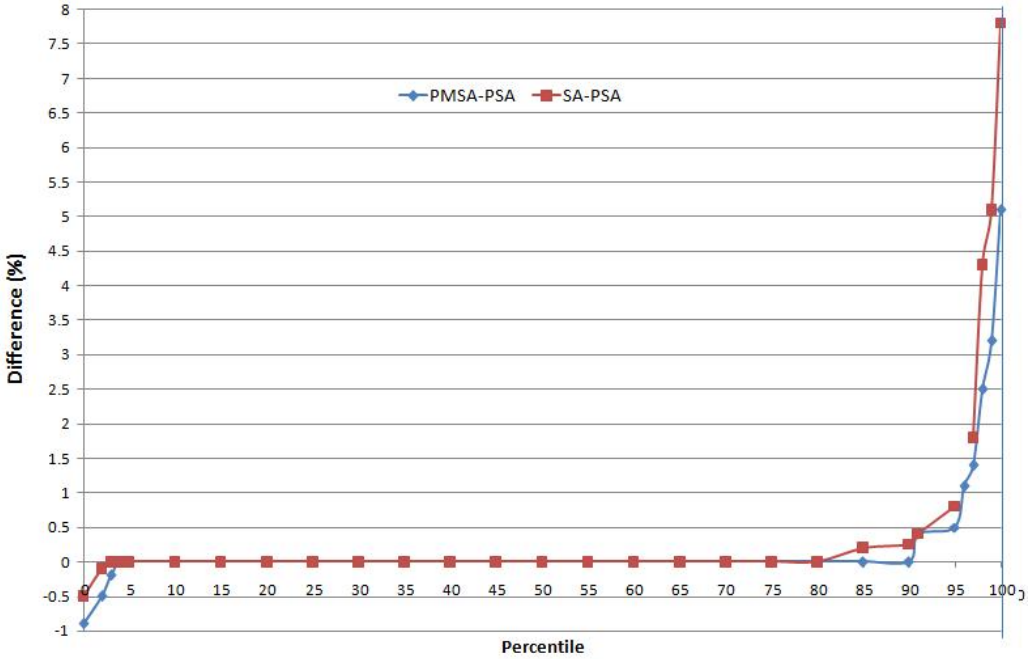


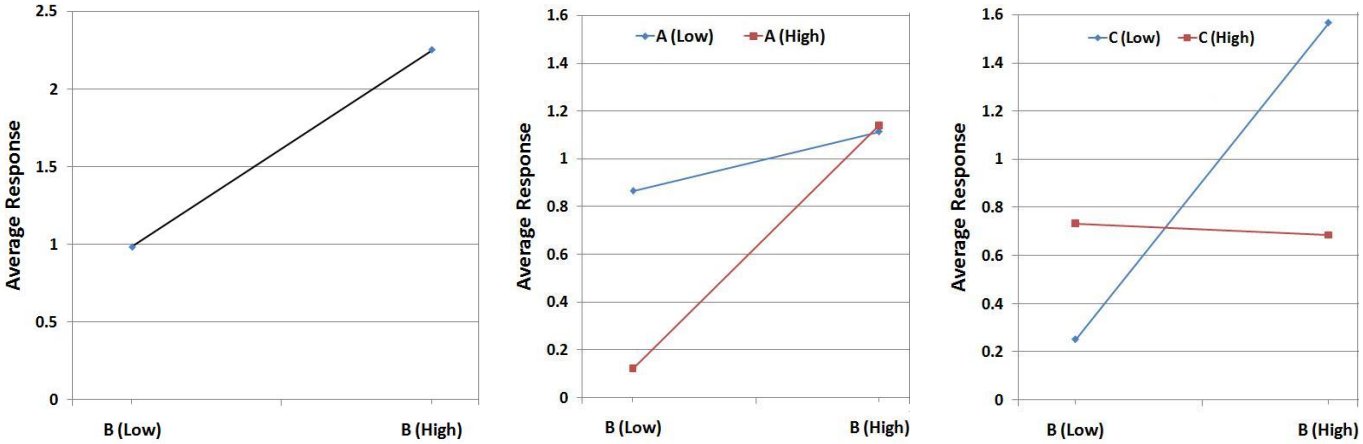
Figure 4. Percentiles of the deviations of PMSA and SA solutions over PSA solutions.

Analysis of variance (ANOVA) results show that, within the investigated factor ranges, Factor B and interactions involving Factor B (AB, BC) have the most significant effect on the DLB response. Figure 5 shows effect plots for factor B and interactions AB and BC for the DLB of PSA. Figure 5a shows that increasing the digraph complexity (Factor B) increases the average deviation from the lower bound. The interaction plots, however, show that this behavior is only significant at the high level of Factor A (large number of part nodes) and the low level of factor C (low machining to assembly time ratio). This is a logical result as increasing the number of part nodes increases the search space and makes it more difficult to find the optimum solution, especially with a complex diagraph. The poor performance at lower machining to assembly time ratios is also consistent with results in the literature [2, 4, 6].

5. Conclusion

In this paper, a parallel simulated annealing algorithm (PSA) was applied to the scheduling

problem of a manufacturing system consisting of machining and assembly stages, with the objective of minimizing the makespan. The performance of PSA is better than both a simple SA and a PMSA available in the literature. Both PSA and PMSA generate solutions through two phases. However, the better performance of PSA may be attributed to the fact that it diversifies the search in the first phase and then intensifies it in the second phase, while PMSA diversifies the search in both phases. This concept of diversification and intensification has been utilized by other authors [e.g., 13] and will be further explored by applying the presented algorithm to other production scheduling problems.



a) Factor B b) Interaction BA c) Interaction BC

Figure 5. Effect graphs involving factor B for the PSA and the DLB response.

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Industry and University Collaboration of Masters in Engineering Management Curriculum Design

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Abstract

The Middle Tennessee State University (MTSU) department of Engineering Technology (ET) collaborated with the Industrial Advisory Board to create a Master of Science of Engineering Technology (MSET) with a concentration in Engineering Management. Members of this board included a global automotive OEM, automotive suppliers, food processors, medical providers, and other local manufacturing operations.

This graduate program curriculum was designed based on a list of competencies that was developed by the Industrial Advisory Board with facilitation support from university ET members. These competencies were compared with survey data from the Society of Manufacturing Engineers (SME) members that provided a ranking of 15 "competency gaps" to further validate and align the design elements of the proposed MSET curriculum. This new program curriculum will prepare graduate students for occupations in such diverse areas as:

- Technology Managers for Manufacturing Operations (both assembly & fabrication), Healthcare, Food Production, Training/Consulting, and Government agencies
- Project Managers for Concrete Industry, Construction Industry, Lean Manufacturing, and Six Sigma Initiatives
- Account Managers for global technology companies
- Engineering Project Managers for process control companies, enterprise resource systems developers, and technology development enterprises

Survey data from undergraduate students clearly indicates a strong desire for a graduate program that emphasizes engineering technical management as opposed to business management (The technology-based program differs significantly from the MBA and has a different set of required foundations of knowledge courses).

1. Introduction

The Engineering Technology (ET) Department was successful in creating a Master of Science in Engineering Technology with a concentration in Engineering Management using the efforts and discussions from the ongoing ET Industrial Advisory Board. This board is chaired and primarily directed by industry leaders with support from the ET faculty to facilitate program changes. These efforts spanned a period of about three years and the results identified the competencies required by these companies for both undergraduate and graduate students that will lead them to become successful engineering and technical managers. These competencies were then compared with both an SME survey

for validation and a survey of upper management conducted by MTSU's Russell Chair of Manufacturing Excellence for further corroboration.

2. Results

2.1. Graduate program

Graduate students and prospective graduate students in the Engineering Technology area have been requesting an alternative to the MBA program that bridges the gap between business and technology and focuses on the skills required to stimulate and manage technological innovation and creativity, and help bring value-creating ideas, goods, and services to the marketplace. The technology-based program differs significantly from the MBA and has a different set of required foundations of knowledge courses.

The purpose is to educate students at the Master's level in the "core" engineering technologies and to include a concentration in the management of those technologies by providing the links between technology & management. In order to be a successful manager of technology the student in this concentration must have both the applications-focused skills in technology, coupled with leadership and management skills.

The Industry Advisory Board identified the interpersonal, management, and engineering skills needed for their success in various industry or businesses. Its focus on these enhanced skills reflects an increasing need in the workplace for graduate students to fast track into engineering/technical management or high-value specialty knowledge management positions. Industry areas include: manufacturing/assembly, medical, human resources/training, service (retail, food service, etc.), as well as applied sciences. What strengthens this procedure for the reader, is that the membership of the Board will take ownership of the program and support it, whereas a program copied from other programs would not necessarily be accepted by the local industries as meeting the local needs.

The goals are to fill the competency gaps as identified and ranked as follows:

1. Project management & soft skills (with work experience)
2. Quality systems – six sigma/lean/TPM
3. Problem solving
4. Teamwork/interpersonal/organizational behavior
5. Oral communications/listening
6. Manufacturing systems
7. Management theory/business skills/financial analysis.
8. Process control
9. International global perspective
10. Supply chain management
11. Product/process design/ergonomics
12. Engineering fundamentals
13. Materials
14. Specific manufacturing processes
15. Written communications

The MTSU ranking above, including the survey data is compared with the SME rankings in Table 1.

The resulting curriculum for the masters program provides the following course summary at the graduate level (refer to Table 2 for catalog listing):

1. ET "core" courses:
    a. Safety planning
    b. Productivity strategies/lean systems
    c. Six sigma/TQM
    d. Project management & soft skills
    e. Research methods
    f. Current & future trends in ET
    g. Thesis research (for thesis option)
2. Engineering management concentration courses:
    a. Inventions & patents
    b. Advanced topics in technology
    c. Management & operations concepts
    d. Information Systems management
3. Electives (for non-thesis option):
    a. International supply chain mgmt.

   b. Electronic commerce
   c. Legal environment of management
   d. Others (as approved by advisor)
4. Internship (required for project experience)

Once, the curriculum design was complete, it was prudent to provide evidence to MTSU administration of the student interest in such a program. To research this need, other programs were investigated at two peer universities (Western Kentucky University & Jacksonville State University), and a local survey was made of all technology undergraduate students which included those in ET, Concrete Industry Management, and Construction Management Technology. (The survey questionnaire and results are included in Exhibit 1).

Western Kentucky University states their program MS in Technology Management, ". . . provides a broad-based core of management competency in the central business functions, along with a deep understanding of the technologies that enable specific business capabilities. Courses develop technical management competency while allowing the student to customize their depth of study in specific technologies that enhance long-term professional career goals [1]." The program curriculum is delivered using a distance learning education format and are offered on a bi-term basis (every 8 weeks) and have no sequenced prerequisites. The non-thesis option requires 36 hours and the thesis option requires 39 hours (includes 6 hours thesis credit). The course listings show a broader range of courses with emphasis in more general opportunities in management of technology, yielding a wider range of possible career opportunities. [2]

A Jacksonville State University (JSU) publication states their MS in Manufacturing Systems Technology program, ". . . gives graduates a broad base of knowledge and skills needed to effectively manage and control production in manufacturing facilities. Located in Alabama, the program coordinator points out, "Along with the increase in manufacturing positions available in the state, there will be a parallel demand for informed industrial leaders who will be able to manage technology and use technology to solve problems [3]." The degree requires 30 credit hours including 18 hours in the Manufacturing Systems Technology major, 6-semester hours in approved electives, and 6 semester hours related to a comprehensive project. While using somewhat different titles, the competencies and course outcomes are similar to the one developed at MTSU [4].

2.2. Undergraduate program

Within the ET Department, at Bachelor of Science in Engineering Technology (ABET accredited) is offered with concentrations in Mechanical, Computer Technology, Electro-Mechanical, and Engineering Systems.

The Engineering Systems concentration is the broadest and is primarily focused on integration of all systems including workplace issues such as lean and six sigma and soft skills communications/teamwork. Almost all the students take an internship or lab practicum in local industries. This concentration is the one that the Advisory Board had developed, over a period of several years, and suggested that it be expanded to form the master's concentration.

During this time of collaboration between industry and university, the brainstorming process provided the basis for what industry needed and what resulting coursework the university need to provide.

First, "Core Competency Skills" were identified as follows:

1. Interpersonal skills
   a. Communication
   b. Problem solving
   c. Teamwork
   d. Leadership
2. System skills (safety, quality, cost, delivery)
   a. Safety
   b. Six sigma & TQM
   c. Lean systems/productivity
   d. Project management

3. Engineering technology skills
    a. Engineering processes
    b. Machine controls
    c. Hydraulics/pneumatics
    d. Engineering economy
    e. Industrial engineering systems

Next, these "skill areas" were used by MTSU ET faculty to define the courses needed and design the curriculum. The Advisory Board subsequently approved the coursework.

3. Industry Advisory Committee

To understand this interaction between industry and the university, some historical background is useful. Going back over 25 years ago there was one departmental advisory committee for all programs. This committee was much too broad and consequently lacked focus. During those early years, the meetings consisted of university faculty presenting results, rather than asking for advice or guidance. With the advent of the departmental changes due to ABET accreditation, each undergraduate program was required to have its own advisory board or committee. One was created for the Industrial Management degree, but selected industry members were either recent graduates or were day-to-day supervisory production-based personnel. While these individuals had great insight into the immediate needs of the next group of graduating seniors, they did not have the business and management perspective to see "long-term" needs or be able to offer what degrees would be needed for future graduates.

As a result, the ET Department "reformulated" this committee to consist of plant managers, CEO's, head of US operations of foreign-owned companies, and other executive-level management. This group of dynamic professionals was able to project future needs and offer the best advice. As part of this change, the committee leadership was turned over to the industrial members. University faculty served only to support and assist in the implementation of program changes.

As a result, the Industry Advisory Board is strong and is made up of those interested in the success of the ET programs at MTSU, and the faculty has confidence in their judgment and recommendations. The following companies are currently members:

1. Automotive:
   Nissan, Bridgestone-Firestone, MAHLE, TACLE, Tridon
2. Medical:
   Middle TN Medical Center, Stinger-Medical
3. Food industry:
   General Mills/Pillsbury, Richs Products
4. Electrical/electronics fabrication/assembly:
   Asurion, Teledyne, Square-D
5. Miscellaneous:
   Comfort Group (HVAC), Insequence (process control software), Tennessee state government, Consultants in lean/six sigma

4. Summary and Conclusions

The MSET with a concentration in Engineering Management differs significantly from the MBA. The MSET has a different set of required foundations of knowledge courses and focuses on management issues and skills required to stimulate and manage today's operational organizations, and help bring value creating ideas, goods, and services to the marketplace. In many ways, the generic MBA programs of typical business schools have become outmoded. In today's complex business environment, it is imperative that managers understand not only the elements of traditional managerial domains such as economics and finance but that they also have deep knowledge of the engineering and operations management process.

"Many of today's CEO's came up the corporate ladder during the period when American manufacturing did not have serious foreign rivals, and hence Finance, Marketing, and to a lesser extent, Accounting were king.

The increase in global competitiveness is demanding that the manufacturing <engineering management> function be a significant part of a firm's arsenal and is therefore likely to open the path to the executive suite to those with manufacturing backgrounds," says Dr. Mark Spearman [5].

Students are encouraged to select courses which will develop their knowledge of a specific project management domain such as e-commerce, health care, information systems, or technology management.

This education provides students with the necessary tools to understand and solve problems found at the intersection of management, technology and entrepreneurship. It presents an exciting opportunity for recent college graduates and applicants with limited work experience who want to pursue a graduate degree in a technology-intensive and information-intensive world. The emergence of technology platforms such as the Internet and the incorporation of digital-based and mobile innovations into the business environment have created a need for managers who are conversant in both engineering technology and business concepts.

One of the requirements of program evaluations is the follow up for student outcomes of each program. It is expected that additional information from program graduates will be provided to the Advisory Board over the next several years to effect a continuous improvement of the original program.

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Table 1. Competency Gaps

Competency Gap Items:	SME Rank	MTSU Rank	RCA Whirlpool	Nissan N.A.	Tridon, Inc.	Asurion, Corporation	Bridgestone-Firestone	General Mills	Average Score
Business knowledge/skills	1	**3**	3	3	3	3	2	2	2.67
Project Management	2	**1**	3	3	3	3	3	3	3.00
Supply Chain Management	3	**5**	2	2	2	3	3	2	2.33
Specific Mfg. Process	4	8	2	2	3	2	1	1	1.83
Mfg. Process Control	5	**4**	3	3	3	3	1	2	2.50
Manufacturing Systems	6	**3**	3	2	2	3	3	3	2.67
Quality	7	**2**	3	3	3	3	3	2	2.83
Materials	8	7	2	2	2	3	2	1	2.00
Product/process design	9	**5**	2	3	2	3	2	2	2.33
Engineering fundamentals	10	6	3	3	3	2	1	1	2.17
Written communication	11								
Oral communication/listening	12	**2**	3	3	3	3	2	3	2.83
International perspective	13	**4**	2	3	3	3	3	1	2.50
Problem solving	14	**2**	3	3	3	3	2	3	2.83
Teamwork	15	**2**	3	3	3	3	2	3	2.83
Other:									
Interpersonal/org. behavior			3						3.00
Accounting, financial analysis				3			2	2	2.33
Ergonomic design					3				3.00
Soft skills						3			3.00
Management theory							3		3.00
Classical TPM, 6-sigma, lean								2	2.00

Notes:
SME ranked 15 competency gaps through a 1997 survey of its members (shown in the "SME Rank" column).
MTSU did same survey of regional companies using the same 15 competency gaps (companies were asked to rank each item in order of importance).
Rankings were based on a Low, Medium, High scale corresponding to the numbers 1, 2 and 3.
Each company was also asked for addional input on "other" gaps seen by employers.
The "average score" was used by MTSU (in the "MTSU Rank" column) to rank the same items as ranked by SME.
The MTSU **top 11** of 15 competency gaps, along with all 5 "other" items listed at the bottom of the survey, are covered in the Engrg Mgmt curriculum.

Table 2. Catalog Listing

		Core ET Courses		
	Thesis Option		**Non-thesis**	
Course No.	Course Name			
ET 6010	Safety Planning	3 hrs		3 hrs
ET 6190	Six Sigma	3 hrs		3 hrs
ET 6390	Productivity /Lean Sys.	3 hrs		3 hrs
ET 6300	Project Mgmt & Soft skills	3 hrs		3 hrs
ET 6620	Research Methods	3 hrs		3 hrs
ET 6710	Current & Future Trends in ET	3 hrs		3 hrs
	Sub-total:	18 hrs		18 hrs
	Req'd Engineering Management Courses			
ET 6510/20	Advanced Topic in Technology	3 hrs		3 hrs
MGMT 6000	Mgmt & Operations Concepts	3 hrs		3 hrs
INFS 6610	Info Systems Mgmt & Applications	3 hrs		3 hrs
BCEN 6910	Internship Program	0 hrs		0 hrs
	Sub-total:	9 hrs		9 hrs
	Supporting Courses			
	Thesis Option		**Non-thesis**	9 hrs
ETIS 6640	Thesis Research	3 hrs	Three (3) electives as approved by the Advisor.	
	Total hours:	30 hrs		36 hrs

Exhibit 1. Undergraduate MTSU student survey

Dear Student:

Are you interested in a graduate degree?
If so, please indicate your response to the newly proposed Engineering Management concentration in Engineering Technology (ET) after reading the brief information about it below:
PURPOSE:
The purpose is to educate students at the Master's level in the "core" engineering technologies and to include a concentration in the management of those technologies by providing the needed links between technology & management. In order to be a successful manager of technology the student in this concentration must have both the applications-focused skills in technology, coupled with both leadership and management/business skills.
CAREER OPPORTUNITIES:
Project Managers for the concrete industry, the construction industry, lean operations, and six-sigma.
Technology Managers for operations, including manufacturing (assembly and fabrication), healthcare, food processing, consulting, and government agencies.
Account Managers for global technology companies.
Engineering Product/Process Managers for process control companies, enterprise resource systems developers, and technology development enterprises.
GOALS AND OBJECTIVES:
The Engineering Management concentration (as part of the Master of Science degree program in Engineering Technology), teaches students interpersonal, management, and engineering skills needed for success in various industries or businesses, and is consistent with the Middle Tennessee State University's mission statement and associated goals. Its focus on these enhanced skills reflects an increasing need in the workplace for graduates of this program to fast track into engineering/technical management or high-value specialty knowledge management positions.
Please indicate in the space below (using the 1 to 5 scale below) your interest level and reply to this email as soon as you can: **[% indicated below are out of 44 respondents]**
1. No interest - not planning on graduate degree at this time. **0%**
2. Interested in graduate degree but unsure at this time. **41%**
3. Plan to apply to a graduate school, but at another university. **5%**
4. Plan to apply to graduate school at MTSU and would like more information about the Engineering Management concentration in ET. **36%**
5. Definitely plan to apply for the MTSU Engineering Management in ET. **18%**

My response is:_____*(pick 1 - 5 based on criteria above)*

Comments? **[See sample of verbatim responses below]**

". . . this will be a dream come true!!!!"

"I was interested in a good follow up degree to my undergrad of construction management and MTSU didn't have one I thought would fit well, but I am very interested in this and possibly continuing on to get my masters here, I had considered UT Knox for their Masters of Planning program. I would love to be updated on this program."

"I think this concentration may be a very good thing because before I saw this email, I had no intention to apply for graduate school at MTSU simply because there is nothing really being really offered of interest after my CETH bachelor's degree. So, yes I would like more Info on it."

"This sounds like a great program, please send me more info about it! I will graduate from the Concrete Industry Management program this December."

Construction Productivity Analysis of Pre-Cast and Conventional Cast-In-Situ Projects: A Case Study in Malaysia

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Abstract

Advantages of pre-cast technology in the construction of commercial, residential and institutional buildings are well documented in literature. However, the acceptance of this technology in Malaysia is relatively low with few projects being constructed with pre-cast components. The objectives of this paper are to measure labor productivity, to examine productivity factors for pre-cast and conventional Cast-In-Situ (CIS) methods, and to explore areas of improvements to promote adoption of pre-cast technology in Malaysia. Data on construction labor productivity are collected using questionnaires, interviews, and observations at the construction sites. Based on the statistical analysis, it is concluded that pre-cast method is better than conventional CIS method in terms of construction labor productivity, time to complete a project, variability of construction activities, and loss of efficiency during the construction process. Correlation of the productivity factors to construction labor productivity are presented as well.

1. Introduction

Construction acts as a stimulant to Malaysia's development. Although construction industry accounts a small percentage of the country's GDP in year 2002 (Malaysian-German Chamber and Commerce and Industry (MGCC), 2004), it has extensive linkages to more than 140 upstream and downstream industries such as basic metal products and electrical machinery (Badir et al., 2002; Ministry of Finance Malaysia, 2003).

This paper describes a comparative productivity study between a few projects to be built using pre-cast technology and conventional CIS method. In Pre-Cast method, all structural components have been manufactured earlier and ready to be set up at construction sites, while in CIS method the components are being formed directly at the sites.

Three project sites are studied: two using pre-cast technology and one using conventional CIS method. The two sites using pre-cast technology are Akademi Binaan Malaysia (ABM) located at Sintok, Kedah and Akademi Audit Negara (AAN) at Nilai, Negeri Sembilan; where as the one using conventional CIS method is SIRIM laboratory located at Bukit Jalil, Selangor.

Labor productivity using pre-cast and conventional CIS construction methods is studied. The measurements are focused on four structural components: beam, column, wall and slab. Data on construction labor productivity are collected using questionnaires, interviews, observations, video camera and secondary data collection such as site daily reports, monthly progress reports, project schedules, structural drawings, and other relevant materials.

In the next sections, data collected from the sites and secondary reports are analyzed and the factors that influence the labor productivity are determined statistically. Comparison on the labor productivity for the two construction methods is demonstrated. It is also shown the percentages of productive time based on activities which contribute to project completion as well as the breakdown of non productive time / non value adding activities which cause project delay. Finally, conclusion and recommendation are presented.

2. Work Hour Breakdown

Construction is a labor-intensive industry especially in the conventional CIS construction method. Although the pre-cast construction method is less labor-intensive, the installation process still requires the labors. Thus, manpower is one of the main factors behind productivity resources in the construction industry. Hence, construction productivity greatly relies upon human performance (AbouRizk, S. and Hermann U.R., 2001; Hanna et al., 1999; Khaled El-Rayes and Osama Moselhi, 2001; Portas, J. and AbouRizk, S., 1997; Sonmez, R. and Rowings, J. E., 1998).

Labor productivity is improved if more time is spent in value-adding activities. Reducing the share of non value-adding activities is one of the strategies to obtain better productivity. Therefore, it is important to identify the most significant time

spent on non value-adding activities as not all non value-adding activities affect the productivity to the same degree.

Table 1 demonstrates the breakdown of time utilization of construction labors (pre-cast structural component installers) at the pre-cast construction site. Data was collected by site observations. The breakdown of non-value adding activities at the pre-cast construction site is shown in Table 2.

Table 1. Breakdown of Pre-cast Labors Time Utilization

Pre-cast Labors Activities	Time Utilization
Productive (Direct Installation)	32%
Non-productive	30%
Correction	25%
Delivery (Unloading)	8%
Extra Break	5%

Table 2. Breakdown of Non Value-Adding Activities for Pre-cast Method

Non Value-Adding Activities	Time Utilization
Move Crane	54%
Wait	14%
Idle	13%
Move Component	7%
Clean up	6%
Move Ladder/Equipment	4%
Look for Tool	2%

Table 3 below shows the breakdown of time utilization from a group of construction workers at SIRIM project. Data for the analysis was collected from the actual site performance. The percentages shown are based on the data recorded through site observations. On average, nearly 41% of the time spent by the site workers during work hours are productive and the rest of the time is non value-added. The breakdown of time utilization for non-productive site activities is shown in Table 4.

3. Loss of Efficiency

Labor efficiency in a project is one of the main factors in productivity. This is because labor efficiency is related to one of the important elements in a project, which is cost. Loss of labor productivity is equivalence to the loss of labor cost that had been paid to the workers. The percent of inefficiency presented in Table 5. Overall, it can be concluded that loss of labor efficiency of pre-cast project is less than CIS project.

Table 3. Breakdown of Conventional CIS Labors Time Utilization

CIS Labors Activities	Time Utilization
Non-productive	59%
Productive hour	41%

Table 4. Breakdown of Non Value-Adding Activities for CIS Method

Non Value-Adding Activities	Time Utilization
Idle and Wait	42%
Look for Tool/Material	35%
Extra Break	12%
Move Material to Work Place	11%

Table 5. Analysis of Loss of Efficiency

Construction Method	Pre-cast		CIS
Project	ABM	AAN	SIRIM
Number of Workday	65	60	154
Percent of inefficiency	45%	55%	61%

4. Correlations of Productivity Factors

Common factors that correlated to labor productivity for the two construction methods is presented in Table 6. Structure geometry complexity displays greater impact on CIS construction project compared to pre-cast projects. One of the reasons is because CIS method involves the complete process or cycle at the construction site. A complete process normally starts from the formwork fabrication until the formwork dismantle.

For most of the time, the worker's performance is affiliated to the location of work and the working space given to them. From the analysis, the effect

of this factor is more prominent for AAN project as this project is a quarters or hostel building with four floors, whereas the rest two projects are two floor buildings. The effect of this factor on CIS project is also quite obvious. Thus, it can be concluded that the work space availability and location of work is an important factor for both pre-cast and CIS projects.

Weather, in terms of hours of rain, can be construed as a crucial productivity factor for CIS construction method but it depicts less significant effect on pre-cast method. Length of workday or overtime is the factor that equally influenced both construction methods. Although that is the case, the impact is not critical as the correlation values shown are less than 0.5.

Crew size or number of workers that work in a group is interpreted as an important factor for CIS project. Yet, it shows a slight effect on pre-cast projects. Therefore, it can be presumed that number of workers is a crucial factor for CIS method compared to pre-cast method.

Apparently, delivery and unloading of structural components only induces poorer productivity for pre-cast construction method. This is due to multi-tasks performed by the workers or installers that include unloading and installation. Whereas in CIS project, only the raw material deliveries affected the productivity because the unloading job is taken over by the general workers.

In the next section, contractors perspective on productivity factors is discussed to expand the overview on the construction labor productivity from the practicality point of view.

Table 6. Analysis of Correlations

Construction Method	**Pre-cast**		**CIS**
Project	AAN	ABM	SIRIM
Factors	Correlation, R^2	Correlation, R^2	Correlation, R^2
Structure Geometry Complexity	0.0913	0.0619	0.3067
Workspace Availability / Location of Work	**0.6356**	0.0667	0.2451
Weather (Hours of Rain)	0.0093	0.2927	0.4270
Length of Workday (Overtime)	0.3686	0.2465	0.2404
Number of Workers	0.0261	0.3868	**0.7329**
Unloading Duration	0.2769	**0.4987**	-

5. Contractors Perspective on Productivity Factors

Worsen in productivity values are caused by numerous factors, no matter how much the effect of the factors to productivity. In order to preliminary comprehend the degree of effects of other poor productivity causes; information had been gathered by using another approach, which is by distributing questionnaires to contractors involved in both pre-cast and CIS projects. Contractors had ranked the factors in different stages based on a 5 point scale, as 1 being no effect at all and 5 being strong effect on productivity.

Table 7 presents the result assembled from the questionnaires distributed to the contractors. The factors that ranked higher than 3 are considered to have more obvious effect on the productivity. Data are collected based on the contractors opinions on the potential productivity factors. Contractors are asked to express their opinions as to what factors or aspects are most likely to contribute to

productivity increases and worsening in their projects.

All factors involved during the design stage, which are the design complexity, the constructability, the component geometry, and the size of component are crucial factors in determining pre-cast and CIS labor productivity.

Delivery schedule in the planning and management stage is an influential factor for both construction methods. Material availability, toll or equipment sufficiency and resource allocation in planning and management stage are the determinants of CIS construction labor productivity. On the other hand, material placement or material storage is considered as the important factor for pre-cast construction method.

At the manufacturing of structural components stage only pre-cast construction project is affected. The respondents assented that the factors involved in this stage such as the quality of components manufactured and fabrication errors are significant to the productivity values.

During the site installation or construction stage, workspace availability (congestion), instruction and supervision given, work sequencing and location of work are the reasons of poor productivity for both pre-cast and CIS construction projects. Besides that, the productivity in pre-cast construction site is also affected by the causes such as site safety condition, length of workday or overtime and location of work. Furthermore, the factors such as weather, skills of labor, rework, length of work period and location of work display higher impact on the CIS productivity values.

Table 7. Comparison of Ranking on Productivity Factors

Construction Field	**Pre-cast**	**CIS**
Productivity Factor	**Rank/ Weight**	**Rank/ Weight**
Design Stage		
Design complexity	4.5	3.7
Constructability	4.0	3.3
Component Geometry	3.5	3.0
Size of Component	3.5	2.7
Planning and Management Stage		
Material Availability	2.5	3.3
Material Placement (Material Storage)	3.5	1.7
Tool/ Equipment Sufficiency	2.5	3.3
Tool/ Equipment Condition	2.5	2.0
Resource (Worker) Allocation	2.5	3.7
Delivery Schedule	3.5	3.3
Work Scope Assigned	3.0	3.0
Manufacturing Stage		
Quality of Component Manufactured	4.0	-
Fabrication Error	4.0	-
Site Installation / Construction Stage		
Weather	3.0	4.0
Skills of Labor	3.0	3.7

Labors' Morale and Attitude	3.0	2.7
Absenteeism	2.5	3.0
Crew Interference	2.0	3.0
Tool/ Equipment Availability	3.0	2.7
Work Space Availability (Congestion)	4.5	3.3
Instruction/ Supervision	4.0	4.0
Work Sequencing	3.5	3.7
Repetition of Work (Rework)	3.0	3.7
Safety Condition	3.5	3.0
Length of Workday (Overtime)	3.5	2.3
Length of Work Period (Workdays per week)	2.5	3.3
Location of Work	3.5	4.0

6. Conclusion

According to the results derived in this research, it can be concluded that the pre-cast method is better than conventional CIS method in terms of the construction labor productivity. Loss of efficiency during the construction process is analyzed. It is demonstrated that loss of efficiency in pre-cast method is less as a result of smaller work force at the pre-cast construction sites. The labor efficiency definitely is the main concern in construction as it will effect on the total cost incurred in the project.

Acknowledgements

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Development of Digital Human Model to Evaluate Excavator Operator Performance

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Abstract

Digital human models are often used to assess the real situation preceding the manufacturing of a product. Since it is very costly to build a mock-up or manufacture the product, digital human models provide an excellent alternative to help evaluating a system before its production. Excavators are important tools in the construction industry. However, learning to operate excavators is no easy task. It is therefore, very important to have a cost effective alternative to help assess operator performance. This paper describes the development process of digital human modeling of an excavator operator. The development process can be divided into four steps: assorting data, dividing parts, building parts, and assembly. An empirical study was conducted using the model to predict and assess operator performance. Profile analysis was used to analyze the results from the low back risk analysis. Findings from this research will provide design suggestions to excavator developers.

1. Introduction

Fluid power control is a well developed technology for the transmission and control of energy by means of a pressurized fluid with the characters of high speed and accuracy [1]. Fluid power can be categorized into hydraulics (using liquid such as the mineral oil or water) [2] and pneumatics (using air or other inert gas) [3, 4]. Since fluids are able to take on the shape of its container, it has the advantage of flexibility over other forms of energy. In addition, fluid power has a higher power density than electric motors that makes it ideal for heavy or large-scale equipment applications. The primary use of the fluid power technology has been in larger machinery since the 1940s [5]. Excavator is one of the most significant applications of hydraulic systems. When used in the excavator, high pressure forces hydraulic fluid through hoses and tubes to control the system's motor and cylinders [6].

Excavators were first seen in the late 1700s and early 1800s and were powered by stream [7]. As developed hydraulic systems, excavators were improved and various types of excavators were brought into the market, which included drag line, backhoe, bucket wheel, long reach, skid loader, the steam shovel/power, the mini, and suction excavators [8, 9].

The basic task of an excavator is to excavate and move earth in various processes. Excavators are used to build plenty of constructions such as bridges, mansions, malls, and they can also be used in other domains such as modern mining. The exterior body of a traditionally designed hydraulic excavator consists of mechanical components such as a pivoting cab, rotary tracks, extendable arm, and a retractable bucket. Its main hydraulics is the boom, cylinders, swing, and track-drive [8]. Excavators are primarily operated via series of multiple controls consisting of buttons, joysticks, pedals, and

levers located on the interior of the excavator cab. Push button controls allow the operator to activate power, monitor system status, and adjust additional settings; whereas, levers and pedals allow the operator to move the excavator to the desired location and control action of the hydraulic tool attachment. The most important controls of the system are the joysticks which are located on each side of the operator's chair. These controls direct dynamic work performance through horizontal rotation and vertical motion of the system's hydraulic components.

Over the years, there are studies that are performed on excavators to evaluate the excavator performance. These studies often focused in the technicalities of system performance rather than on the human operator. Consequences of operator difficulties and complex interactions with the system have resulted in errors and loss of efficiency [10].

Since performance depends on both the machine and the operator, it is necessary to model human performance and to better understand the interaction between humans and technology. Human performance modeling tools can be used to mimic performance in various task scenarios to further aid in evaluating the effects of human-machine interaction to better support the needs of operators [11, 12].

The operational interface of the excavator is one of the factors that can affect the operator performance in terms of efficiency, energy, and safety [8]. Traditionally, excavators use levers and sticks with the cooperation of the two hands to control the activity of the excavator. Recently, there is an attempt to use haptic controls [13] to replace joystick controls in the excavator hoping the extra modality can help improve operator performance. Although haptic control seems very promising, it is unclear how effective it will be to improve operator performance. Ideally, this question can be answered using real excavators with different controls built in the excavators. However, it is too costly, time-consuming, and difficult to do that. Instead, it is necessary to use a different approach. Digital human modeling provides an alternative for this problem. Using digital human models, such as Jack®, operator performance can be predicted fast and easily. Jack® is a powerful tool that can analyze operator fatigue, posture comfort, low back pressure, metabolic energy expenditure, and ovako working posture [14]. Through the use of Jack® (and Jill) digital humans, information about what users can see and reach, how comfortable they are, when and why they're getting hurt, when they're getting tired and other important ergonomics information can be provided. This information can help designers provide safer and more effective products faster and for less cost.

The objective of this research is to develop a digital human model for excavator operators using Jack® and conduct an empirical study using the developed model to assess the impact of different controls on human performance.

2. Method

The development process of the digital human model for the excavator can be divided to two parts: (1) backhoe excavator, and (2) Jack, the digital human.

A Bobcat compact excavator (Model: 435ZHS) as seen in Figure 1 was used as the prototype for the excavator model development.

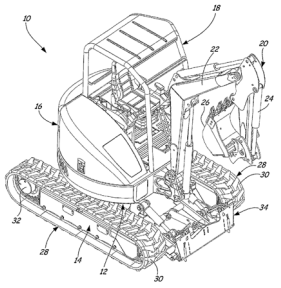

Figure 1. Compact excavator

There are several ways to develop models in Jack®. For simple simulations or analysis, the primitives such as cones, cylinders from the component library can be imported to build the model. If it is necessary and feasible, company developed models can be imported directly to Jack®.

The development process using Jack® can be divided into four steps: assorting data, dividing parts, building parts, and assembly.

2.1. Assorting data

Prior to developing the excavator model, data was measured and collected based on real dimensions of the excavator, hence, the scale between the digital model and the real excavator is 1:1. The components of the excavator are measured manually and recorded according to each segment. Data includes the length, width and height of the bucket, the arm, and the boom, height, radius and related parameters for the cabin, which contains the inside configuration of the operational interface such as joysticks, levers, chair, and pedals, and the length, width and height of the tow tracks.

2.2. Dividing the parts

A backhoe excavator can be divided into the following parts based on its functionality: digging parts, rotating parts, and moving parts. The digging parts include a bucket, an arm and a boom. The rotating parts include the cabin and the rotation cylinder. The moving parts include the tracks and the conjunction of two tracks.

There are three main segments in this backhoe excavator model: the traces, the cabin and the digging parts.

For each segment certain parts have a joint with each other to make a movement. The cabin has the capability to rotate around the axis that is perpendicular to the trace through the joint which is located between the trace and the cabin segments. In the digging parts, the bucket, arm and boom have joints that can mimic the digging task. Inside the cabin, there are two levers, and two joysticks that can be used for controlling the movement of the excavator.

In this research two excavators were built, one with the joystick controls and the other with the haptic controls. Both excavators have the same configurations except the controls. The haptic device modeled in this research was a Phantom Omni.

2.3. Building the parts

Each part and its components were built using the components in the library of the Jack ® using the real dimensions collected.

2.4. Assembling the parts

After each part was developed, the final job is to assemble them together to build this digital excavator model. The final digital model can be seen in Figure 2 and Figure 3.

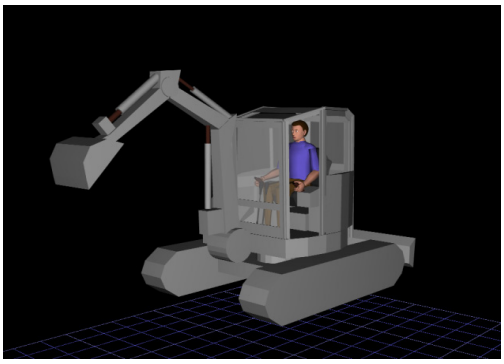

Figure 2. Excavator model using the joystick control

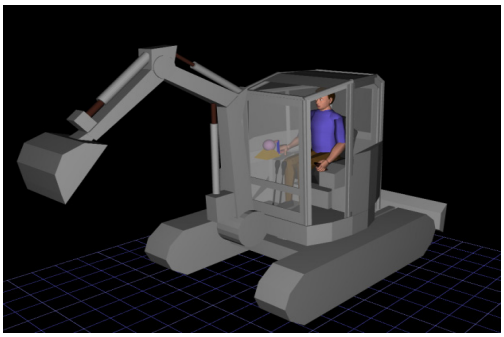

Figure 3. Excavator model using the haptic control

2.5. Jack-the digital human

Once the digital model of the compact excavator is completed, the digital human – "Jack" can be placed inside the excavator. These digital humans are based on the anthropometric data provided by the Jack® software. By specifying the percentile, ergonomic assessment can be done for various populations.

3. An empirical study

Using the developed digital models, an empirical study was conducted to assess the impact of the different controls (joystick vs. haptic) on excavator operators.

3.1. Stimulus material

The stimulus material used in this study was the digital human models with different controls developed in this study.

3.2. Equipment

A PC with Windows Vista operating system was used in this study. Jack® software was used to run the simulation.

3.3. Experimental Design

A completely randomized design was used in this study. The independent variable is the type of controls (joystick and haptic) and the dependent variable is the low back risk, forearm twist and wrist flexion.

3.4. Procedure

For each of the two excavators, five different digital humans were used (the first percentile, the fifth percentile, the fiftieth percentile, the ninety fifth percentile, and the ninety ninth percentile) to complete an excavation task which is to dig a trench on the ground. Based on the predefined steps, the excavator operator would dig a trench and move the soil from one side and pile it up on the other side.

3.5. Data collection

Data was collected by the Jack® software automatically. To assess the operator performance, four different points of time during each task were identified. The first point is at 7.77 seconds after starting the task (time P1), the second point is at 19.77 seconds after the start (time P2), the third point is at 23.77 seconds after the start (time P3) and the last one is at 35.77 seconds after the start (time P4).

In this research, low back risk analysis, forearm twist and wrist flexion in Jack® was used to assess operator performance. For the low back risk analysis, there is a back compression action limit standard of 3400 N (it is safe under this level). For forearm twist and wrist flexion Jack® has a comfort analysis tool in the occupant package toolkit that is designed to provide a quantitative estimate based on empirical studies of how comfortable a real driver might be in the vehicle packaging design. Dreyfuss 3D is one of the tools used for comfort analysis in Jack®. There are three attributes for the Dreyfuss 3D tool: the low value, the high value, and the mode value of the forearm twist angle. The forearm twist test measures the forearm twist angle in terms of pronation and supanation, the motion of the wrist flexion tested here includes flexion and extension of the digital human's right hand. Then compare them to the ideal (mode) value to evaluate the digital human's effort of performing a task under a certain working environment using the comfort analysis tool in Jack®.

There are three color coded scales in the above three assessments. Green means safe domain and this operation design is in good condition. Yellow means the work posture may be harmful to the operator and caution needs to be taken. Red means the force beyond the limitation of safety, and it needs to be addressed immediately.

4. Results and Discussion

The following sections will provide both descriptive and inferential statistics on the low back risk.

4.1. Descriptive statistics

Descriptive statistics such as the mean and the standard deviation of the low back risk (measured in N) forearm twist and wrist flexion (measured in degree) are calculated and shown in tables 1-6.

Table 1. Low back risk analysis results for the joystick control (in N)

	P 1	P 2	P 3	P 4
Mean	616	656	643	593.4
Standard Deviation	19.70	22.43	21.46	18.34

Table 2. Low back risk analysis results for the haptic control (in N)

	P 1	P 2	P 3	P 4
Mean	620.8	651.4	642	588.2
Standard Deviation	24.22	24.43	19.99	19.14

Table 3. Forearm twist absolute difference for the joystick control (in degree)

	P 1	P 2	P 3	P 4
Mean	42.2	40.8	39.9	41.0
Standard Deviation	11.14	6.97	12.15	10.08

Table 4. Forearm twist absolute difference for the haptic control (in N)

	P 1	P 2	P 3	P 4
Mean	19.9	11.2	11.4	8.1
Standard Deviation	10.49	6.47	5.75	5.44

Table 5. Wrist flexion absolute difference for the joystick control (in degree)

	P 1	P 2	P 3	P 4
Mean	17.5	13.7	13.6	14.9
Standard Deviation	6.91	5.73	6.50	6.22

Table 6. Wrist flexion absolute difference for the haptic control (in N)

	P 1	P 2	P 3	P 4
Mean	7.62	20.2	14.4	5.2
Standard Deviation	4.02	4.69	8.30	3.83

4.2. Inferential statistics

Since the same performance measure was measured at four different times for each of the two interfaces, a multivariate statistical approach, profile analysis was used to analyze the results.

4.2.1. Analysis of low back risk:

Results of the profile analysis indicating in Figure 4 revealed that overall, there is no significant difference in low back risk between the two interfaces ($F(1,8)=0.01$, $p=0.91$).

No significant difference was found between the two profiles for the two interfaces (Wilks' Lambda=0.68922348, $F(3,6)=0.90$, $p=0.4933$). The two profiles can be seen in Figure 4.

Lastly, results showed that the profiles are not flat (Wilks' Lambda= 0.00402530, $F(3,6)=0494.86$, $p<0.0001$).

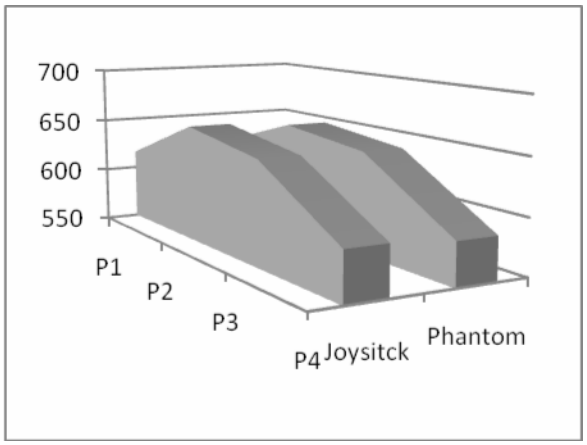

Figure 4. Profiles of the two interfaces for low back risk

4.2.2. Analysis of forearm twist:

Results of the profile analysis indicating in Figure 5 revealed that overall, there is significant difference in forearm twist between the two interfaces ($F(1,8)= 37.59$, $p=0.0003$).

No significant difference was found between the two profiles for the two interfaces (Wilks' Lambda=0.41583614, $F(3,6)=2.81$, $p=0.1303$). The two profiles can be seen in Figure 4.

Lastly, results showed that the profiles are flat (Wilks' Lambda= 0.44992940, $F(3,6)=2.45$, $p<0.1618$).

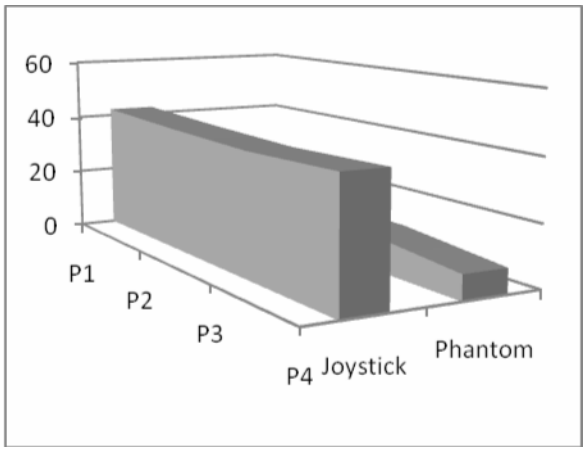

Figure 5. Profiles of the two interfaces for forearm twist

4.2.3. Analysis of wrist flexion:

Results of the profile analysis indicating in Figure 6 revealed that overall, there is no significant difference in forearm twist between the two interfaces ($F(1,8)= 1.17$, $p=0. 3111$).

Significant difference was found between the two profiles for the two interfaces (Wilks' Lambda=0.11253317, $F(3,6)=15.77$, $p=0.0030$). The two profiles can be seen in Figure 4.

Lastly, results showed that the profiles are not flat (Wilks' Lambda=0.08126018, $F(3,6)=22.61$, $p<0.0011$).

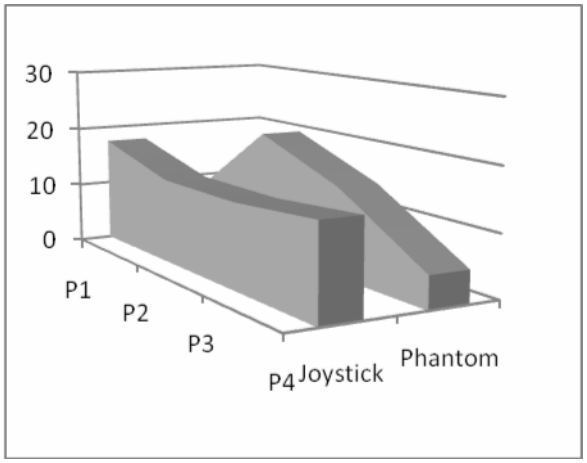

Figure 6. Profiles of the two interfaces for wrist flexion

4.2.4. Results summary:

Statistical results revealed that the low back risk and wrist flexion are very similar for both interfaces as shown in Figure 4 and figure 5 for forearm twist is different for two interfaces as shown in Figure 6.

The low back risks and forearm twist at four different points of time for both interfaces have the similar profiles. In other words, the two profiles are parallel to each other. Wrist flexion at four different points of time for both interfaces is different, they are not parallel.

In addition, both interfaces have similar amount of low back risk and wrist flexion as evidenced by the lack of significant difference between the two profiles. The significant difference was found for the four different point of times, indicating that the low back risk and wrist flexion vary during the task.

5. Discussion

From the analysis results forearm twist, significant difference can be found between two types of interface. It indicates that there is different effect for human performance in terms of different interface. For future study, a further analysis is expected to be conducted to explore how effectiveness of each interface and what can

be done to improve interface to make more efficient performance.

In addition to the low back risk analysis, forearm twist and wrist flexion, other analyses can also be done to further assess operator performance. For instance, ovako working posture analysis and metabolic energy expenditure analysis can be conducted. For ovako working posture analysis, it evaluates the relative discomfort of a working posture based on the positioning of the back, arms and legs, as well as load requirements based on the Ovako Working Posture Analysis System (OWAS). For metabolic energy expenditure, the assessment is used to evaluate the energy expenditure of both task energy and posture energy. For those larger and more complex tasks, these additional analyses will be very helpful. Due to the small scale and the simple nature of the current experiment, only low back risk analysis was used in this study.

6. Conclusion

This research developed digital human models for a compact excavator. The development process was discussed in detail. Based on the developed models, an empirical study was conducted to evaluate operator performance between two interfaces: one with joystick control and the other with haptic control. Statistical results revealed that for the selected tasks, there were no significant difference in low back risk and wrist flexion, and there was significant different in forearm twist for the two interfaces. This research intends to present a method to help assess excavator operator performance without going through time consuming training and/or using expensive mockups. Such a tool can help better design the excavator and improve operator performance.

7. Acknowledgement

This research is partially funded by the NSF engineering research center for compact fluid power.

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Experimental Investigation on Radio Frequency Excited Compact Continues Wave Hydrogen Cyanide Gas Laser

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Abstract

Basic types of experiments for the radio frequency (RF) excited compact continuous wave hydrogen cyanide gas laser with an integral power oscillator directly coupled to the laser tube were performed. The effects of coupling-hole size, laser tube diameter, and the gas condition on the output power intensity have been experimentally investigated. The effect of adding He, Ar, H_2, O_2, or air to the active gas CH_4 + N_2 on the output characteristics of a compact Continuous Wave Hydrogen Cyanide (CW-HCN) gas laser was considered. The gas mixture ratio CH_4: N_2 = 1:1 showed better performance than the 2:1, 1:2, and 1:4 ratios for the overall efficiency of operation and intensity of output power. The output power was increased by RF-excited discharge due to lowering of the gas temperature, better uniformity of the gas discharge, and better stability of the discharge. The output power from self-oscillator directly coupled system has a less efficient matching condition than the oscillator/amplifier system. The matching network was the key to more output power for the RF driven HCN laser. Two tubes of the same type can be connected for push-pull operation so as to obtain twice as much output as that of a single tube. A push-pull amplifier has an advantage in that the circuit can more easily be balanced than a single-tube RF amplifier.

1. Introduction

RF discharge waveguide laser technology has been extended from the 10.6 μm CO_2 to include 2.7 μm HF, 3.8 μm DF, and several other rare gas mid-infared lasers [1, 2].

RF excitation is advantageous because it eliminates the need for a high voltage source, and offers a laser output with high electrical conversion efficiency. Transverse RF excitation in the waveguide configuration has generated much interest because of potentially increased laser lifetime, easy starting, and the capability of high-pressure operation [3].

The ability of the control grid of a vacuum tube to control large amounts of plate power with a small amount of grid energy allows the vacuum tube to be used as an amplifier. It is this ability of the vacuum tube to amplify an extremely small amount of energy up to almost any level without change in anything except amplitude which makes the vacuum tube such an extremely valuable adjunct to modern electronics and communications.

The difference between the various classes of vacuum tube amplifier is determined primarily by the value of average grid bias employed and the maximum value of the exciting signal to be impressed upon the grid.

Class C amplifiers are used chiefly as RF amplifiers because of their high efficiency. With bias at about twice cutoff value, the grid excitation is just enough to start the resonant circuit in the plate circuit of the tube on a single

oscillation. While the grid is on its negative swing, the "flywheel" effect of the resonant circuit completes the other half of the RF cycle until the next grid pulse arrives to start the process over again. The efficiency of these amplifiers runs as high as 80 percent.

The output power from self-oscillator directly coupled system has a less efficient matching condition than the oscillator/amplifier system. The coupling network was the key to more output power for the RF driven HCN laser.

2. Materials and Methods

This work was carried out at Oak Ridge National Laboratory. The experimental set up used is shown in Fig. 1. The two basic types of experiments carried out are discussed in this section.

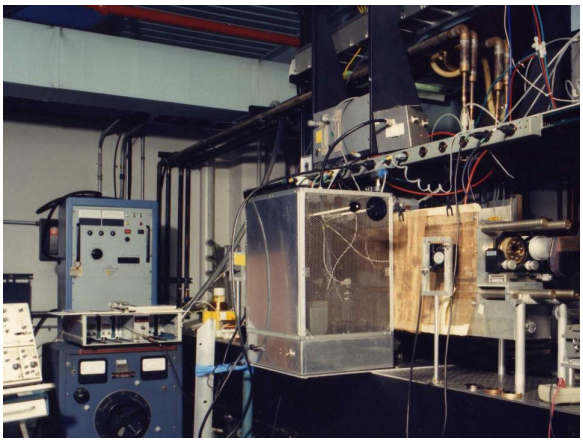

Figure 1. Experiments performed at Oak Ridge National Laboratory

Power tetrodes-the Eimac 4CX350A (8321) tube: The Eimac 8321/4CX350A is a compact radial beam tetrode with maximum plate dissipation of 350 watts and is intended for class-AB, audio or RF amplifier service [4].

By adjusting the RF grid one can obtain the specified plate current at the specified grid bias, screen voltage, and plate voltage. If this procedure is followed, there will be little variation in output power when tubes are changed, even though there may be some variations in grid and screen currents. The grid and screen currents which result when the desired plate current is obtained are incidental and vary from tube to tube. These current variations cause no difficulty so long as the circuit maintains the correct voltage in the presence of the variations in current. If grid bias is obtained by means of a grid resistor, the resistor must be adjustable to obtain the required bias voltage when the correct RF driving voltage is applied.

The 4CX350A may be operated in any position. An Eimac Air-System Socket, SK-600 series is required. Sufficient cooling must be provided for the anode. The Eimac SK-600 socket is used with the SK-606 chimney and air-flow in the base-to-anode direction.

In calculating and predicting the operation of a vacuum-tube as a class C radio-frequency amplifier, the considerations which determine the operating conditions are plate efficiency, power output required, maximum allowable plate and grid dissipation, maximum allowable plate voltage, and maximum allowable plate current. The values chosen for these factors will depend upon the demands of a particular application and the tube chosen (Fig. 2).

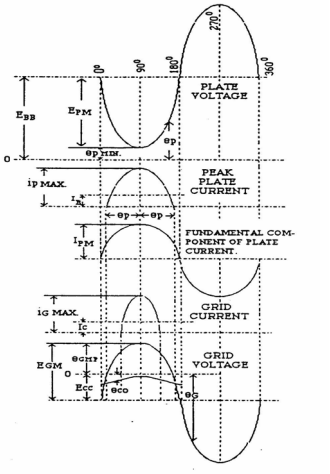

Figure 2. Instantaneous electrode and tank circuit voltage and currents for a class C RF power amplifier

The approximate analysis that follows has proved to be sufficiently accurate for most applications. This type of analysis also has the advantages of giving the desired information at the first trial. The system is directed in giving the desired information since the important factors – power output, plate efficiency, and plate voltage are arbitrarily selected at the beginning.

The first step in the method to be described is to determine the power which must be delivered by the class C amplifier. In making this determination it is well to remember that ordinarily from 5 to 10 percent of the power delivered by the amplifier tube or tubes will be lost in well-designed tank and coupling circuits at frequencies below 20 MHz. Above 20 MHz, the tank and circuit losses are ordinarily somewhat above 10 percent. The plate power necessary to produce the desired output is determined by the plate efficiency (N_p):

$$P_{in} = P_{out}/N_p \qquad (1)$$

Two tubes of the same type can be connected for push-pull operation so as to obtain twice as much output as that of a single tube. A push-pull amplifier also has an advantage in that the circuit can more easily be balanced than a single-tube RF amplifier. The various inter-electrode capacitances and the neutralizing capacitors are connected in such a manner that the reactance on one side of the tuned circuits is exactly equal to those on the opposite side. For this reason, push-pull RF amplifiers can be more easily neutralized in very-high-frequency transmitters; also, they usually remain in perfect neutralization when tuning the amplifier to different bands.

Inductively Coupled RF-Excited System of CW-HCN Laser: The coupling coil was the output inductor of this oscillator (Fig. 3). Two 4CX-350A tubes are used for a push-pull amplifier of the grounded-cathode type. Class C amplifiers are used chiefly as RF amplifiers because of their high efficiency with bias at about twice cut-off value, the resonant circuit in the plate circuit of the tube on a single oscillation. While the grid is on its negative swing, the flywheel effect of the resonant circuit completes the other half of the RF cycle until the next grid pulse arrives to start the process over again. The efficiency of these amplifiers runs as high as 80 percent. Class C amplifier was chosen to be used in push-pull circuits. The output power was around 1 KW. If 120 MHz is used for resonant frequency one may calculate the inductive reactance of the coupling coil using:

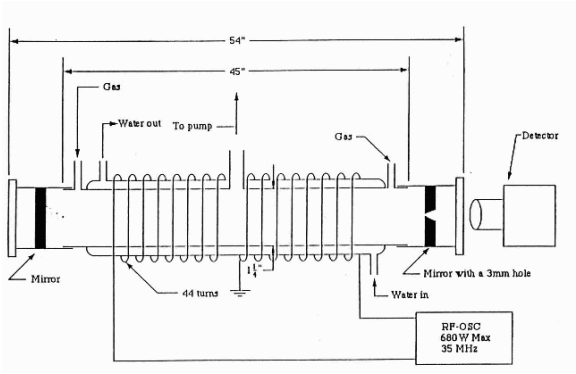

Figure 3. Inductively coupled system

$$X_L = 2 \pi f L \qquad (2)$$

It is known X_L = 3900 ohms and hence $L = X_L /2 \pi f = 5.17$ μH, where X_L = inductive reactance in ohms, f = frequency in cycles per second, L= inductance in henrys, and π = 3.1416.

The number of turns of a coupling coil for a required value of inductance is calculated using:

$$n^2 = L (9a + 10b)/a^2 \qquad (3)$$

where L = inductance in microhenrys, a = coil radius in inches, b = coil length in inches, and n = number of turns. $n^2 = 5.17 (9 \times 1 + 10 \times 36)/1^2 = 44^2$ and n = 44 turns.

Four 100 ohms resistors must be connected in parallel to each cathode for current limiting. For this circuit one can see the discharge but no output power from this system at all (Fig. 4). Therefore, a push-pull amplifier of the grounded-cathode type and the vacuum capacitor for tank circuit were used to obtain better discharge (Figs. 5 and 6) [5].

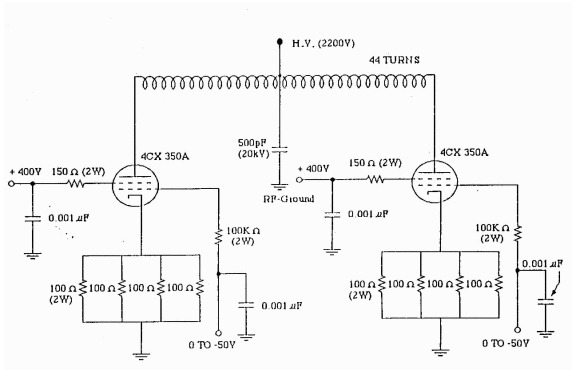

Figure 4. Design circuit for IC RF-oscillator

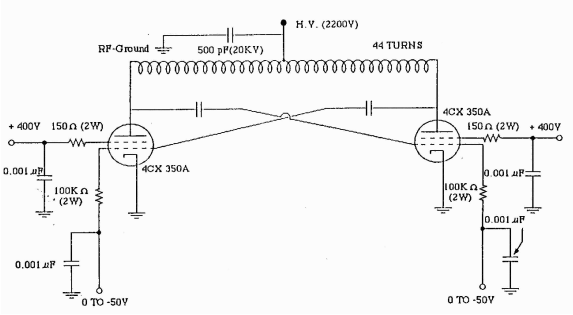

Figure 5. A push-pull RF power oscillator of the ground-cathode type

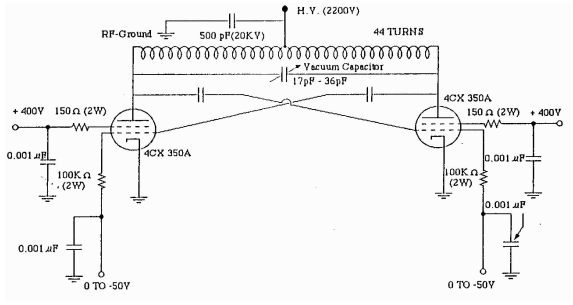

Figure 6. A plate-tank circuit arrangement for push-pull stages

Figure 7 shows the plate-tank circuit arrangement for push-pull class C amplifier. This was the best design for using two 4CX350A tubes as a RF-excited HCN laser system. The vacuum capacitor has the range from 17 PF to 36 PF. The frequency can be adjusted by the vacuum capacitor from 15 MHz to 21 MHz with 10 turns of the coil.

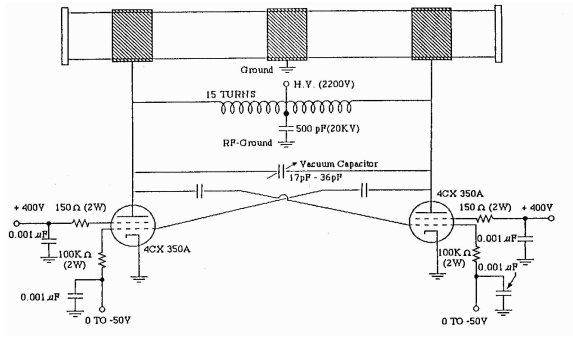

Figure 7. Plate-tank circuit arrangements for push-pull class C RF power oscillator

3. Results and Discussions

Output power measurement using 4CX350A for the class C push-pull power oscillator: The experiment was a comparison of two amplifiers. One is inductively coupled amplifier and the other one is capacitively coupled amplifier [6]. Based upon the results of the experiment the capacitively coupled amplifier gave the greater output power. Hence, the capacitively coupled amplifier was used for the following experiments. A mixture of CH_4 and N_2 was used as the operating gas with a ratio 1: 3 with a gas flow rate of 60 cc/min STP. Four coupling hole diameter of the output side mirrors were prepared for three different sizes (3, 4, and 5 mm) at the center. Two output side mirrors are gold coated with 3 mm and 5 mm coupling holes at the center and the other two mirrors are copper with 3 mm and 4 mm coupling holes.

The discharge started at 0.1 torr with 15 cc/min N_2. The pressure was increased to 0.3 torr with 45 cc/min N_2 and CH_4 gas with 15 cc/min was added into the laser tube. The pressure was about 0.52 torr and a strong discharge was seen inside the laser tube. The

pressure and flow rate were very critical. The gas CH_4 flow rate was maintained between 10 cc/min and 20cc/min. The gas N_2 flow rate was maintained between 50 cc/min and 10 cc/min. Otherwise no discharge will be produced. The best flow rate for this system to get maximum power from the output was CH_4-45 cc/min and N_2-15cc/min. Without a water jacket the laser tube turned to brown in a few minutes. The tube was very hot, discharge was not strong enough, and there was no output.

Figure 8 shows the results in the case of 0.53 torr pressure. Three different diameter sizes of the coupling holes (3, 4, and 5 mm) and a coil of 50 turns were examined. The results indicate that 3 mm diameter coupling hole may be an optimal value, as its size vary independently under certain gas conditions.

Figure 9 shows the maximum output power versus resonant frequencies with the gas flow volume as a parameter. The both end mirrors are gold coated with the coupling hole diameter 3 mm and the number of turns of the coil 13. The maximum output power of 2.3 mW in the continuous wave was obtained with 0.62 torr pressure and 1360 watts plate input power.

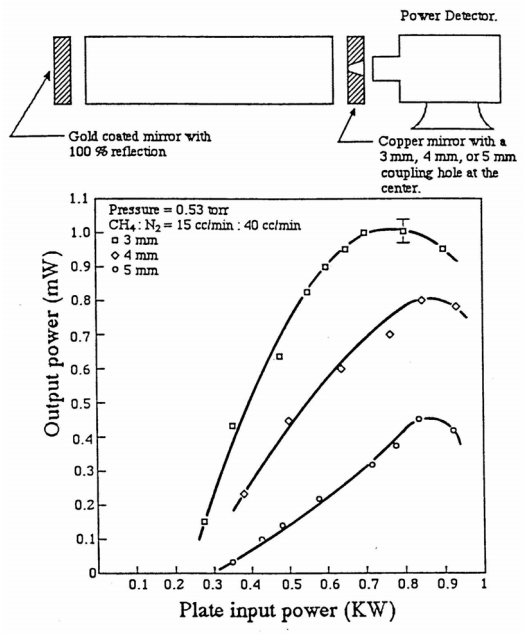

Figure 8. Output power vs input power with coupling hole diameter as parameter

Three primary conditions must be considered to get high power into the laser system:

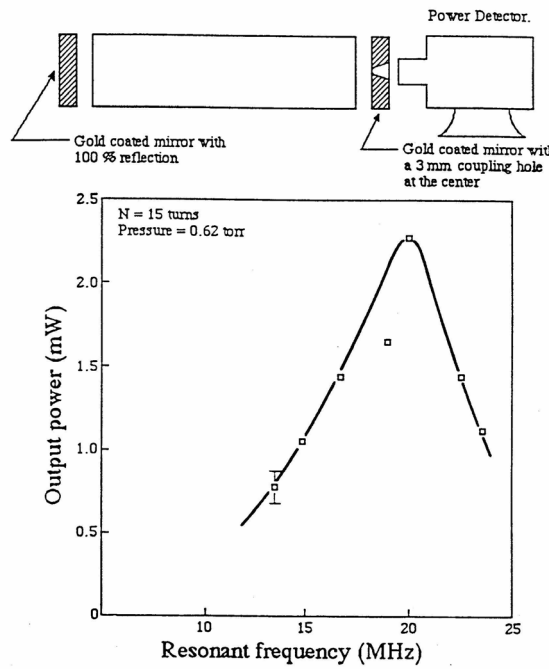

Figure 9. The output power vs resonant frequencies with the gas flow volume as a parameter

a) Tank Circuit: A class C amplifier receives energy in the form of short pulses of plate current which flow in the amplifier tube. But the tank circuit must be able to store enough energy so that it can deliver a current essentially in sine wave form to the load. The ability of a tank to store energy in this manner may be designated as the effective Q of the tank circuit. The effective circuit Q may be stated in any of several ways, but essentially the Q of the tank circuit is the ratio of the energy stored to two times the energy lost per cycle. The energy lost per cycle is equal to the energy delivered to the tank circuit by the class C amplifier tube or tubes.

b. Radio-Frequency Chokes: Radio-frequency chokes are connected in the circuits for the purpose of stopping the passage of RF energy while still permitting a direct current to pass. They consist of inductances wound with a large

number of turns, either in the form of a solenoid, a series of solenoids, a single universal pi winding, or a series of pi windings. These inductors are designed to have as much inductance and as little distributed or shunt capacitance as possible. The unavoidable small amount of distributed capacitance resonate the inductance, and this frequency normally should be much lower than the frequency at which the transmitter or receiver circuit is operating. The direct current which flow through the RF choke largely determines the size of wire to be used in the winding. A very high inductance RF choke has more distributed capacitance than a smaller one, with the result that it will actually offer less impedance at very high frequency [7].

c. Negative Feedback for Neutralizing Circuit: At radio frequencies the reactance of even very small interelectrode capacitances drops to very low values. A resistance-coupled amplifier gives very little amplification at RF, because the reactance of the interelectrode "capacitors" is so low that they practically short-circuit the input and output circuits. This is overcome at radio frequencies by using tuned circuits for the grid and plate, making the tube capacitances part of the tuning capacitances. In this the circuits can have the high resistive impedances necessary for satisfactory amplification.

4. Conclusions

The purpose of this paper is to design and examine the compact CW-HCN waveguide gas laser by using the Eimac 4CX350A tubes to design the class C push-pull RF power oscillator [8].

The output power increases by RF-excited discharged because of lowering the gas temperature and better uniformity of the gas discharged and better stability of the discharge.

The output power from self-oscillator system is much less than the oscillator/amplifier system. That means the self-oscillator directly coupled system has a less efficient matching condition.

The most important objective for future research would be to ascertain how to better match the impedance of a radio-frequency power generator to a gas laser discharge tube.

Acknowledgment

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Development of a Course Concepts Alignment and Management System

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Abstract

The goals for any degree program should be to limit duplication of course concepts, the alignment of concepts so they build on one another, and the inclusion of all the necessary concepts for the chosen field of study. Furthermore, since degree programs are expected to adapt to changes in the field and to show continuous improvement, they need a system that can bring all course concepts for a degree program together for analysis and proper alignment. An industrial distribution and logistics degree program in North Carolina has developed a database system that assists in this endeavor by allowing faculty to enter their course concepts and goals into a shared system. Since every course concept is entered into the same system, faculty members are able to generate reports that enable them to identify duplicate or missing course concepts and goals within the degree program.

1. Introduction and literature review

Academic institutions must ensure that course concepts and goals within a degree program are correctly aligned. If course concepts are not carefully aligned, there is a potential for duplication within a degree program. Another more serious problem that may result from a lack of course concept alignment is the potential to miss essential course concepts that should have been included within a degree program.

Additionally, most programs in the US are subject to, and seek program certification, either at a state, regional or federal level at a minimum [4]. Most engineering and technology programs, as well as medical and law programs for example, have a certain component of skills training that must be embedded in the course work and often tested by licensing agencies when students graduate and head out into the workforce.

In the past, accreditation bodies often simply assessed outcomes based on time spent in the classroom [4]. However, this time in classroom model is weak as an assessment tool and has been therefore changing and adapting to better match current market and student needs. For example, as it became expedient and necessary to examine how or if a student might earn academic credit for work experience; academic institutions faced the dilemma of assessing the student's knowledge and/or skill by tracing that knowledge/skill concept to a specific class for which the student might receive academic credit. That particular trend is one of several that likely resulted in many advanced degree programs in the US expanding their requirements that certain skills and competencies be clearly tracked to specific courses taken. This process worked in two ways to assure competency of student graduates of technology and engineering programs. Students who already had and could prove certain skills or knowledge based on their experience were able to receive appropriate academic credit that was traceable and definable in the academic process. On the flip side, this process of reviewing and matching competencies and skills to course work helped academic programs identify deficiencies in their degree curriculum and shore those up in review and revision. This in turn helps assure industry that students who graduate with these degrees in hand are work ready and capable with the skill sets and competencies demanded in the work place setting. As

academic institutions, especially state universities, begin to see a boom in both curriculum and degree development and student populations, effectively evaluating degree programs and their requisite course concepts and goals becomes more critical.

Therefore, the necessary evaluation and alignment of course concepts, combined with the reality of professional licensing processes, means that programs must manage their course content better in order to provide clearer more converged evidence that student-learning goals are being met over time. This proof may be assessed during reviews for initial or renewed accreditation or it may be evident in the pass rates of students on professional licensing exams. Additionally, with more emphasis than ever being paid to retention rates at universities, there is more emphasis now on course efficiency and management designed to appropriately move students through a course of study and out into the workplace. Course and curriculum management may also become part of the process of the long term strategic planning for any one unit and if so then there must be a useable, effective system to track progress synchronously over long spans of time. It is simply ineffective and inefficient to look backwards every 5-10 years, depending on accreditation cycles.

While there is not yet a body of literature studying directly this kind of database implementation because of the newness of the endeavor, there are areas of study that are directly relevant to the need for tracking and matching competencies to course content as well as literature related to the value and process of accreditation and specialized standards in industry and the impacts those are having on curriculum development and implementation over time. For example, there is a small but solid body of literature related to the accreditation process including some praising and some resisting the additional control exercised by outside authorities over curriculum that is inherent in this process [4], [5]. There is some literature as well on the processes of licensing accreditation as opposed to state or federal accreditation [1]. There is even a move towards trying to go beyond the guidebooks provided by accrediting agencies that purport to help move colleges and universities through the accreditation or the renewal of accreditation processes [5]. As programs move more and more towards accreditation, many engineering and technology programs are faced with meeting the demands of regional agencies and their own professional ones. These academic units are on the front lines of the reporting and assessment battle. They are faced with finding a way of creating a system that tracks learning assessments and goals of courses over time, as they continue to grow. It is becoming rapidly clear that those assessments and reporting functions are beginning to move away from evidencing outcomes solely based on time spent in the classroom.

In a few of the specialized agencies, there is some evidence of standards being rewritten in the past decade to focus on evidence of skills, knowledge, and ability rather than course sequences and curriculum standards. For instance, according to Wellman [4, p.65] "the National League of Nursing Accreditation Commission, the National Council for the Accreditation of Teacher Education, and the Accreditation Board for Engineering and Technology all focus on expected student learning outcomes, framed as knowledge, skills, and abilities."

In addition to the issue of reporting for accreditation boards, programs face two more fundamental difficulties in assessing and improving their own curriculum as it is taught and adjusted on a regular basis. Furthermore, these two identified difficulties affect retention rates and likely faculty satisfaction in the classroom as well. These two potential problems affecting the integrity of any degree program are: (1) the need to avoid redundancy and, (2) the need to plan/see over a long span of time and across a broad swath of content in order to add new course content or update older content.

If programs fail to overcome these difficulties, they face a future of failure and uncertainty for many reasons. For instance, duplication of course concepts or redundancy can lead to student boredom, dropouts and

poor performance in the classroom environment by both faculty and students. On the other hand, failure to cover essential concepts at all in any course can lead to unprepared graduates. The goals for any degree program should be to limit duplication of concepts, alignment of concepts so they can build on one another over time in the curriculum, and including all the necessary concepts for the chosen field of study.

Academic institutions have long used traditional methods to align course concepts, which are incomplete and rife with human error as programs grow and become more complex. These traditional methods require numerous faculty meetings and countless hours of discussion to develop a course concepts plan for the entire degree program. Making the task even more difficult is that it must be repeated on a regular basis if academic programs are to be kept current. Furthermore, since course concepts and goals are typically included in each course separately, administrators as well as faculty would have to display all of courses in the degree program to be able to see the learning path students within a degree program undertake. This lack of visibility hampers the evaluation of course concepts in their respective degree programs.

The labor intensive process and lack of visibility is characteristic of traditional methods of course concept alignment and management. These characteristics necessitate the need for an automated method that is accessible to all at any time, to accomplish this necessary task an academic program must undertake. Some may express concern however that faculty will resist using technology to manage the content and education points covered in their courses. While it is possible that faculty may balk at learning new technology, it is likely they will be willing to use the system this paper describes because of its ease of use and the value it adds to the overall function of the department. In fact, many programs currently use course management systems for any number of tasks from monitoring interns and fieldwork students, to enhancing the learning experience in distance education classes [2], [3]. Because most faculty are already familiar with the use of these kinds of course management systems, the move to encouraging faculty to consult a database management system when they adapt, develop, or change their course content should not be a difficult leap. Faculty seem to adapt to using new technology applications when they see a clear benefit for student learning and assessment and assuming the learning curve for use is not overly steep.

One distribution and logistics degree program in North Carolina has developed such a database system that allows faculty to enter their course concepts, goals, and course changes into a shared system. Since every course's processes, goals, and content is entered into the same system, faculty members are able to generate reports that enable them to identify duplicate or missing course concepts within the degree program. Furthermore, since degree programs are expected to adapt to changes in the field of study, the use of a live system that can be easily updated with current course concepts allows for a more effective management of degree programs and a better reporting system when the program faces accreditation or the renewal of accreditation evaluations. Material that has been gathered synchronously over time and weaknesses that have been dealt with in real time, and corrected in any degree program as a reporting process, should be more believable and more effective in the accreditation and renewal of accreditation processes.

2. Background

In order to ensure academic institutions are effectively preparing students for challenging careers they need to evaluate their degree programs on a regular basis. This evaluation process is made more difficult without automation. Prior to the development of the Course Concepts Management (CCM) database system, course managers within the Distribution and Logistics degree program met over a series of weeks to analyze, realign, and add or delete

course concepts for all of the courses within the major.

There are 13 Distribution and Logistics courses that are part of the Bachelor of Science in Distribution and Logistics degree program. The remaining courses are owned and managed by other degree programs. Since the remaining courses are owned and managed by other degree programs, a faculty member within the Distribution and Logistics degree program requested a list of course concepts from the other degree programs that owned the respective courses that make up the entire degree program.

The course concepts that were obtained from the other degree programs were provided on a copy of the course syllabus for the respective course. If the course syllabus was not updated on a regular basis, the concepts listed on the syllabus may not be the actual concepts taught in the course.

Furthermore, a lack of uniformity exists among degree programs with respect to syllabi. While some instructors or degree programs listed all course concepts covered within a course, some only included general statements and course objectives on the syllabi. When attempts to obtain all course concepts for a course failed, Distribution and Logistics faculty members had to improvise by making assumptions about the specific course concepts covered within those courses.

The traditional course concepts review and alignment process then continued for several weeks, where course owners discussed each course they owned with the others and exchanged lists of course concepts. The process was time consuming and lead to many revisions of the course concepts for each course.

Since each list of course concepts was separate from the other lists, tying course concepts to each other was extremely difficult and often confusing. Also, determining the most appropriate sequence of course concepts was a challenge. This challenge can be attributed to course owners having to use the whiteboard, projection screen, and pen and paper to list the course concepts in the right order for the entire degree program.

Further complicating the process is the lack of a centralized system to store and align course concepts, making it difficult to identify gaps and overlaps in course concepts. Course owners had to scan the entire list of course concepts for each course to identify overlaps and gaps. While overlaps were slightly easier to identify, gaps proved to be more difficult since an entire map of course objectives was not readily available.

3. Planning and design approach

Since most of the course owners felt a better method to align and manage course concepts was needed within the degree program, a faculty member with extensive experience in database development volunteered to develop a database system that would allow every course owner to enter and manage their course concepts and course changes from their own computer. The database would consist of two separate Microsoft® Access files: a back-end file housed on a departmental server all course owners have network access to and a front-end file located on each course owners' computer that contains the user interface for the system.

All of the data entered and managed in the system would be stored on the back-end Access file. A link would exist between the course owners' computers and the back-end database using the built-in features provided by Access. This design approach will ensure that everyone is using the most current data to create a variety of reports and to facilitate the course concepts management process.

Furthermore, the new CCM database system would be password protected so that only the database administrator has complete control of the data and each course owner would have access to their course concepts only. Although any course owner can see all of the course concepts for the entire degree program, only the course owner for that course can change any of the course concepts. This approach will prevent

unauthorized changes to course concepts without a course owner's approval.

The underlying structure of the back-end database Access file consist of six related tables linked through common fields (Figure 5). This relational database approach reduces redundant data and provides other benefits typically associated with relational databases. Another critical design approach of the CCM database system is the separation of the data files from the other database objects, such as forms, queries, and reports. Instead of these objects being included in the same Access database as the tables, they are included in the front-end database making up the graphical user interface used by each course owner.

To control access to critical core data and components of the database, the Access objects are hidden from users' view. The CCM database manager has access to the core data and components through the Database Maintenance and Annual Review option on the main switchboard, which is not available to course owners (Figures 1 and 2).

On the other hand, course owners are restricted to certain areas of the CCM database through the main switchboard, a few input and output forms (Figures 3 and 4), and reports. This design structure protects critical data and database objects from accidental or deliberate deletion and unauthorized updates.

Course owners as well as the database manager have access to a variety of reports through the main switchboard (Figure 1). These reports aggregate data from all courses that are stored on the back-end database tables, not visible to users. Some of the standard reports included on the reports submenu include the Course Changes Report, Course Concepts Report, and the Course Changes by Instructor Report.

The Course Changes Report provides a chronological report of all the changes for each course within the Distribution and Logistics degree program. The Course Concepts Report integrates all of the course concepts provided by each course owner into one cumulative report. As course concepts are realigned during the course concepts realignment process, the report is automatically updated the next time it is produced. This single feature of the CCM database system saves countless hours redoing manual reports previously generated in Microsoft® Word. Furthermore, since every report can be previewed without printing, printing costs are significantly reduced.

4. Limitations

Since the CCM is still evolving, it has several limitations inherent to all new systems. One of these limitations is that it does not have all of the reports an academic institution could possibly ask for. Another limitation is that it does not currently include a feature to upload course syllabi data and the ability to generate course syllabi. The next software version due for release in the spring of 2010 will include the ability to automatically generate standard course syllabi and an input screen that allows an instructor to enter data specific to the particular section of the course, such as the instructor's name, day and time of the week the course will be taught, and the grading scale used. This input screen will then feed the associated syllabi with the supplied data.

The lack of a feature to upload all documents used to analyze and assess the effectiveness of every course concept is another limitation of CCM. This feature is currently under development and will be included in the next version of the CCM. Once these and other features are included in the CCM, course managers will have one system they can use to manage and assess the effectiveness of their courses.

Another limitation of CCM is that it is an Access database system that does not scale as well as other database system such as Oracle. Furthermore, if the number of concurrent users nears the 100 mark, CCM may experience delays. It is unlikely that a specific degree program will have that many course owners attempting to update data at the same time.

Like other information systems, CCM is also effective if the data is kept current and

the system is used by all course owners. Therefore, administrators will need to ensure all course owners are incorporating the system in their course management attempts.

5. Conclusion and Recommendations

The effective management of any degree program requires proper sequencing and management of course concepts. Not including critical course concepts in a degree program employers expect graduates to know, can cheapen the degree program and negatively affect its future enrollment. Furthermore, haphazardly aligning course concepts within courses can lead to duplication of concepts that can create boredom as well as confusion for students. Furthermore, failing to demonstrate continuous improvement within a degree program can affect the outcome of accreditation processes and result in loss of accreditation or being required to implement sudden, costly, and time consuming processes to attempt to retroactively correct perceived or real failures in curriculum. This, of course, is often the death knell for technology or engineering programs. Probation or loss of professional accreditation can result in loss of faculty and your best students. At best, without automation gathering data over long spans of time related to course content and competencies is overwhelming and haphazard.

Therefore, the traditional method used to align and manage course concepts, which has been a time consuming and cumbersome process, today necessitates automation. The development of the CCM system is evidence that automation can be used to aggregate course concepts and reduce the time and effort spent realigning course concepts as changes occur within a field of study on a continuous basis over long spans of time. Furthermore, accreditation boards as well as administrators can benefit from a centralized system that can generate new as well as standardized reports within a fraction of the time it took using traditional methods.

Since the CCM is a relatively new approach to managing course concepts, it requires more testing and feature enhancements. Also, a need exists for the development of more comprehensive systems that tie in the entire administrative functions course owners are expected to perform, since systems of this nature are likely to reduce the time spent managing and assessing courses within a degree program. Furthermore, studies are also needed to more precisely determine the effectiveness of CCM over an extended period of time. Other studies should compare CCM to other similar systems in use in academia.

6. References

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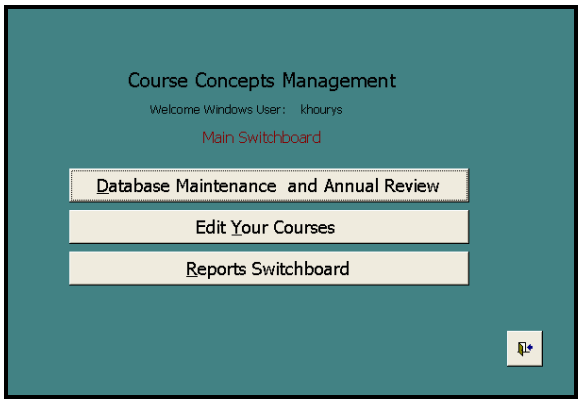


Figure1: The CCM Main Switchboard

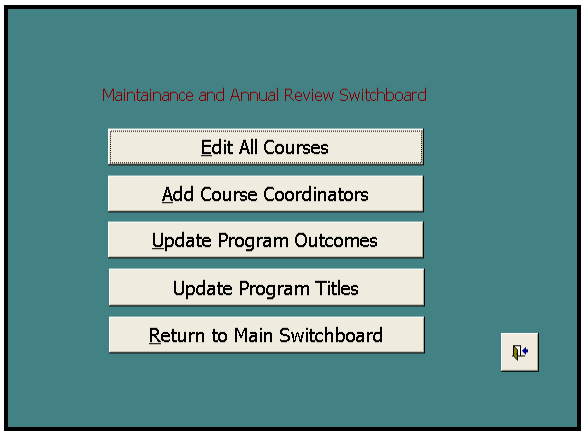


Figure 2: The CCM Maintenance Menu

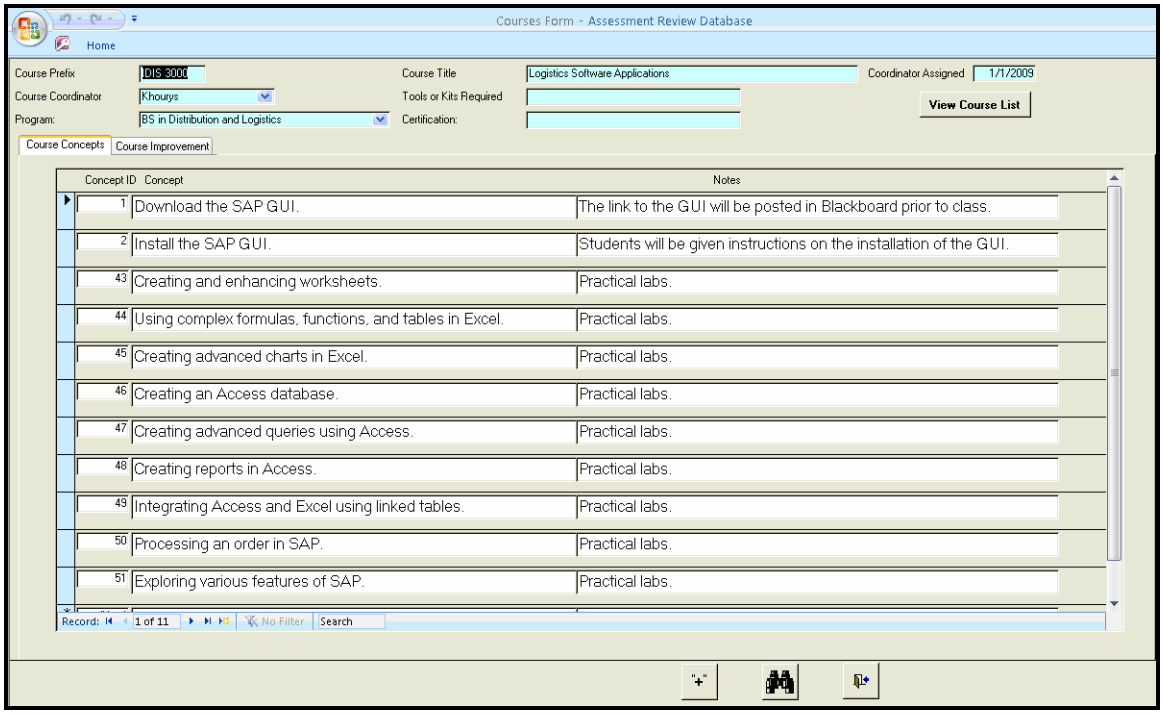
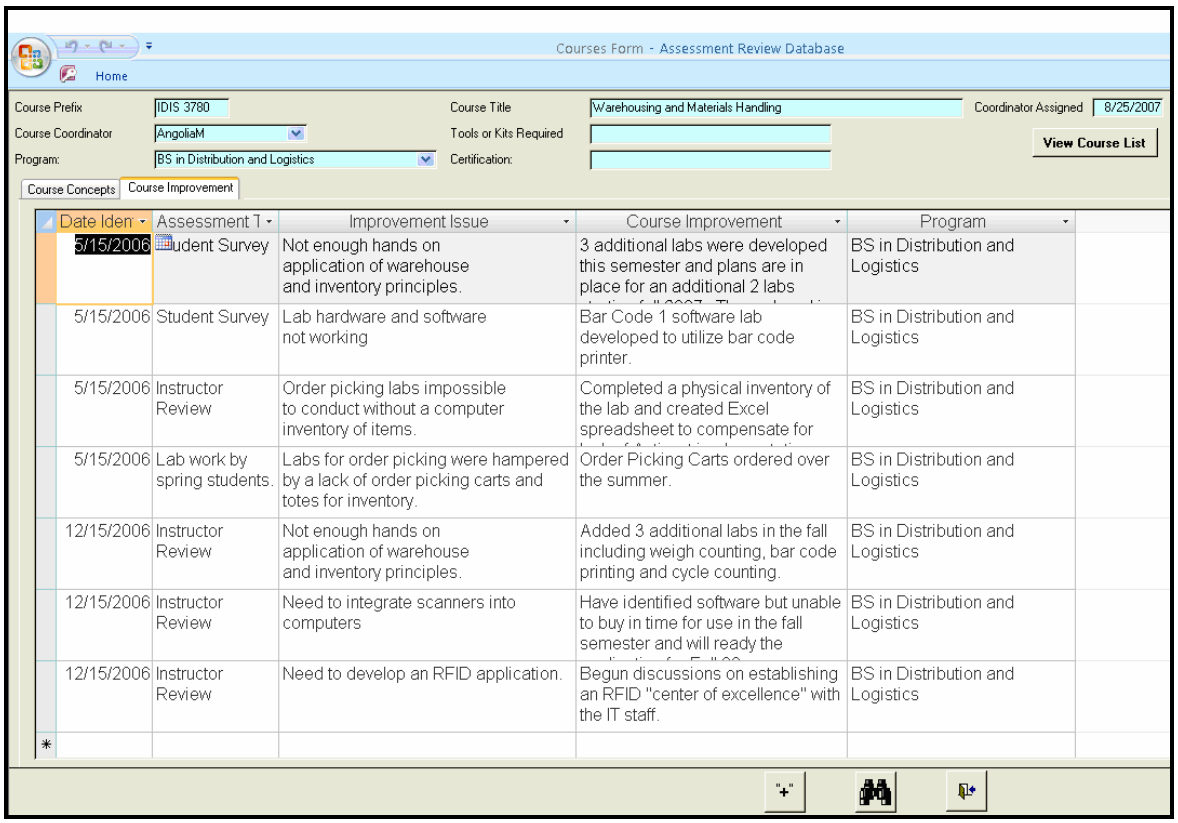


Figure 3: Course Concepts Entry/Edit Form



Date Iden	Assessment T	Improvement Issue	Course Improvement	Program
5/15/2006	udent Survey	Not enough hands on application of warehouse and inventory principles.	3 additional labs were developed this semester and plans are in place for an additional 2 labs	BS in Distribution and Logistics
5/15/2006	Student Survey	Lab hardware and software not working	Bar Code 1 software lab developed to utilize bar code printer.	BS in Distribution and Logistics
5/15/2006	Instructor Review	Order picking labs impossible to conduct without a computer inventory of items.	Completed a physical inventory of the lab and created Excel spreadsheet to compensate for	BS in Distribution and Logistics
5/15/2006	Lab work by spring students.	Labs for order picking were hampered by a lack of order picking carts and totes for inventory.	Order Picking Carts ordered over the summer.	BS in Distribution and Logistics
12/15/2006	Instructor Review	Not enough hands on application of warehouse and inventory principles.	Added 3 additional labs in the fall including weigh counting, bar code printing and cycle counting.	BS in Distribution and Logistics
12/15/2006	Instructor Review	Need to integrate scanners into computers	Have identified software but unable to buy in time for use in the fall semester and will ready the	BS in Distribution and Logistics
12/15/2006	Instructor Review	Need to develop an RFID application.	Begun discussions on establishing an RFID "center of excellence" with the IT staff.	BS in Distribution and Logistics

Figure 4: CCM Course Improvement Form

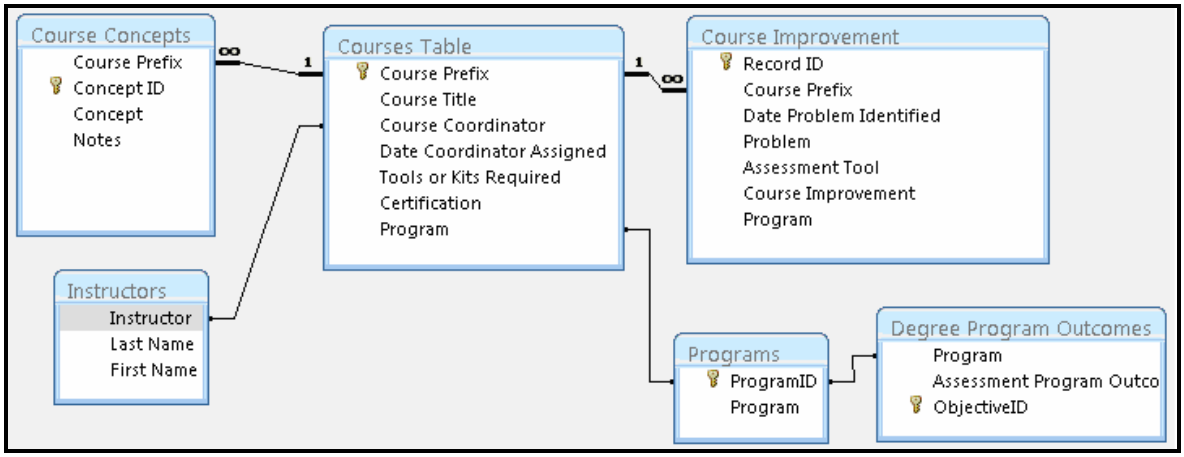


Figure 5: CCM Tables with Relationships

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Planning of Embankment Compaction Operations

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Abstract

Soil embankments are used extensively in many types of construction projects such as roads, railways, dams, bridges, etc. In most of these projects, embankment construction represents the major cost element due to the large amounts of materials operated. Therefore, the operations of embankment layers construction should be carefully planned to make the best use of equipment capabilities, especially the compactors, which have a basic effect on the quality and cost of the highway construction.

This study presents a methodology for planning the compaction operations involved in the construction of embankment layers. The major concern is to obtain the optimum number of compactor passes that will economically achieve the density required for the embankment. The proposed methodology involves six main tasks including: (1) Finding the optimum moisture content and maximum dry density of the soil, (2) Exploring the effect of number of blows on the dry density at different moisture contents, (3) Finding the relationship between laboratory compaction effort and number of compactor passes, (4) Calculating the compaction capacity (m^3 of compacted material per hour) for each alternative (moisture content and number of compactor passes), (5) Calculating the cost of compaction for each alternative, and (6) Evaluating the results and selecting the optimum alternative. An application of this methodology to a real highway construction project is also presented.

Soil embankments are used extensively in many types of construction. They are used to support pavements for highways and airports, support railways, to resist the passage of water as dams, and for bridges approaches. In these types of construction, the embankment construction normally represents the major cost element due to the large amounts of materials operated. Therefore, the operations of embankment layers construction should be carefully planned to make the best use of equipment capabilities, especially the compactors, which have a basic effect on the quality and cost of the highway construction.

Soil Compaction

Pavement performance is highly influenced by the strength, permeability, and other subgrade characteristics. Subgrade compaction increase strength, decrease permeability, and reduce undesirable settlement. The economic climate prevailing in most developing countries make it essential that resources available for highway construction are used as cost-effectively as possible. This challenge is made all the more difficult in those countries having arid or semi-arid climates, as a consequence of which there is generally a scarcity of water for road construction. In these regions, the surface soils are usually sandy, having low natural moisture content and occurring at very low in situ densities.

Typical specifications for earthworks compaction generally require the field processing moisture content to be close to the laboratory derived optimum moisture

content (OMC). In arid or semi-arid environments, the in situ moisture content of the sandy soils in the dry season is generally of the order of one quarter to one third of OMC. Hence, significant amounts of scarce and usually expensive water, of the order of 750-12000 m^3 per kilometer per lane, are required for compaction purposes. In addition, some current specifications also require relative deep compaction of these low density and often slightly cemented subgrade soils (*1*).

From considering of the above, it is apparent that significant cost savings would be achieved if the amount of compaction water could be reduced, and the thickness of construction layers increased, without detriment to the quality of the finished product. New techniques like Intelligent Compaction (IC) technology has been recently used in some experimental projects. FHWA (*2*) defined the Intelligent Compaction (IC) technology as "Vibratory rollers that are equipped with a measurement/control system that can automatically control compaction parameters in response to materials stiffness measured during the compaction process. The roller must also be equipped with a documentation system that allows continuous recordation, through an accurate positioning system, of roller location and corresponding density-related output, such as number of roller passes and roller-generated materials stiffness measurements." The Intelligent Compaction (IC) is made possible because of the ability of a vibratory roller to first sense the material response of soil under loading, to process this information and compare it to the input requirements, and then to "decide" how to adjust compaction parameters to most efficiently compact the material. Since none of these features are available on conventional vibratory rollers, IC represents a major innovation in soil compaction technology (*2*). Currently, this technology is marketed by BOMAG from Germany, AMMANN from Switzerland, and DYNAPAC from Sweden. CATERPILLAR has also a system available for demonstration (*3*).

Unfortunately, attainment of these goals is not normally possible with the regular vibrator compactors and the traditional compaction planning methods. There is a great need, especially in developing countries; to develop a methodology to optimize the compaction resources and fulfill the needed compaction energy. The presented methodology has brought about the scope for effecting significant saving in compaction cost.

This study presents a proposed methodology for planning the compaction operations in highway construction. The major concern is to select the moisture content and the corresponding number of compactor passes that will economically achieve the level of compaction required for the embankment. An application of this methodology to the construction of embankment layers for one the major corridor is also presented.

Proposed Methodology

The proposed methodology for planning the compaction operations involves six main tasks including:

1- Finding the optimum moisture content and maximum dry density of the soil through the laboratory tests.
2- Exploring the effect of number of blows on the dry density at different moisture contents for the same type of soil.
3- Creating the relationship between laboratory compaction effort and number of compactors passes.
4- Estimating the compaction capacity (m^3 of compacted material per hour) for each alternative (moisture content and number of compactor passes).

5- Calculating the cost of compaction for each alternative, and
6- Evaluating the results and selecting the optimum alternative.

These tasks are illustrated through an application of the proposed methodology to the construction of embankment layers for the highway project.

Application of the Proposed Methodology

The highway under study is considered one of the most important national and civilized projects in Egypt. It connect the Egyptian Capital "Cairo" with one of the newly developed industrial cities. The highway length is about 14 km, and its width is 34 m, divided into three lanes in each direction and a 7-m wide middle median. The road surface ranges from 6 to 8 m above ground level, to prevent the establishment of random communities.

The road embankment represented the major cost element in this project. The project total cost was estimated at about L.E. 26.7 million, of which 14.6 (about 55%) was allocated to the construction of embankment. The planning of compaction operations for the embankment construction involved the following tasks:

Optimum Moisture Content and Maximum Dry Density

The optimum moisture content and maximum dry density of the soil to be used (sand) were determined using the modified Proctor test. Based on the results of this test, the relationship between dry density and moisture content was determined, which is plotted in Figure 1. The soil type was sandy to clayey-sand soil and the figure reveals optimum moisture content of about 8.7% and a maximum dry density of about 1.93 gm/cm^3.

Effect of Number of Blows on Dry Density

Laboratory samples of the dry sand with different moisture contents (3.0%, 6.0%, 7.5%, and 8.5%) were tested using the modified Proctor test. To estimate the required compaction energy, each sample was exposed to different numbers of blows (25, 35, 45, and 55 blows), which represent different compaction efforts. The results are plotted on Figure 2, which shows the increase of dry density with increasing the number of blows at different moisture contents. The figure also indicates that the maximum dry density (1.93 gm/cm^3) can be achieved with various moisture contents by using different number of blows. This is illustrated in Figure 3, which shows the relationship between the moisture content and the number of blows necessary to achieve the maximum dry density. This figure also indicates that the number of blows increases with the decrease of moisture content.

Relationship Between Laboratory Compaction Effort and Number of Compactor Passes

The laboratory compaction effort is determined as the compaction energy applied in the modified Proctor test, computed using the following formula:

$$C_L = (W * H * L * N_1) / V \qquad (1)$$

Where:

C_L = laboratory compaction energy (kg.m/m3);
W = weight of hammer (kg);
H = height of hammer (m);
L = number of layers;
N_1 = number of blows; and
V = volume of mould (m3).

Under the modified Proctor test conditions used (W = 4.536 kg, H = 0.4572 m, L = 5

and V = 9.46 x 10^{-4} m^3), Equation (1) reduces to:

$$C_L = 10{,}961 * N_1 \quad (2)$$

To achieve the required level of compaction, the laboratory compaction effort (C_L) should be equivalent to the field compaction effort, which is determined as the number of compactor passes (N_2) multiplied by the field compaction effort due to one pass (C_{F1}). This can be expressed as:

$$C_L = N_2 * C_{F1} \quad (3)$$

From Equation (3), the number of compactor passes required to achieve a certain laboratory compaction effort (C_L) can be calculated using the formula:

$$N_2 = C_L / C_{F1} \quad (4)$$

The field compaction was conducted using the compactor model "CA25D", with the following operating conditions:

- Medium frequency.
- Medium amplitude.
- Speed of 3.0 km/hour.

For these conditions, the compaction effort (or energy/volume) of one pass is 87,603 kg.m/m^3 *(6)*. Substituting this value into Equation (4), it reduces to:

$$N_2 = C_L / 87{,}603 \quad (5)$$

Compaction Capacity

According to the Egyptian Code of Highway (*7*), the compaction capacity can be calculated sing the formula:

$$Q = e * (D * T * S * 1{,}000) / N_2 \quad (6)$$

Where:
Q = compaction capacity (m^3/hour);
e = efficiency factor;
D = drum width (m);
T = layer thickness (m); and
S = roller speed (km/hour).

Under the used operating conditions, the values of these variables were as follows: e = 75%, D = 2.13 m, T = 0.5 m., and S = 3.0 km/hour. Applying these values into Equation (6), it reduces to:

$$Q = 2{,}396 / N_2 \quad (7)$$

Table 1 presents the compaction capacity using different numbers of compactor passes.

Compaction Cost Calculations

Compaction cost, which include compactor and water cost, can be varied between construction sites. The main factors affect this cost are the selected moisture content and the corresponding number of compactor passes required achieving the maximum dry density at that moisture content. The cost of compaction was calculated as follows:

$$C_t = C_w + C_c \quad (8)$$

$$C_w = c_1 * w_c * \gamma_d \max \quad (9)$$

$$C_c = c_2 / Q \quad (10)$$

Where:
C_t = total cost of compaction (L.E. /m^3);
C_w = cost of water (L.E. /m^3);
C_c = cost of compactors (L.E. /m^3);
c_1 = unit cost of water, including operating cost (L.E. /m^3 of water);
c_2 = rental rate of compactor, including operator cost (L.E./hour);
w_c = moisture content (%); and
$\gamma_d \max$ = maximum dry density (gm/cm^3).

Table (2) presents the cost of compaction using different moisture contents (and correspondingly different numbers of compactor passes) based on the following cost elements:

- Unit cost of water (including operating cost) = L.E. 1.0, L.E. 2.0, and L.E. 3.0/m^3.

- Rental rate of compactor (including operator cost) = L.E. 40/hour.

Evaluation of Results and Selection of Optimum Alternative

The selection of optimum alternative (moisture content and number of compactor passes) will be based on the cost of compaction only, since all other cost elements of the embankment construction (cost of material, cost of grading, etc.) are almost the same for all alternatives.

The cost of compaction at different moisture contents is plotted in Figure (4). From this figure, the optimum alternative varies according to the availability of water. If water can be delivered at a fair cost (L.E. 1.0/m^3 for example), it is recommended to use high moisture content (7.5%), and correspondingly a small number of five compactor passes. On the other hand, if water can only be delivered at a much higher cost (L.E. 3.0/m^3 for example); it is recommended to use low moisture content (3.0%), and correspondingly a large number of 15 compactor passes.

Conclusion

A proposed methodology for planning the compaction operations involved in the construction of embankments has been presented. This methodology, involving six main tasks, was illustrated through an application to the construction of embankment for a real highway project. Target density can be archived through different values of moisture content and number of compactor pass. The selection of optimum alternative (moisture content and number of compactor passes) varies according to the availability of water. In situations where water is available at reasonable costs, the trend is to use higher moisture contents and correspondingly smaller numbers of compactor passes. On the other hand, in situations where water is scarce and can only be delivered at much higher costs, the trend is to use lower moisture contents and correspondingly larger numbers of compactor passes.

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Notation

The following symbols are used in this paper:

c_1 = unit cost of water, including operating cost (L.E./m^3 of water);
c_2 = rental rate of compactor, including operator cost (L.E./hour);
C_c = cost of compactors (L.E./m^3);

C_{F1} = field compaction effort due to one pass;

C_L = laboratory compaction energy (kg.m/m3);
C_t = total cost of compaction (L.E./m^3);
C_w = cost of water (L.E./m^3);
D = drum width (m);
e = efficiency factor;
H = height of hammer (m);
L = number of layers;
N_1 = number of blows;
N_2 = number of compactor passes;
Q = compaction capacity (m^3/hour);
S = roller speed (km/hour); and
T = layer thickness (m);
V = volume of mould (m3).
W = weight of hammer (kg);
w_c = moisture content (%); and
γ_d max = maximum dry density (gm/cm^3).

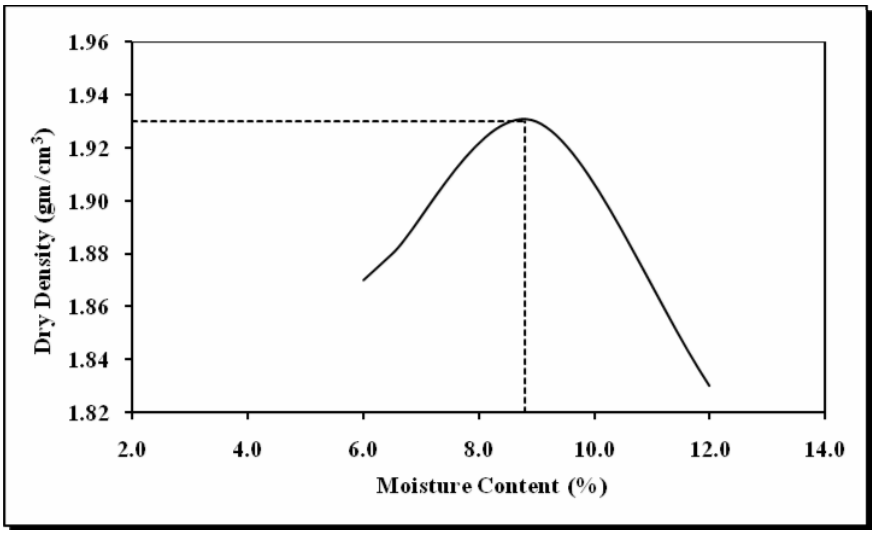

Figure (1): Relationship between Dry Density and Moisture Content

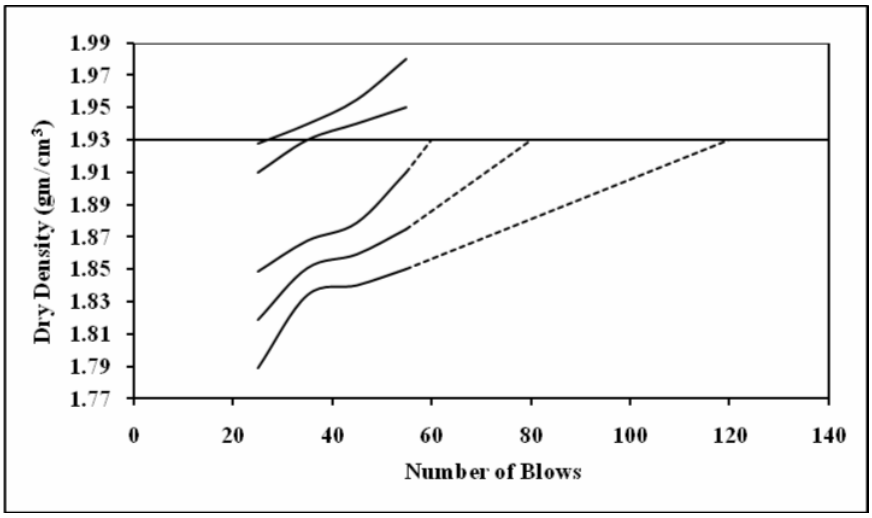

Figure (2): Relationship between Dry Density and Number of Blows

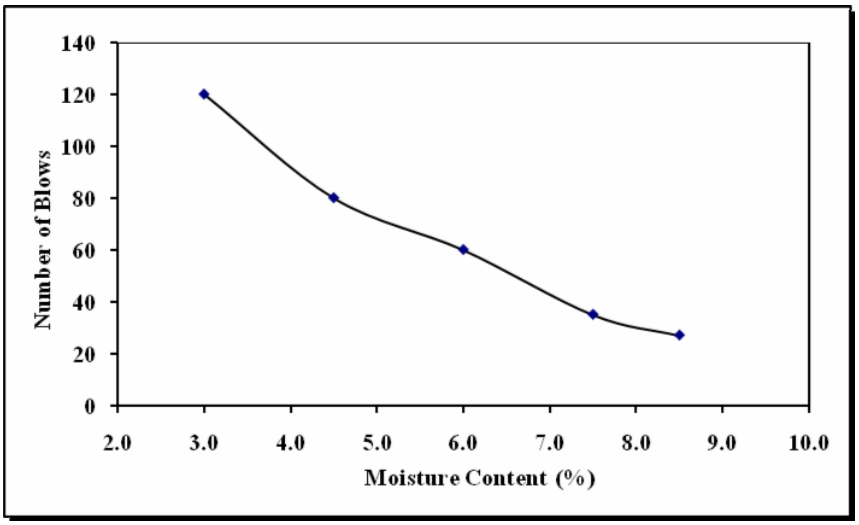

Figure (3): Relationship between Number of Blows and Moisture Content (at maximum dry density of 1.93 gm/cm^3)

Table (1): Compaction Capacity at Different Number of Passes

Moisture Content (%)	No. of Blows * (N_1)	Laboratory Compaction Effort ** C_L (kg.m/m^3)	No. of Compactor Passes *** (N_2)	Compaction Capacity # Q (m^3/hour)
3.0	120	1,315,320	15	160
4.5	80	876,880	11	218
6.0	60	657,660	8	300
7.5	35	383,635	5	479
8.5	27	295,947	4	599

* From Figure. (3). *** Using Equation. (5).
** Using Equation. (2). # Using Equation. (7).

Table (2): Cost of Compaction at Different Moisture Contents

Moisture Content (%)	No. of Compactor Passes (N_2)	Compaction Capacity Q (m^3/hour)	Cost of Water (including operating cost) * ($L.E./m^3$) x 10^{-2} c_1 = L.E. 1.0	c_1 = L.E. 2.0	c_1 = L.E. 3.0	Cost of Compactor (including operator) ** ($L.E./m^3$) x 10^{-2}	Total Cost of Compaction *** ($L.E./m^3$) x 10^{-2} c_1 = L.E. 1.0	c_1 = L.E. 2.0	c_1 = L.E. 3.0
3.0	15	160	5.79	11.58	17.37	25.04	30.83	36.62	42.41
4.5	11	218	8.69	17.37	26.06	18.36	27.05	35.73	44.42
6.0	8	300	11.58	23.16	34.74	13.36	24.94	36.52	48.10
7.5	5	479	14.48	28.95	43.43	8.35	22.82	37.30	51.77
8.5	4	599	16.41	32.81	49.22	6.68	23.08	39.49	55.89

* Using Equation (9) ** Using Equation (10) *** Using Equation (8)

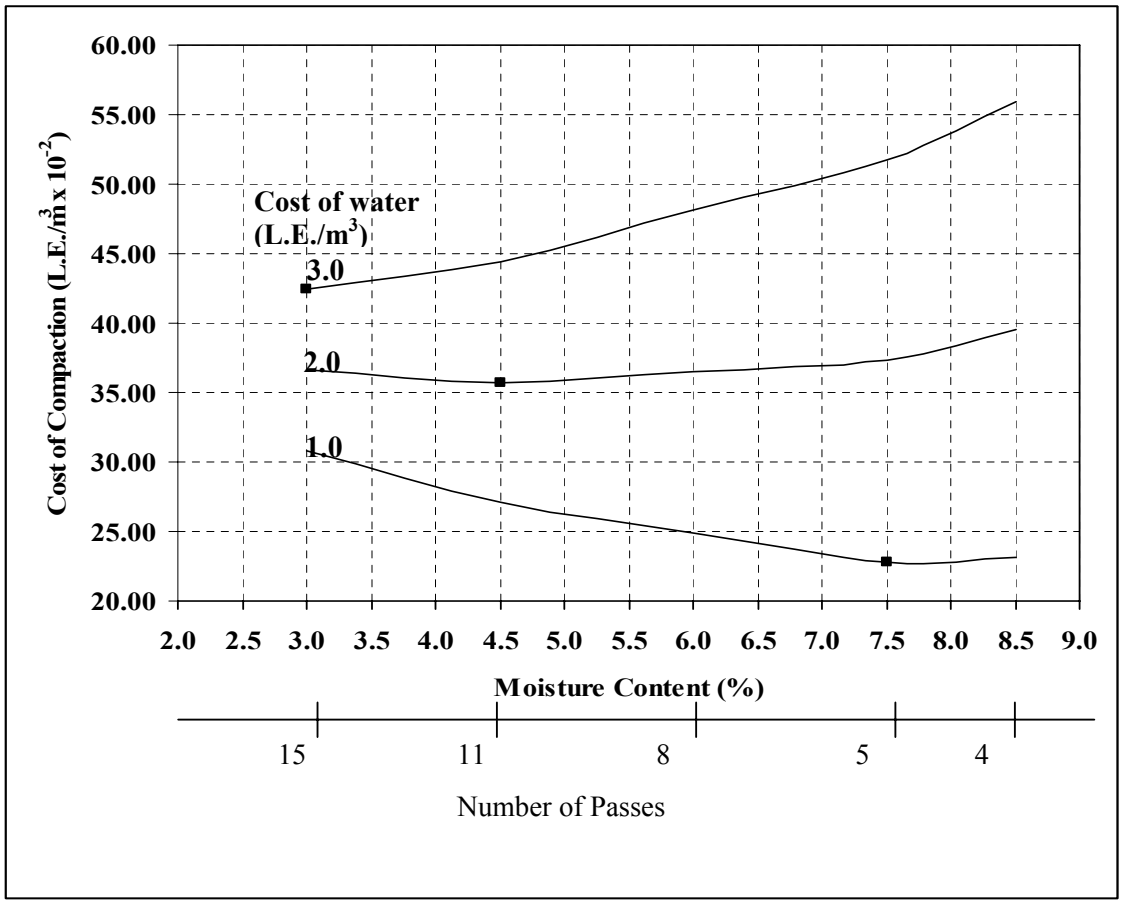

Figure (4): Cost of Compaction at Different Moisture Contents

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Usability Concerns for Specialized Software Applications

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Abstract

People love new gadgets – especially ones with novel interaction methods. Over time, the expectations that these devices must undoubtedly create slowly seep into the desires of users and designers and inevitably then influence the perception of what is considered "easy" and "enjoyable to use." For designers of complex and specialized software applications, whose functional and interaction requirements are burdensome, this presents a tricky problem – how to make an effective and efficient application that is perceived to be reasonably easy to learn and enjoyable to use by the culture that it targets. In this paper, we explore a single specialized software application in order to evaluate how one set of designers dealt with this problem and what interactive snags were not caught in their design process. Through usability testing we uncover hard evidence that indicates the large impact that even small, seemingly insignificant errors in interaction design can have. Using the test results as feedback, combined with established design principles and published knowledge on the topic, we then provide constructive recommendations to correct the problem areas. Though the results of this particular usability test are interesting, especially to the developers of the software, we believe that the findings of the test may possibly hold greater significance. We believe that the results might shine light on more broadly applicable issues related specifically to complex, specialized software applications.

1. Introduction

It is reasonable to assume that when most software designers embark upon the task of creating or adding to a software application, they do so with the intent of making it usable. By usable, we mean that a product is "easy to learn" [19] and can be used to achieve specific goals "with effectiveness, efficiency, and satisfaction" [6]. However, software designers, like all humans, are limited in their capability to perceive and consider all aspects of a challenge when developing a solution. In addition, developers may not have the opportunity to practically use the products that they design [1]. This is something that may be especially true if they are designing specialized software applications, which we define as software programs created with the intent of enabling or assisting in a set and particular type of activity. The lack of practical experience that designers may have in using these systems then makes it difficult for them to truly understand what a user really needs or desires from and in the product being designed. These restrictions render the developers inept in knowing all reasonable manners in which the products that they are designing may be used. These issues can then be exacerbated by the difficulty faced in trying to find a proper balance between providing advanced tools and functions that users will need, while making the application simple and intuitive.

In this study, we evaluated a geospatial intelligence exploitation program, referred to from this point forward as GIEP. The GIEP is a specialized software application designed to ingest, process and then display geospatially referenced intelligence information. More specifically, the program specializes in movement-based intelligence and allows for the layering, manipulation and analysis of intelligence data with the

purpose of creating intelligence products. The user needs levied upon this application require it to have human computer interactions that command functions to be performed on the data that are often complex. This forces the software developers to overcome additional obstacles when working to make a system optimally usable and capable. Therefore, we elected to perform a usability test on the GIEP with the purpose of (1) evaluating the adherence of the software to a core set of interaction usability goals, (2) learning what underlying factors may influence user interaction for a piece of specialized software like the GIEP and (3) providing recommendations on guidelines and specific solutions for identified usability problems to the software designers.

2. Methodology

Attempting to have test participants evaluate all aspects of human computer interaction in one session that are incorporated into the GIEP would be impractical, and likely to evoke frustration. Consequently, we chose to have test participants assess the program by providing them with eleven tasks that cover some of the basic, yet core functions of the software. The user responses to the eleven tasks were then analyzed with the purpose of evaluating their adherence to usability goals and discovering the underlying factors affecting interaction. To detect specific usability issues present in the GIEP the test and subsequent analyses were designed to look specifically for adherence to the usability goals of effectiveness, efficiency, safety and learnability [19], with the intent of finding "usability problems that [the] software designers never imagined" [7]. The problems and information discovered in the data analysis were then considered against the interactive design principles of visibility, feedback, constraints, consistency and affordance [19].

2.1 Testing documents

In an effort to properly prepare the participants for the usability test, execute the test itself, log observations, categorize the users and then learn from their experiences with the GIEP, we created a set of primary documents and several additional supplementary spreadsheets. Of these documents, the Test Instructions were given the most attention, since their design had to capture some of the core functions of the software program in a very limited number steps. The eleven tasks that were selected as the most fundamental functions of the operation of the GIEP were chosen based on a subjective opinion from a highly experienced user.

We also gave participants a Pre-Test Survey prior to testing to capture specific, relevant background information on each of the individuals being tested [5]. It covered the participants' intended academic major, frequency of computer use and level of Geospatial Information System (GIS) experience, in order to offer contextual insight into any trends revealed in data analysis. Additionally, we collected observable information like hesitations, errors, time to accomplish task, steps used to accomplish the task and verbal comments made by the participants during the usability test [18]. Hints given by the test administrators for any task were also recorded. These metrics provided quantitative and qualitative data for each task and allowed for insight into the usability of specific functions. Lastly, a Post-Test Survey was given to participants to collect measurable feedback from them regarding their perception of the application and how they believe it can be improved upon [19]. Part of the survey used Likert scale questions for understanding "opinions, attitudes, and beliefs" and another portion of the survey used open-ended questions to uncover new thoughts or ideas [19].

2.2 Recruiting

We recognize that enlisting appropriate participants for testing the usability of any product is important [11]. Therefore, we focused on recruiting Army ROTC seniors from Florida Institute of Technology (FIT) with varying majors for testing the usability of the GIEP. The relevant nature of the testing material and potential applicability of the software to their upcoming carrier or activity in the military made

the future military officers a natural fit as participants in this test [19].

3. Literature review

We sought out articles and books that discuss usability in software programs and basic human computer interaction design tools and principles for software applications. The information provided by them assisted in guiding our analysis and recommendations.

3.1 Human computer interaction

Human computer interaction (HCI) is the study of how humans devise, implement, and make use of interactive systems [2]. It also studies how these computer systems affect individuals, corporations, and societies (Bryson, 1996). Most articles and books on HCI emphasize the importance of enjoyable and effective human computer interaction in today's culture. The interface, through which interaction often occurs, is critical to the success of products in the marketplace, as well as the safety, usefulness, and pleasure of using computer-based systems (Bryson, 1996).

Human-computer interaction arose as a field from intertwined roots in computer graphics, operating systems, human factors, ergonomics, industrial engineering, cognitive psychology, and the systems part of computer science [4]. Since its inception, however, it has witnessed great transformation and development [6]. Now, defined checklists on how to best implement proper HCI techniques into interactive systems and discussion on HCI issues internal or external to the user interface are readily found [16]. Affordance is one of the specific topics within the field of HCI that we chose to focus on for the usability testing of the specialized software. Affordance refers to all of the action possibilities of a computer interface that are readily perceivable by the user [13].

3.2 Usability

Usability refers to the ease with which people are able to utilize tools and other tangible objects in order to achieve a particular goal [7] and it is a key element to effective human computer interaction and user satisfaction. The purpose of testing usability is to, "find problems and make recommendations to improve the utility of a product during its design and development" [7]. In testing for usability a set of factors must be selected for evaluation. A stated sets of human factors are compatibility, consistency, flexibility, learnability, minimal memory load, minimal action, perceptual limitation, and user guidance [9]. Another viable set is visibility, feedback, constraints, consistency and affordance [19]. The choice of evaluation factors will ultimately drive information collection and analysis. For collecting information, one article discusses the USE Questionnaire, standing for "usefulness, satisfaction, and ease of use," and its effectiveness in conducting a usability test [10]. These three dimensions were most prevalent during early usability testing development [10] and are still worthy of consideration now.

A theme that we found and considered important to keep in mind concerning usability is that usability engineering can take place before, during, and after the development of an interface or software product [12]. Although there are different techniques that should be followed based on what stage of the lifecycle a product or software is in, proper usability implementation can take place at any time.

4. Results

4.1 Positive findings

Through testing the usability of the GIEP for effectiveness, efficiency, safety and learnability [19] several features of merit were found, as well as a few aspects that might benefit from revision. We will start with the compliments, discussing the features of merit that were found in the analysis, and then move on to the potential problem areas.

The results of the usability test revealed that the software application as a whole was considered by the users as being of high quality, scoring an average of roughly 4 out of 5. The GIEP demonstrated a respectable level of efficiency as well. Once learned, many of the operations required in the Test Instructions could be performed with only a very short set of steps. The system also uses shortcuts, or

accelerators, like 'drag and drop' for loading data and fully customizable key mapping, which speed up the system's operations for experienced users [14]. The accelerators that were used often by the participants were those consistent with popular commercial software applications, like the drag and drop function and a small handful of the preloaded key mappings. Most of the accelerators, however, were not used by the participants in this test, all first time users, due to the advanced nature of shortcuts in general.

Several elements within the program were observed by test administrators or cited by participants as contributing to system learnability, and were relied heavily upon by the participants to complete the usability test. Those elements were icons that are common or closely resemble their function, changes in the cursor when it moves over an entity that has a context sensitive (right click) menu available and scroll wheel for zooming, all of which exhibit good affordance and/or visibility, as well as external consistency with popular commercial programs. The feedback mechanisms, such as icons and entry selections that quickly change in color or shape when active or acted upon, that are designed into the GIEP dynamically reinforce user learning by affirming that the operation performed has had an effect [3]. Additionally, each particular type of feedback is consistent across all like functions. Internal consistency is also found in the series of steps required for like activities. The benefit of this form of consistency is manifest in the response of several participants as they moved from one Drawing and Annotation task to another. Successive operations of similar types were performed more quickly and with fewer errors.

Users will always make mistakes, especially during the steep initial ascent of learning [8]. For this reason, system constraints are necessary for learning and effectively using the system [15]. The GIEP tested employs system constraint methods like stippling out toolbars or functions that are unusable under the conditions and content sensitive menus that don't allow unusable selections to be shown. These constraints provide information while increasing system safety and learnability.

4.2 Specific issues

4.2.1 Popular commercial software:

The influential power of popular commercial software is enormous. In our usability test of a relatively unknown specialized software application, Microsoft (MS) Office and Google Earth appear to have significantly impacted user interaction. In no way do we assume that these two programs are the sole software applications that influenced user interaction with the GIEP; they are simply the most obvious and prominent. Methods used by the participants for basic display manipulation and tool operation were seemingly obvious to have been influenced by them, palpable in observed tendencies and explicit user comments.

For example, the preferred method of users for manipulating the geographic display was to use the scroll wheel when zooming. Four out of six participants used the scroll wheel "to zoom into [Iraq]" as the initial task required, just as they would if they were using the popular mapping and geospatial applications of Google Maps, Google Earth or NASA's World Wind. To place the observation in even more secure context, all of the participants were admittedly familiar with at least one of these applications. However, the GIEP's current default is set to make a bounding box in the geographic display that expands from the selected location and moves outward to zoom in. This method is not necessary inherently less intuitive than "pan" and scroll for zoom or manipulation, but the lack of external consistency between the default settings in the GIEP and those of popular commercial software applications resulted in frustration. A few users even commented, saying that the "zoom was a little tricky," and to "work on defaults, like mouse is always in pan rather than zoom."

The GIEP's use of familiar MS Office-like icons, such as those for functions relating to PowerPoint and Save, and other capabilities that follow a similar interaction method used in MS Office, like context sensitive menus, appear to have increased the ease of learning for some of the program's functions. Conversely, a lack of conformity with MS Office concerning a number of standard operations was found to be detrimental to the test participants' ability to

learn the GIEP and become comfortable with some of its operations. Most notable of the specific complaints, backed by observed interaction problems were a lack a working Undo function and the omission of a Toolbar menu allowing users to find, show and hide toolboxes/functions. The GIEP was also found wanton for the ability to attach the small toolbox windows to the side of the application. These problems are due to a lack of external consistency with MS Office for such things, which is essentially the de facto standard for them.

When all of the mentioned comments and observations are viewed as a whole, it makes one thing somewhat clear - the usability of the GIEP is directly related to popular commercial software. This can be either beneficial or detrimental to the learnability of the application, all depending on the development path of the application.

4.2.2 Acronyms:

The use of acronyms in the GIEP is a significant inhibitor to learnability, made very clear by the test results. A task requiring users to find the "Comment" in the Information window of any point on the screen resulted in the longest aggregated time for completion. Though this operation might take 7-10 seconds at most for an experienced hand, it took between 1:14 and 3:53 to complete for the test participants. Figure 1 shows that the total time for this extremely simple task consumed 17% of the total test time! Not a single participant was able to identify the specific sub-menu that should be used upon opening the fly-out (right click) menu, requiring all of them to open every single sub-menu to find the appropriate one. Interestingly the problem was very simple – the necessary menu was labeled "DA [XXX]" and none of the participants were aware that "DA" meant Drawing and Annotation. Visually displaying a function does not guarantee visibility; it requires that the senses be able to easily discover how a desired action is mapped to an actual operation within the program [16]. As found in the testing, acronyms don't work and can, in effect, make a function imperceptible to the user.

4.2.3 Icons:

Icons matter…a lot. Five of the six participants demonstrated a tendency to scan across any visible icons when they became confused. Therefore, it is reasonable to conclude that the appearance of icons and how well they resemble the operation that they symbolize, along with any associated tool tips, greatly impacts the learnability of a system. Reinforcing our observations, several users commented expressly on this topic, with one user suggestive of changing the Playback symbol "to a play symbol not a watch." The other participants were equally as frustrated and confused by the Playback icon. Four out of the six searched through the Tool Bar using the tool tip or looked through various menus in attempt to find the data playback tool, despite its prominent and visually obvious placement. The simple and quick task requiring the users to "play the data and set the playback speed" ended up with the fourth highest total test time because participants could not determine how to bring up the control (Figure 1). This situation is analogous to the issue with using acronyms, in that the inability for the user to intuitively link the desired action to the proper icon for the operation effectively makes it "invisible" [16].

4.2.4 Choosing words:

Every person has heard the adage "choose your words wisely," though it is usually associated with a scolding from parents. However, we have found that the choice of words can make a large difference in how a user perceives functions within a software application. In particular, the lack of specificity in using the word "Track" in several functions caused confusion in two out of six participants when they were asked to "draw a Polyline that traces the vehicle's path." Eliminating this type of confusion through more specific and precise wording is important in making the use of tools intuitive and reducing the learning time required for the GIEP.

4.2.5 Help:

Interestingly, only one participant chose to make use of the extensive and detailed Help tool that is built into the GIEP. It has proved to be serendipitous, however, because it reveals the

stark difference between a user that took advantage of the Help tool and all others. The participant using Help completed the test several minutes faster than other participants, reported some of the highest system satisfaction ratings and even praised as the tool as "excellent". The GIEP follows near textbook requirements for a Help tool [19] and the testing results show the powerful difference it can make for both learning and using a program.

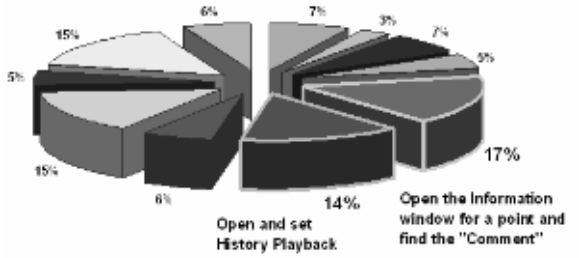

Figure 1. Percentage of Total Time per Task

5. Recommendations

Through a deep analysis and interpretation of the data collected from the testing process, we are presenting specific recommendations and guiding principles that we consider to be beneficial for improving usability throughout the GIEP. Each of the recommendations, from the overall guiding principle to the specific system modifications, takes into consideration the basic interaction design principles discussed earlier.

5.1 Top recommendation

The strongest recommendation that we feel should be made is to suggest that designers of specialized software applications, like those of the GIEP, should continuously monitor the software industry for emerging and evolving interaction trends present in widely popular commercial software applications and thoroughly consider such methods for adoption into their application. For the moment, Google Earth/Maps and MS Office appear to have the greatest influence on the GIEP, so their interaction methods for functions should be seriously considered. This is a general and enduring guideline, though it also affects some of the specific recommendations that we provide.

5.2 Consistency

Several of the interaction methods or system defaults should be aligned to be externally consistent with MS Office or Google Earth/Maps. The particular functions we consider as being in need of immediate correction are (1) creating an Undo function, (2) setting the geographic display default to "pan", (3) creating a Toolbars selection under the View menu that allows users to find, hide and show tools, and (4) allowing users to attach toolbox windows to the side of the application. The above list is given in order of priority.

People make mistakes; this is an inescapable reality. As a result, most popular software, including MS Office, has the capability to compensate for this by providing an Undo feature. Crafting a similar feature for the GIEP that allows for the departure from an unwanted state for the return to a prior one will eliminate the aggravation associated with being bound to a misstep. It can also prevent the data loss that occurs from having to delete out entire layers as a result of a simple mistake, contributing to greater system integrity [7].

In addition, the default setting in the GIEP for geographic manipulation should be set to "pan" to allow for the ability to click-and-drag along the globe and zoom in through use of the scroll wheel. This will replace the current default setting that uses an expanding bounding box to zoom into an area, which is not consistent with other geographic information systems. The shift toward greater consistency will allow for easier skill transfer, thereby reducing the amount of time needed for a user to learn how to operate the system [19].

It is important for users to quickly be able to understand the most basic comments and navigation options to assist them in locating wanted information [7]. This very issue was raised by our test participants and can be rectified to a great extent if the accessibility of tools and functions in the GIEP were consistent with MS Office. This can be corrected specifically by implementing a Toolbars menu that permits a "view/hide" selection feature and allowing available toolboxes to be attached to the side of the application. These two additions will alleviate some, if not all, of the frustration

and uncertainties expressed by the participants concerning tool access. It also reinforces the concept of making all options and actions clearly visible and/or easily retrievable at all times.

5.3 Wording

The exact syntax, word or arrangement of letters selected to describe or indicate an operation or option greatly impacts whether it is understood. Therefore, arrangements of letters composing abbreviations should not be permitted in the system, and features that use terms that can have multiple meanings should be modified to increase their precision. Consequently, the seemingly ambiguous abbreviation of "DA" in the "fly out" and "Options" menus that is used in place of the phrase Drawing and Annotation needs to be replaced with something like "Draw/Anno" or "Draw/Pt". This simple fix will eliminate an element in the system that caused five of the six test participants severe confusion. Also, the terms Track and Tracker should have the word "Auto" inserted in front of them to indicate that the tools are intended to initiate an automated process, not purposed to assist in manual tracking, as several participants assumed.

5.4 Icons

The usability test showed the affect that icons have on the ease of which a system and its operations are understood and learned. With simple corrections and purposeful attention to a couple of principles when making additional icons, future confusion and lost time due to the GIEP's icons should be prevented. When analyzing a program and determining the most user friendly construction, one cannot overlook the importance of checking that all icons and functions are precisely labeled and common images depict their functions when possible. The greatest guiding principle when making or changing icons is to make them as visible as possible – meaning users must have the ability to easily sense what function or operation the icon is mapped to [16]. When applying the concept to constructing or choosing an icon for the GIEP, the designers should apply or look for a mixture of identifiable articles and symbols that best encapsulates the most prominent parts of the action or function [17]. The need to do this pertains directly to the Playback icon, which caused so much confusion and lost time in the usability test. We recommend that the current stopwatch icon used for this function have the easily recognized "play button" overlaid on the lower right corner of it. Since the suggested modification is not a drastic change from the existing icon, it should allow existing users to identify the function while making it more intuitive for newer users to learn that the icon is associated with history playback for data.

6. Conclusion

The usability testing conducted on our selected geospatial intelligence exploitation program (GIEP) revealed some specific usability issues exclusive to the program itself. However, some of the lessons that were learned from the test results appear to have greater applicability to complex specialized software applications in general.

The commercial software applications that are wildly popular within the culture surrounding the GIEP significantly impacted user perception of the interaction methods associated with it. We consider this to be a potentially universal rule for specialized software applications. This means that for the sake of reducing learning time through skill transfer and increasing user satisfaction by following interaction methods that users are comfortable with, specialized software applications should seriously consider employing interaction techniques that are externally consistent with widely popular software products. Also, expending the necessary resources to develop quality icons that effectively map to their function appears extremely important for complex and specialized software applications. Due to the complicated operations of some systems that may not easily be related to the physical world, special attention should be given in attempting to use identifiable symbols or relatable articles to enable users to better sense the purpose of the icon. Lastly, we found the need for careful and precise selection of words and terms for tool tips and labels necessary to prevent confusion over the purpose of different tools and functions. We believe this

to be applicable to other systems that allow for a variety of complex but like functions that may be found in specialized software applications.

We have found all of these issues to be valid and true in this instance, and consider it reasonable to assume that they may be applicable to other complex and specialized software applications. In the least, we believe our findings to provide cause for further inquiry and study into the matter.

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Test Retest Reliability of Bone Conducted Speech Intelligibility Using the Callsign Acquisition Test

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Abstract

Bone-conducted radio communication research has received a lot attention in recent years as an alternative to the traditional air-conducted radio communication because they are lightweight, inconspicuous and allow radio communication without compromising the listener's awareness of his/her surroundings. An important measure of testing the validity of bone-conducted speech is the reliability of the test material. This study investigates the reliability of bone-conducted speech using the Callsign Acquisition Test (CAT). Two bone vibrator locations: mastoid and condyle, and two background noises: babble and white noise were used in this study. For each condition, three CAT tests were administered at three-day intervals. Results from the study indicate that the CAT is very reliable in measuring the intelligibility of bone conducted speech.

1. Introduction

Effective communication on the battleground is very crucial to the success of a military mission. Air conduction, a natural process by which sound waves are collected by the outer ear and transmitted through the ear canal to the inner ear for processing, has been dominant in the development of two-way radio communication devices. These systems use boom microphone and audio transmitters that occlude the ears of soldiers, which often compromise the awareness of their surroundings, potentially putting them in harm's way. To overcome this problem, bone conducted communication system can be considered. Bone conduction is the mechanical process by which sounds are transmitted from the cranial bones of the head to the inner ear without passing through the ear canal [1]. Bone conduction radio systems collect sounds through vibrations of the skull of the talker using a contact microphone and are transmitted through a bone vibrator attached to the skull of the listener. Bone conducted communication system has several advantages over the air conducted systems in military applications. The most important advantage is the improvement of situation awareness and the ability to localize ambient noise since the ears of the soldier will not be covered. In addition, the transducers in bone conducted communication systems are lightweight, inconspicuous, and can easily be integrated into military headgear.

The effectiveness of a communication system can be measured by performing speech intelligibility testing. Speech intelligibility can be defined as the percentage of speech units that is correctly identified by a listener over a given communication system in a given acoustic environment [2]. Simply put, speech intelligibility is the degree to which a listener understands a speaker's message. It is important for a communication system to have good speech intelligibility because reduced speech intelligibility can severely compromise communication and social interaction for

affected individuals. This could pose serious problems in military applications.

Traditional speech intelligibility tests were developed primarily for clinical diagnostic testing. Some commonly used tests include the Modified Rhyme Test (MRT), Diagnostic Rhyme Test (DRT), Northwestern University Test Number 6 (NU-6), Diagnostic Medial Consonant Test (DMCT) and Central Institute for the Deaf Test (W-22) among others. Since these tests often have poor validity in military settings, the Auditory Research Team (ART) of the Army Research Laboratory Human Research and Engineering Directorate (ARL-HRED) developed the Callsign Acquisition Test (CAT) specifically for military applications [3]. CAT consists of eighteen two-syllable military code words which were derived from NATO and the International Civil Aviation Organization standard word list (such as alpha, beta) and seven one-syllable digits from one to eight, except seven which is two-syllable. In all, there are 126 items in CAT. In addition, the CAT test has greater appeal among military personnel because it uses military code words familiar to soldiers and they are therefore more likely to respond correctly when these speech materials are presented [3]. A shorter version of the CAT with sixty items was developed by Gripper [4], and reported that the sixty-item list has the capability of providing the same predictive power as the full CAT test.

Before CAT can be applied in military application, it is necessary to assess its reliability. Reliability can be described as a measure of how much a person can *trust* the results of a test and can sometimes be viewed as 'repeatability' or 'consistency'. There are four major types of reliability: inter-rater reliability, test-retest reliability, parallel-forms reliability, and internal consistency reliability. Inter-rater reliability, also called inter-observer reliability, is used to evaluate the degree to which different raters provide consistent estimates of the same phenomenon and is especially important when the task is complex. When a phenomenon does not change between two different points of time, test-retest reliability can be used to evaluate the consistency of the same measure from one time to another or the degree to which the two measurements are related to each other. Parallel-forms reliability is used to evaluate the consistency of the results of two tests constructed in the same way from the same content. Internal consistency reliability, also called inter-item reliability is used to evaluate the consistency of results across items within a test. When multiple items are used to measure a single concept, inter-item reliability is the right choice.

Since the same dependent variables were measured at different times in this reliability study, the test-retest reliability was deemed the appropriate technique.

The intelligibility of bone conducted speech can be affected by many factors including bone vibrator placement, background noise and others [5, 6]. In a pilot study conducted by the authors to investigate the favorable locations on the head for optimum bone vibrator placement when administering the CAT, five locations (the forehead, temple, condyle, mastoid, and chin) were used for bone vibrator placement in the CAT test [5]. Five students from North Carolina Agricultural and Technical State University (NCA&T) were recruited to participate in the study. Results from this study was in agreement with an earlier study conducted by McBride, Letowski, and Tran [7] which investigated the sensitivity at eleven bone vibrator locations on the head using pure-tone signals. Both studies indicated that the condyle location (the bony protrusion in front of the ear) and mastoid location (the protrusion of the temporal bone behind the ear at the base of the skull) were the most favorable for bone vibrator placement. This study, therefore, chose both condyle and mastoid as the test location for bone vibrator. Another

reason of choosing these two locations is that both the condyle and mastoid are close to the ear, and therefore, it is possible for the ear to collect residual sound waves that might leak from the bone vibrator that is placed at these two locations. Similarly, both the condyle and the mastoid are located conveniently close to where the headgear rests, thus a bone vibrator could quite easily be incorporated into headgear. The two locations selected for the current research are shown in Figure 1.

Since background noise has a significant impact on the intelligibility of the bone conducted speech [6], babble (multitaker) and white (all frequency) were chosen as the background noise in this study.

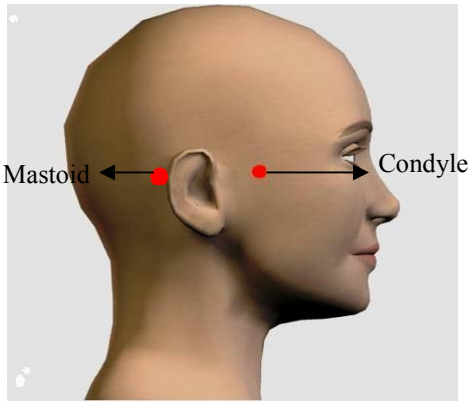

Figure 1. Condyle and mastoid location on the scull

The objective of this research was to assess the test retest reliability for bone conducted speech using CAT in different environments and investigate the impact of vibrator placement and background noise on speech intelligibility. Section 2 presents the methodology used for the study, Section 3 reports both subjective and objective results obtained from the study, while Section 4 discusses the experimental results and draws relevant conclusions from the study.

2. Method

2.1. Participants

Twenty undergraduate and graduate students 11males and 9 females, ages 18 to 35 (mean = 22.7 and standard deviation =3.2) enrolled at North Carolina Agricultural and Technical State University were recruited for this study. All participants were African Americans, a reflection of the fact that NCA&T is a historically Black University. All subjects in the study were required to (1) have a normal hearing defined by a threshold better than or equal to 20 dB HL (hearing level) at audiometric frequencies of 250 Hz to 8 kHz, (2) have the difference between the right and left ear thresholds to be less than 20dB to hearing symmetry (ANSI S3.6-1996). Audiometric screening was performed prior to each experiment, and involved standardized clinical equipment and procedures that complied with the ANSI S3.1-1991 requirements for audiometric testing under earphones. Test was carried out in a sound treated booth and only those volunteers who passed the audiometric screening were invited to participate in the study.

2.2. Stimulus material

The modified version CAT-60 with sixty test items was used in this study instead of the original CAT with 120 items.

Sound Forge 8.0 software was used to mix CAT-60 items at 80 dB SPL and background noise at 89 dB SPL to produce a signal-to-noise ratio (SNR) of –9dB. Sound level meter was used to accurately measure the sound intensity produced by the bone vibrator. Table 1 shows a sample of the sixty callsigns that were used in the experiment.

Table 1. Sample Callsigns

Alpha 1	Charlie 4	Hotel 1
Alpha 2	Charlie 5	Hotel 3
Bravo 2	Charlie 6	Hotel 8
Bravo 3	Charlie 8	Kilo 1
Bravo 8	Echo 2	Kilo 3

2.3. Equipment

The equipment used for this study included a Gateway Desktop Computer with a CD ROM drive, Sound Forge 8.0® Software, proprietary CAT software developed at the U.S. Army Research Laboratory to administer CAT items, Dell Desktop Monitor and Keyboard inside an acoustically treated sound chamber (Acoustic Systems 143 MC), step attenuator (Kay Elementrics 839 Attenuator), Radioear B-71 bone vibrator, a pair of Telephonics TDH-39 earphones, digital force gauge, headband, and calibration equipment (Larson Davis Precision Sound Level Meter Kit containing a(n) 824 Sound Level Meter, AMC 493 Artificial Mastoid, and Precision Acoustic Calibrator).

2.4. Experimental design

A 2x2 factorial design was used in this research. Two independent variables, background noise and vibrator location, were investigated. Background noise had two levels (white noise and babble noise), and location had two levels (condyle and mastoid). The dependent variable was listener's word recognition score, expressed as percentage of words, numbers, and word-number combinations (total callsign) identified correctly. Each of the 20 participants went through each of the four treatment conditions three times (see section 2.5 for details). The experiment was completely randomized to remove carry-over effect. The CAT items were randomly presented each time a participant took the test.

The following hypotheses were tested in this study: (1) the location of bone vibrator has no impact on speech intelligibility, (2) background noise has no impact on speech intelligibility, and (3) there is no interaction effect between location and background noise.

2.5. Procedure

All participants were briefed on the purpose of the research followed by verbal instructions and a chance for them to ask questions. All volunteers in the study were required to have normal hearing. Volunteers who passed the hearing evaluation were asked to read and sign consent forms in order to participate in the study.

It took each participant five days to complete the experiment. Day 1, 3, and 5 were test days while Day 2 and 4 were rest days.

On a test day, participants were seated at the listener's station in a sound treated booth in front of a Dell desk-top computer (that displays the CAT items) with keyboard for data input.

A bone vibrator was placed at the listener's condyle or mastoid and fastened in place with a headband (Figure 2).

Figure 2. A participant taking test with bone vibrator attached to condyle

A digital force gauge was used to measure the force exerted by the headband to ensure that adequate, but not unnecessarily high and uncomfortable force was applied to the head of the listener. For this experiment, a static force of

3.5N to 3.9N (to ensure consistency) was used in accordance with audiology related literature, which recommends that the static force applied by bone vibrator to the human head must fall within the range 2.5N (minimum required for stable position) and 5.9N (level of discomfort)[10].

Participants were asked to listen to incoming CAT items (displayed on the monitor in front of them) and identify them by pressing the appropriate keys on their keyboard. For example, if a listener heard the callsign "Quebec 3", the correct response would be to press the "Q" key, followed by the "3" key and then the "Enter" key.

Listeners were instructed to make their best guess if they were unsure of what they heard, because there was no repetition of signals and the next signal was not presented until a response to the current signal was given. A screen shot of what listeners saw on their computer screen while taking the test is shown in Figure 3.

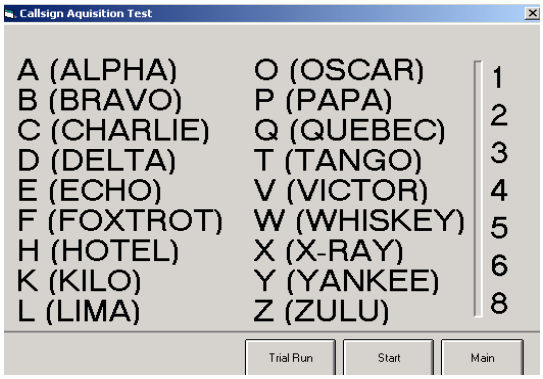

Figure 3. Screen shot of CAT items on participant's computer

At the start of the experiment, the experimenter clearly explained the procedure to participants and showed them how to enter their responses by running a trial. At the end of the trial, all questions were answered and the actual experiment commenced. Listeners' responses during the experiment were stored in a file and subsequently imported into an Excel spreadsheet for analysis.

2.6. Data collection

Both subjective and objective data were collected from this study. Subjective data such as demographic information and feedback was collected from pre-test and post-test questionnaires. Objective data was automatically collected using the software and included the percentage of correctly identified total callsign (TC), the percentage of correctly identified word (TW), and the percentage of correctly identified number (TN).

3. Results

3.1. Subjective data

The subjective data showed that most subjects (85%) felt wearing the bone vibrator with headband was comfortable; though most felt using it over a long period of time may be uncomfortable. The data also showed that most subjects (90%) preferred headphones over the bone vibrators. In terms of bone vibrator location, most subjects (90%) preferred the mastoid over the condyle.

3.2. Objective data

3.2.1. Descriptive statistics

Descriptive statistics such as mean and standard deviation of the data were summarized for each dependent variable for each of the experimental conditions in Tables 2-4.The notation "C-W" represents Condyle location with White background noise, "C-B" represents Condyle location with Babble background noise, "M-W" represents mastiod location with white background noise, and "M-B" represents mastoid location with babble background noise.

Table 2. Descriptive statistics for TN (in percentage)

	C-W	C-B	M-W	M-B
Test 1				
Mean	21.3	14.2	24	13.3
Std	7.01	8.1	8.5	7.4
Test 2				
Mean	24.5	17.7	25.7	16.5
Std	8.7	8.2	7.3	7.2
Test 3				
Mean	26.6	21.9	29.2	20.3
Std	8.2	8.2	7.6	7.2

Table 3. Descriptive statistics for TW (in percentage)

	C-W	C-B	M-W	M-B
Test 1				
Mean	28.1	19.7	30.6	20.2
Std	7.8	9.3	9.3	6.9
Test 2				
Mean	30.3	22.1	32.9	23.1
Std	9.4	9.1	9.2	8.7
Test 3				
Mean	32.5	25.7	36	28.3
Std	8.2	7.0	7.8	6.5

Table 4. Descriptive statistics for TC (in percentage)

	C-W	C-B	M-W	M-B
Test 1				
Mean	35.9	26.2	38.9	27.4
Std	7.9	10.4	7.5	9.7
Test 2				
Mean	38.2	29	40.7	30.1
Std	8.1	10.3	8.2	9.2
Test 3				
Mean	40.2	32.0	42.5	32.6
Std	7.3	8.7	6.1	8.1

3.2.2. Inferential statistics

Correlation analysis and the two-way Analysis of Variance (ANOVA) were used in this research. Correlation analysis was conducted to assess the test-retest reliability for each experimental condition on each of the three measures. Tables 5-8 provide the correlation matrix for the three performance measures (TN, TW, TC) on each of the four experimental conditions where T1-T3 represents the measurement at three different times. As stated earlier, each of the four experimental conditions was tested three times (every other day).

Table 5. Correlation matrix for C-W

TN			
r p value	T1	T2	T3
T1	1.000	0.71135 0.0004	0.77406 <0.0001
T2	0.71135 0.0004	1.000	0.85026 <0.0001
T3	0.77406 <0.0001	0.85026 <0.0001	1.000
TW			
r p value	T1	T2	T3
T1	1.000	0.72743 0.0003	0.73128 0.0002
T2	0.72743 0.0003	1.000	0.84102 <0.0001
T3	0.73128 0.0002	0.84102 <0.0001	1.000
TC			
r p value	T1	T2	T3
T1	1.000	0.87077 <0.0001	0.86712 <0.0001
T2	0.87077 <0.0001	1.000	0.96394 <0.0001
T3	0.86712 <0.0001	0.96394 <0.0001	1.000

Table 6. Correlation matrix for C-B

TN			
r p value	T1	T2	T3
T1	1.000	0.85774 <0.0001	0.93181 <0.0001
T2	0.85774 <0.0001	1.000	0.89990 <0.0001
T3	0.93181	0.89990	1.000

	<0.0001	<0.0001	
TW			
r p value	T1	T2	T3
T1	1.000	0.83652 <0.0001	0.87376 <0.0001
T2	0.83652 <0.0001	1.000	0.90348 <0.0001
T3	87376 <0.0001	0.90348 <0.0001	1.000
TC			
r p value	T1	T2	T3
T1	1.000	0.71512 0.0004	0.84853 <0.0001
T2	0.71512 0.0004	1.000	0.82716 <0.0001
T3	0.84853 <0.0001	0.82716 <0.0001	1.000

Table 7. Correlation matrix for M-W

TN			
r p value	T1	T2	T3
T1	1.000	0.81947 <0.0001	0.86680 <0.0001
T2	0.81947 <0.0001	1.000	0.84534 <0.0001
T3	0.86680 <0.0001	0.84534 <0.0001	1.000
TW			
r p value	T1	T2	T3
T1	1.000	0.70169 0.0006	0.69490 0.0007
T2	0.70169 0.0006	1.000	0.83553 <0.0001
T3	0.69490 0.0007	0.83553 <0.0001	1.000
TC			
r p value	T1	T2	T3
T1	1.000	0.67752 0.0010	0.72472 0.0003
T2	0.67752 0.0010	1.000	0.73739 0.0002
T3	0.72472 0.0003	0.73739 0.0002	1.000

Table 8. Correlation matrix for M-B

TN			
r p value	T1	T2	T3
T1	1.000	0.91260 <0.0001	0.87782 <0.0001
T2	0.91260 <0.0001	1.000	0.85073 <0.0001
T3	0.87782 <0.0001	0.85073 <0.0001	1.000
TW			
r p value	T1	T2	T3
T1	1.000	0.86776 0.0006	0.69687 0.0006
T2	0.86776 0.0006	1.000	0.64570 0.0021
T3	0.69687 0.0006	0.64570 0.0021	1.000
TC			
r p value	T1	T2	T3
T1	1.000	0.78456 <0.0001	0.50516 0.0231
T2	0.78456 <0.0001	1.000	0.79533 <0.0001
T3	0.50516 0.0231	0.79533 <0.0001	1.000

Clearly, results indicate that test retest reliability of the bone conducted speech intelligibility using CAT is very high as evidenced by the correlation coefficients in the matrices are very high.

Results of the two-way ANOVA revealed that no significant interaction effect between vibrator location and background noise on any of the three measures. No significant location effect was found on any of the measures as well. However, there was a significant effect of background noise for TC at all three times ($F(1,36)=16.26$, $p<0.05$, ($F(1,36)=17.01$, $p<0.05$, and $F(1,36)=16.91$, $p<0.05$ respectively). A significant noise effect was also found for TW (($1,36)=16.91$, $p<0.05$, ($F(1,36)=5.07$, $p<0.05$, and $F(1,36)=4.21$, $p<0.05$ respectively), and TN

((1,36)=19.03, $p<0.05$, ($F(1,36)=6.16$, $p<0.05$, and $F(1,36)=5.95$, $p<0.05$ respectively) at all three different times. This means that depending on the type of background noise used (i.e. white noise or babble), the TW correctly identified by participants was significantly different. In all situations, performance in babble noise background was significantly weaker than in white noise background.

4. Discussion and conclusion

The most salient finding of this research is that the test retest reliability of the bone conducted speech intelligibility using CAT is very high, indicating this test material is appropriate to use for speech intelligibility research. Results of this research again confirmed earlier finding that there was no statistical significantly difference between condyle and mastoid location for vibrator placement. This study also revealed that performance with babble noise background is significantly worse than with white background. Since the babble noise is closer to the situation in the battleground than the white noise, it indicates that laboratory research needs to use babble noise whenever possible instead of white noise as the background. Results from this research can be used to provide guidance in designing bone conducted communication systems for military applications.

5. Acknowledgement

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Employing Resources to Enhance Academic Advisement

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Abstract

The current trend of distance education has brought the need for efficient means of communication in the academic advisement process. This research determined the various business needs for communication through a number of channels between the Advisement Department and students within the School of Business and Industry (SBI) at Florida A&M University (FAMU). Our research introduces an three-phrase framework to facilitate the enhancement of the School of Business an Industry's current advisement and auditing system. Furthermore, this research proposes more efficient method to employ underutilized resources to become implemented to meet these business needs.

1. Introduction

In order to remain competitive it is advantageous for all businesses to incorporate the latest trends and technology into the products and or services they provide[1]. The education industry is no different; with distance learning comes new competition from schools anywhere in the world [2]. Due to the availability of new technology and the overwhelming trend of distance learning sweeping the globe it has become obvious that a functional system must be in place to allow students of the School of Business and Industry to submit information by electronic means. This information can be disseminated, processed, and stored for future use by advisors in a completely digital process as to allow students from any location to be advised. This research determined the various business needs for communication through various channels between the Advisement Department and students within the School of Business and Industry (SBI) at Florida A&M University (FAMU).

Furthermore, this research uses a framework to employ underutilized resources to meet these business needs as the current method requiring both student and advisor to physically meet with paper documentation is antiquated and outdated. In an effort to lay groundwork towards becoming a part of this new form of education a framework has been devised to facilitate the submission and process of information in a completely digital format. Our research discusses solutions for the Advisement Department and students within the School of Business and Industry. However, the design can be adopted to adjust to other FAMU department, colleges, and schools. This will also serve the purpose of allowing students to be audited through a completely digital system which can be accomplished by the two parties (student and advisor) no matter where each are located.

2. Overview

The Advisement Department within the School of Business and Industry works as a resource to assist students in enrolling in the proper courses needed for graduation. The problem currently facing the department is the inefficiency of its process for advising current students and its inability to effectively advise distant learning students. The key factors influencing the inefficiency of the process are the amount of hardcopy information collected on each student in individual student folders; to no fault of their own, the lack of knowledge of advisement capabilities on OurFAMU/iRattler, the new system for FAMU which allows students to register for classes, view transcripts and do other administrative work. Another key

factor includes the inability of communication between the advisement staff and distant students. These factors lead to the clear identification of project objectives 1) to assist SBI's Advisement Department with supplying the Office of Academic Advisement (General Studies) the updated course information to ensure the current OurFAMU/iRattler auditing tool executes correct auditing results for SBI students, and 2) to create a process that will proactively prepare SBI's Advising Department for future electronic advisement of students taking online and distance education courses offered by SBI. These objectives will enhance the system currently in place by enabling the department to communicate electronically with all students utilizing the OurFAMU/iRattler system, an online registration point for students. This will effectively open the doors of communication and reduce the number of hardcopies currently kept by the department. However, before the current system can be enhanced, the process of determining the best methodology suited for the task and the evaluation of options must be performed.

3. Methodology Review

Over the past 30 years organizations have found it beneficial to use a standard process incorporating a set of steps entitled systems development methodology [3]. Systems development methodology has been used to structure, plan, and control the process of developing an information systems. Various methodologies have been created and modified over the years to best suit the specific kinds of projects, based on varying technical, organizational, project, and team considerations. It is also known that one system development methodology is not necessarily suitable for use by all projects. This section provides an overview of the four commonly used methodologies.

3.1. Systems Development Life Cycle

The Systems Development Life Cycle or SDLC is a traditional methodology used to develop, maintain, and replace information systems [3]. SDLC is a series of six phases that direct a project from identification through maintenance of the completed application. While the process' phases can be completed chronologically, there are actually multiple methods for completing the process according to the nature of the project and organization [4]. A single cycle phase can be completed multiple times in a project until a desired result is achieved, in parallel with another step, or in a variety of ways consistent with the unique approach considered optimal for the specific project.

3.2. Joint Application Design

Joint Application Design (JAD) was created in the late 1970's by personnel at IBM in an effort to create a new process for collecting information system requirements and reviewing system designs [4]. The basic premise behind JAD is to bring structure to the requirements-determination phase of analysis. Key users, managers, and systems analysts of the current system are brought in to collect information from. This methodology is followed in hopes of allowing creators to hale all the key people together in one place at one time allowing them to see where there are areas of agreement and where there are conflicts. A JAD employs thousands of dollars of corporate resources, the most expensive of which is the time of the people involved.

3.3. Rapid Application Development

Rapid Application Development (RAD) is an approach to developing information's systems that allows for better, cheaper systems, and more rapid deployment by having systems developers and end users work together in real time to develop systems [5]. RAD is the result of two trends 1) the increased speed of business transactions in the late 1980's and early 1990's, and 2) the ready availability of high-powered computer based tools to support systems development and easy maintenance. RAD is becoming a highly popular option due to its fast, easy, development of e-business applications. The phases of RAD are broken down into

similar phases of SDLC but shortened and combined to produce a more streamlined development technique. These phases are broken into the following 1) Requirements Planning, 2) User Design, 3) Construction, and 4) Cutover.

RAD requires extensive user involvement and has similarities to the JAD sessions during the prototyping phase with the primary difference being that the RAD prototype becomes the basis for the new system. RAD is a close alternative to our choice of SDLC, but because of the high intensity of user involvement in development and the use of prototypes, SDLC became a more viable candidate.

3.4. Prototyping

Designing and building a scaled-down yet functional version of a desired system is known as Prototyping [6]. Prototyping can be built with any computer language or development tool, but special prototyping tools have been developed to simplify the process. With prototyping as a development technique, analysts work with users to determine basic requirements for the proposed system. The analyst then builds a prototype which the users work with and give feedback back to the analyst. The analyst then uses this feedback to edit/alter the system and the new system is then brought back to users to be re-evaluated. This process is repeated until users have a version they are satisfied with [7]. Advantages of this technique include the large amount of user feedback received which helps in the analysis and design of the final product and the methodologies ability to capture requirements in concrete form[8]. Prototyping is known to be extensively time consuming [9] and is prone very high resource use due to multiple re-formatting of a system based upon continuous feedback.

4. Framework Introduction and Overview

The Advisement and Auditing framework was developed to facilitate the enhancement of the current advisement and auditing system within the School of Business and Industry. The framework consists of three main phases, each with three sub-phases (Figure 1):

- **Project Identification**
  - Determine Need
  - Prioritize Need
  - Evaluate Resources
- **Analysis**
  - Create Objectives
  - Designated Duties/Create Timeline
  - Design
- **Implementation**
  - Create Prototype/First Draft
  - Test/Install
  - Maintain/Update

Project Identification is the first phase which the information systems needs are identified. This is achieved through three sub-phases; Determine Need, Prioritize Need, and Determining Resources. A thorough evaluation of the current system is conducted to addresses flaws, determine weaknesses, and discern any inabilities to meet the current needs. Needs are then prioritized by importance and resources are evaluated to determine the availability of each when accomplishing the established goals.

Analysis is the second phase which proposed goals are turned into objectives that must be met by completion of the project. The three sub-phases include Create Objectives, Designate Duties/Create Timeline, and Design. Once the project objectives are created the designation of duties are carried out by members of the creative team. In addition, a timeline for their completion is established followed by a thorough study and analysis of the current system. With the created objectives and understanding gained from analysis of the current, a design of the system is formulated according to the needs of the client(s). Deliverables such as Data Flow Diagrams, Entity-Relationship Diagrams, and Structured English are created to assist in the design of the system and give a visual representation of the flow of information between each process [10].

Implementation is the third and final phase of the framework. In this phase information is coded, tested, installed, and supported. The three sub-phases are Create a Prototype/First Draft, Test/Install, and Maintain/Update. During implementation, system specifications are turned into a working system that is tested and put into use. Maintenance/Updating is the last sub-phase where programmers make changes that users request. The system is then modified to reflect the changing business conditions. Essentially, this phase is where the information system is methodically repaired and improved. After implementation, an assessment will take place to evaluate the success of the project. Surveys will be released seeking feedback and opinions of end-users and other involved individuals concerning the system. This information is vital in maintaining and improving the system.

5. Results

The Fall 2008 Systems Theory and Design class was given the task of improving the current auditing tool utilized by SBI's Advising Department to ensure that it is being used with maximum efficiency. Objective one of the project was to assist SBI's Advisement Department with supplying the Office of Academic Advisement (General Studies) the updated course information to ensure the current OurFAMU/iRattler auditing tool executes correct auditing results for SBI students. Objective two was to create a process that will proactively prepare SBI's Advising Department for future electronic advisement of students taking online and distance education courses offered by SBI.

The class was divided into groups and formulated a framework to improve the current SBI advisement and auditing system. Groups utilized the framework and within the Project Identification Phase were as innovative as possible to determine the best needs for the Advisement Department. Within the Analysis Phase interviews were conducted with the advisement staff to devise goals, formulate ideas to address both objectives on how to employ underutilized resources, and ultimately create a fully electronic advisement process. Project Managers for each team were assigned the responsibility of reviewing all deliverables, such as the Statement of Project Scope, the Baseline Project Pan, Data Flow Diagrams, Entity-Relationship Diagrams, and Structured English. These documents were then given to the project sponsor for approval before submitting to the client. A Project workbook was established for each group to document all deliverables. A milestone timeline was created to ensure progress of the creation and implementation of the proposed system was on track.

Multiple views of the system were created and depicted through the use the aforementioned Data Flow Diagrams, Entity-Relationship Diagrams, and Structured English. The Data Flow Diagrams (Figure 2) graphically depict the systems targeted flow of information through each process with the new modifications employed. The Entity-Relationship Diagrams indicate the relationship between involved portions of the system. Structured English displays the actual tasks to be performed with a process (Table 1).

The final phase of the framework, entitled the Implementation phase, turned the project specifications into a working system. In addition, the Advisement Department's staff currently receives weekly hands-on training on how to function and properly utilize the enhanced version of the system. Additional enhancements include installing functionality that will allow the staff to view multiple interfaces. The Advisement Department staff will also be trained on how to utilize these options.

6. Conclusion

This paper introduces a three-phase advisement and auditing framework created to identify, analyze, and implement an enhanced system for the Advisement Department within the School of Business and Industry. The project's goal included determining the necessary tools, process, or procedures to

expedite, simplify, and standardize the academic advisement process to ultimately add value to the users of the academic advisement tool. In doing so, the system provides students and advisors with the most accurate and up-to-date information during the advisement process. A standardized and simplified system will enhance productivity in the advisement office, which allows advisors to provide more specialized service to students.

The project brainstormed many issues that addressed the internal advisement structure of SBI, identified discrepancies within the system and offered system improvements. In addition, strides have been taken to provide remote advisement for students taking SBI distance education courses. This enhanced system can ultimately be adopted in other FAMU department, colleges, and schools.

7. Future Work

The Advisement Department within the School of Business and Industry not only desires to facilitate the submission and process of information in a completely digital format, but aspire processes to become fully automated as well. Future work includes additional training for the Advisement Department staff to utilize additional enhancements that will allow the staff to view multiple interfaces. This is currently taking place. Additional functionality will also need be installed to assist advisement for students taking online and distance education courses offered by SBI who may never physically come to campus. The system will need to authorize communication between advisor and student no matter where each are located. The Advisement Department within SBI plans to work with the university's Enterprise Information Technology (EIT) department to include these enhancements and then adopt to other university department, colleges, and schools.

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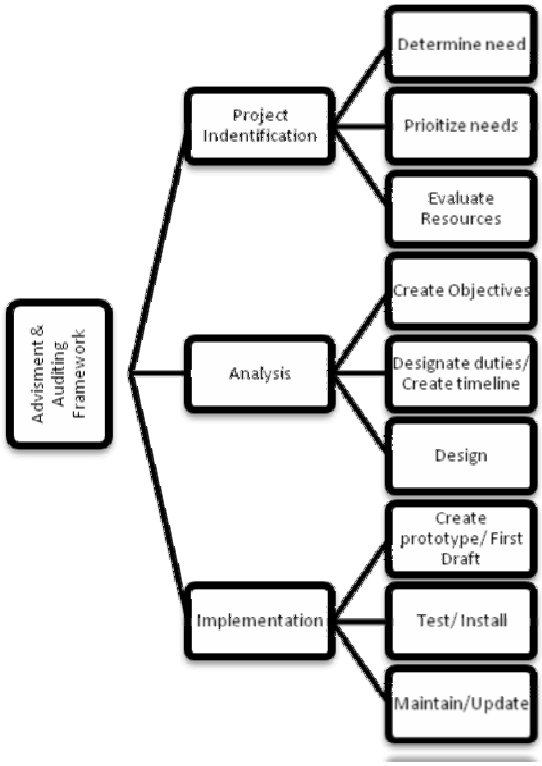

Figure 1. Advisement and Auditing Framework

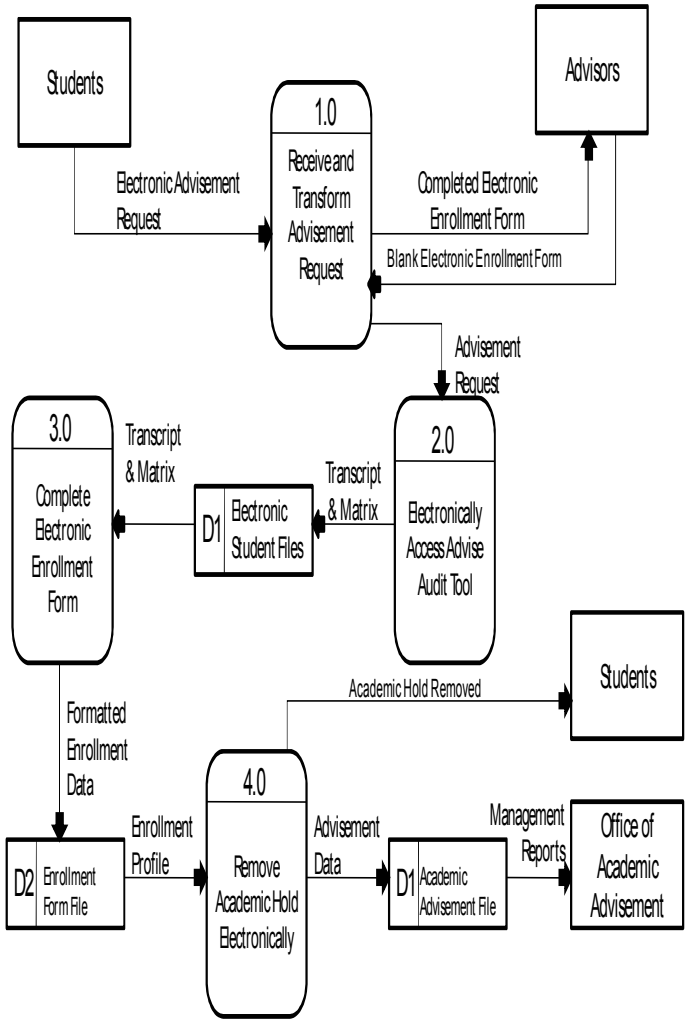

Figure 2. Level-0 DFD proposed system for objective #2

Table 1. Objective 2: Structured English for proposed system
Process 1.0: Receive and Transform Advisement Requests DO READ next Electronic Advisement Request MERGE Blank electronic enrollment form CREATE Completed electronic enrollment form to Advisors MOVE Advisement Request END DO
Process 2.0: Compare matrix with Transcript DO READ Advisement Request GENERATE transcript and matrix ADD Electronic Student Files END DO
Process 3.0: Complete Enrollment Form DO READ and COMPARE Transcript and matrix GENERATE Formatted Enrollment data ADD Enrollment form file END DO
Process 4.0: Remove Academic Hold DO FIND Enrollment form file READ Enrollment Profile GENERATE Advisement Data ADD Academic Advisement File GENERATE Academic Advisement Report SUBTRACT Academic Advisement Hold END DO

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Production Cost Using the Pascal Distribution

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Abstract

Several models for calculating production yield with a rework cycle have been proposed, using one type or another of probability distributions, to describe this type of production process. One such model assumes an infinite number of rework cycles and a binomial distribution. There are obviously some limitations to such a model. In this paper a different sort of model is derived in which the probability distribution describing the production process is assumed to be a Pascal, and the number of rework cycles can be terminated at any value. This equation relates production yield to the number of initial units of raw material and the number of rework cycles. This equation is then used to derive a new equation for unit production cost. This article contributes to the existing literature by providing a more realistic approach to the problem of production rework economics, and one which has more practical value.

1. Introduction

For production systems producing relatively large numbers of units in a single lot, using a stable manufacturing system, quality sampling at the manufacturing site is performed relatively less frequently until sampling reveals that a quality problem has developed. In such production situations, it is also the case that quality sampling is often deferred until the time of shipment of a lot, at which time a sample is drawn to assess the quality of the lot. In such production situations, when the probability of producing a defective unit is low, it is desirable to know how many production units must be started in order to reasonably expect to have an adequate number of good units to satisfy a given production quota. Further, as Chase, Jacobs and Aquilano (2006) point out, it is possible to calculate the cost of defectives at which it is economically justifiable to perform 100% inspection In such cases, it is desirable to size the production run such that it has a high probability, say 95% or 99%, of satisfying the required production quota. Also, in such cases it has been generally assumed that the production process is best described by a binomial distribution as discussed by Nevins and Whitney (1989). However, there are some serious problems with this assumption. These are discussed in the "Methodology" section below.

Although the economics of rework pose a very significant production problem, most prior research deals with the issues of production remanufacturing in various contexts. For instance, Flapper (2002) has performed a survey of the planning and control of rework in the process industries. Also, Lund (1998) and Majumber (2001) discuss the fact that remanufacturing accounts for a very significant portion of the business volume in the United States. Further, Nasr (1998) concludes that remanufacturing employs a very significant number of workers in the United States. This paper takes an analytical approach to choosing rework processes so as to minimize the cost of rework. Inderfurth and van der Laan (2001) have analyzed the relationship between lead-time and stochastic inventory control in remanufacturing. Similarly, Tang and Grubbstrom (2005) have dealt with stochastic lead times and deterministic demands in the issue of manufacturing/remanufacturing with returns. While that paper does not specifically deal with the issue of rework, the model used (pg. 286) is similar to the model developed later in this paper. Flapper and Teutner (2003), and

Inderfurth (2003, 2005) have analyzed the issue of rework when the units undergoing rework suffer deterioration before rework occurs. The latter Inderfurth paper is aimed at cost minimization with deterioration. Also, Lindner, (2001), Flapper (2003) and Inderfurth, (2003) have addressed the issue of planning and control problems introduced by rework when the normal production units and the units to be reworked use the same production equipment.

Abdel-Malek and Asadathorn (1996) have analyzed the problem of process planning with rework. Using the specified tolerance limits for products, the order of processes for rework is analyzed so that rework is achieved at minimum cost. However, the focus of that paper is to determine the most cost effective process(es) for reworking defective units to bring them within the required tolerance limits.

In summary, a survey of the available literature indicates that while some research has been done in the area of rework, none has investigated the role played by the assumed distribution in describing the effect upon the production process when unlimited rework is included.

2. Methodology

The production cycle with rework upon which the paper is based is shown in Figure 1. In figure 1, it is assumed that "N" units of material are started through the production process, "M," which has a capability of "c." As each unit undergoes the production process, it is tested. Some of the units processed, "c*N," will be found good, and contribute toward satisfying the required production yield "Y." However, some number of these units, "(1-c)*N will be found defective. Of these units, some will be found to be reworkable, "(1-c)*N*w, while others, "(1-c)*(1-w)*N," will have to be scrapped. Thus, "Y" is comprised of those units that are initially good, and those that can be successfully reworked, after a number of "p" rework cycles.

It has been shown elsewhere by Sutterfield and Nkansa (2006) that for a required production yield of "Y," and permitting "p" passes through the rework cycle, the number of units "N" that initially must be started is expressed by equation 1) …

1) Equation

where the variables are defined as above. To summarize, in order to arrive at a production quota or yield of "Y," using a production process with a capability of "c," after "w" passes through the rework cycle, it is necessary initially to start "N" units. It should be noted that if "M" were perfect, viz, that "c," the capability of "M," were equal to 1, "N" would be equal to "Y." Thus, if the production process were perfect, it would be necessary to start only "N" units through to arrive at a production quota of "Y." On the other hand, if c = 0, "N" would have to be infinite to achieve a production quota of "Y." To put it a bit differently, if "c" were equal to zero, no number of rework passes, "p," would be sufficient to comply with the required production yield. Next, we define the additional symbols to those introduced above.

G – Cost of realizing one good unit from the manufacturing process - $/unit

R – Cost of reprocessing one re-workable defective - $/unit

TPC – Total cost of manufacturing a production lotsize of "Y" units - $

UPC – Unit production cost for lotsize "N" - $/unit

Then using a mathematical approach almost identical with that used to develop Equation 1 (Sutterfield, et al, 2006) Equation 2 was derived for total production cost.

2) Equation

Next, the nature of the production process itself is considered. Since there are only two possible outcomes for a reworked unit, either pass or fail, the production process can be characterized as involving what are known as

Bernoulli trials, that is, a process that produces only one of two possible outcomes. The best known example of a Bernoulli process is that of flipping a coin: Here the outcomes are either "heads" or "tails," two and only two possible outcomes. In the case of the production process, each outcome is either "pass" or "fail." It might be tempting to use the binomial distribution to describe the production process, but this would entail some problems. One is that the use of the binomial involves performing a fixed number of repetitions, "k," and calculating for the fixed number of repetitions the probability of the desired outcome "r." However, for reasons to be discussed below, the Pascal distribution is chosen instead, as shown in Equation 3:

3) Equation

What is desired for our application is a probability distribution to describe the production process in which "r" is fixed, and "$k \geq r$" in order to satisfy the requirement for "r" successes in "$k \geq r$" trials. It should here be pointed out that the "r" required successes corresponds with the required production yield, "Y." With the Pascal distribution, it is assumed that "k-1" repetitions have been performed resulting in "r-1" successes. The probability is then calculated of obtaining the "r^{th}" success, i.e. the production yield of "Y," on the "k^{th}" repetition. It will be seen that with the Pascal distribution, the fewest number of repetitions required to obtain the production yield "Y," i.e. "r," is "k" repetitions. The probability of achieving the required production yield in fewer than "r" repetitions is then zero. This feature of the Pascal distribution removes one of the objections to the Binomial distribution. Now it can be shown that for the Pascal distribution the expected value is …

4) Equation

Since the Pascal distribution is not so well known as the Binomial and other distributions, the derivation for both the expected value and the standard deviation of the Pascal are shown in the Appendix. It was pointed out above that with the Binomial distribution, the number of *trials* is fixed and the probability of some number of successes calculated. By way of contrast, with the Pascal distribution the required number of *successes*, "r," is fixed and the expected number of trials required to achieve these successes is calculated. It can be seen, then, the required number of successes is equivalent to the required production yield, "Y." Adapting Eq. 3 for our purpose by setting "Y" equal to "r," we obtain …

5) Equation

Now returning once again to Eq. 2, it will then be seen that it contains the term "c*N." Thus, Eq. 2 is really an expression for the number of units, "N" that must be started through the production process "M" as a function of the expected number of Pascal repetitions. Thus, Equation 2 can be written in the following form:

6) Equation

Equation 6 then becomes an expression for the TPC as a function of required production yield, "Y," the initial processing cost, "G," the re-work cost, "R," the process capability, "c," and the number of trips through the re-work cycle, "p."

It will be seen that if the process capability c = 1, that Equation 6 reduces to Y = N. This is to say that for a perfect process, viz, one in which c = 1, that the yield "Y," for the process would equal "N," the number of units initially started through the production process. However, since Eq. 1 is in a more convenient form for our purposes, we shall use it in the subsequent development. Next, we turn to the issue of unit production cost.

Now, if "M" were perfect, no defectives would be generated in the manufacturing process and the cost of manufacturing a lotsize of "N" units would be …

7) Equation

Then, the UPC for manufacturing a lot-size of "N" units would be …

8) Equation

But for a perfect process, the yield, "Y" is equal to the number of units passing through the manufacturing process, "N," so that the unit production cost simply reduces to "G," or for the perfect case …

9) Equation

Referring to Figure 1 once again, when a manufacturing process is less than perfect (the real world), it generates defectives. In Figure 1, these are indicated as "(1-c)*N." Of the units found to be defective, some will be re-workable, as indicated by "(1-c)*w*N," and some will not be found re-workable, as indicated by "(1-c)*(1-w)*N." Then the total cost of producing a lot-size of "Y" units with a *single* re-work cycle is …

10) Equation

Further, the unit production cost for a *single* re-work cycle is …

11) Equation

where Equation 10 expresses the total cost of producing a lot-size divided by the yield, "Y," the actual number of good units obtained after a single re-work cycle. Now, Equation 11 can be rewritten as …

12) Equation

Now dividing both sides of Equation 2 by "Y," and noting from equation 5 that Y = c*N, we obtain the unit production cost for a manufacturing operation described by a Pascal distribution …

13) Equation

Thus, we have an equation to describe unit production cost for a manufacturing process described by a Pascal distribution for any number of re-work cycles. Once again, it will be seen that for a perfectly capable process, i.e., c = 1, the unit production cost, UPC, Equation 13 reduces to yield simply "G." On the other hand, if the process were perfectly incapable, c = 0, the UPC becomes significantly larger than the initial production cost "G.".

3. Application of Methodology

Using Equation 13 from above, Table 1 was constructed with model parameters set as indicated in table 1.

The ranges of values chosen for analysis were rather arbitrary, having been chosen in ranges that are fairly inclusive for most production operations, and which would demonstrate the model. However, the model is perfectly general, and a user might employ it over any range of values that might be found desirable. For any given production operation the initial production cost and the re-work cost would be known. Consequently, the model could be further generalized by expressing the re-work cost as a fraction of the initial production cost, i.e., R = c*G, where "c" is a proportionality constant. The data from Table 1 are shown in Figure 2.

As would be expected, if a production unit undergoes only one pass through the production cycle, it is implied that the UPC will equal the initial production cost "G." It was also stated above that as the capability of the Pascal process approaches unity, the unit production cost approaches the cost of initial production. Further, it was noted that as the process capability approaches zero, the unit production cost grows significantly larger than the initial production cost. Both Table 1 and Figure 2 bear out these statements. For the data used in the Pascal re-work cycle model, at low process capabilities the upper limit on the number of re-work cycles is approximately three. This is because at these process capabilities the marginal unit production cost of the third to fourth re-work exceeds the cost of a single rework cycle. However, for higher process capabilities, additional re-work cycles would be feasible because the marginal unit production cost of additional re-work cycles would be less than the cost of a single rework. In general, this type of analysis can be used to determine when

it is economically infeasible to perform additional re-work cycles. Interestingly enough, the analysis indicates that the more capable the Pascal re-work production cycle, the more re-work cycles that would be economically feasible before the marginal cost is exceeded; but the more capable the process, the less probable that re-work would be required.

However, another and perhaps more important purpose for which this type of analysis might be used is that of deciding when it is cost effective to replace an existing piece of production equipment. Returning once again to Table 1 and Figure 1, suppose that a machine originally were operating at a capability of approximately c = 1. As the machine were operated over a period of years, its capability would gradually deteriorate. If the machine capability were to deteriorate to say c = 0.9, one to two re-work cycles occasionally would be required to satisfy a production quota. These re-work cycles would entail a marginal unit production cost increase of approximately $3.18. Using this marginal cost, along with a production schedule, would make it possible to perform a cash-flow analysis, along with a capital recovery analysis to determine the best time to replace an existing piece of production equipment.

4. Conclusions

In the foregoing analysis, Equation 1 was employed from Sutterfield and Nkansa (2006) for the relationship between the number of units that must be started through a production process and some required production yield. Next, through a similar mathematical development, Equation 2 was derived, which provides a relationship for Total Production Cost as a function of process cost, process capability, and the number of rework cycles. Upon Equation 2, was imposed equation 5, which the required that the production process be described by the Pascal distribution. This resulted in Equation 13 for Unit Production Cost (UPC) for a production process described by a Pascal distribution. This relationship is general, being valid for any required yield, any machine capability and any number of rework cycles. Although the yield would be set by a production contract and the machine capability by the general condition of the machine, the number of rework cycles, viz, the number of times the correction of a defective unit might be attempted, would be set by company policy.

To illustrate the practical use of Equation 13, illustrative values were assumed for initial production and re-work cost, and with this the values in Table 1 were calculated. These values were then plotted as shown in Figure 2 for UPC as a function of process capability. The model was parameterized in *EXCEL* to facilitate easy variation of the model variables. As indicated by Figure 2, and as pointed out earlier, as the process capability approaches zero, the UPC exceeds three times the initial process cost "G." Intuitively, it would seem that if the process capability were to approach zero that the UPC would grow without bound. This is in fact true, and the foregoing results, for this reason, are somewhat illusory. This is because as the process capability approaches zero, the probability of finding a good unit to re-process approaches unity. Thus, it will be seen from Equation 13, that as "c" approaches zero and "w" approaches unity and consequently, the UPC indeed will grow without bound. However, because the exact nature of the relationship between "c" and "w" is unknown, this consideration has not been taken into account in the analysis. Aside from this consideration, Equation 13 precisely describes the relationship between UPC and the other model variables.

Finally, an important practical analysis for which the foregoing model might be used is that of deciding just when a given piece of production equipment might be appropriately replaced. As the process capability decreases, the marginal UPC increases, because of the need to send more units through the re-work cycle. Using a production schedule with the incremental UPC, a discounted cash-flow analysis could be performed to determine when it would be cost effective to purchase a new piece of production equipment. This sort of analysis could also be used to determine when it

might be cost effective to re-condition a piece of production equipment. This type of analysis is anticipated for a future article.

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6. Figures, Tables and Equations

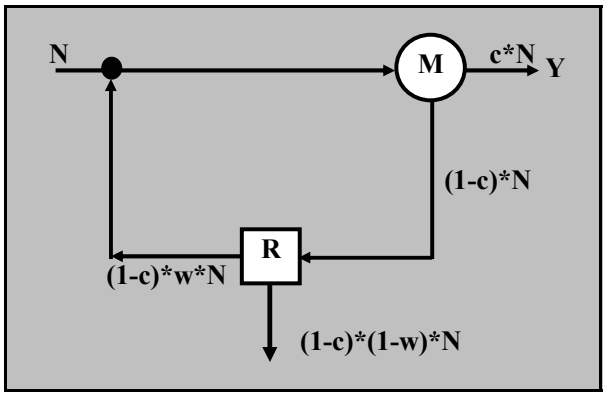

Figure 1: Production Cycle with Rework

The model variables are defined as follows:

N – number of units required to realize a production yield of Y, where N ≥ Y
M – Manufacturing and testing process
R – rework cycle
c – capability of process
Y – required production yield
w – fraction of rejected units that can be reworked
p – number of passes through the re-work cycle

Table 1: Unit Production Cost for Pascal Re-work Cycle

G = $100 **p = 2**

R = $50 **p = 3**

w = 0.6 **p = 4**

Unit Production Cost (UPC) - $/unit

c	p =2	p =3	p =4
0.00	-----	-----	-----
0.10	127.00	141.58	149.45
0.20	124.00	135.52	141.05
0.30	121.00	129.82	133.52
0.40	118.00	124.48	126.81
0.50	115.00	119.50	120.85
0.60	112.00	114.88	115.57
0.70	109.00	110.62	110.91
0.80	106.00	106.72	106.81
0.90	103.00	103.18	103.19
1.00	100.00	100.00	100.00

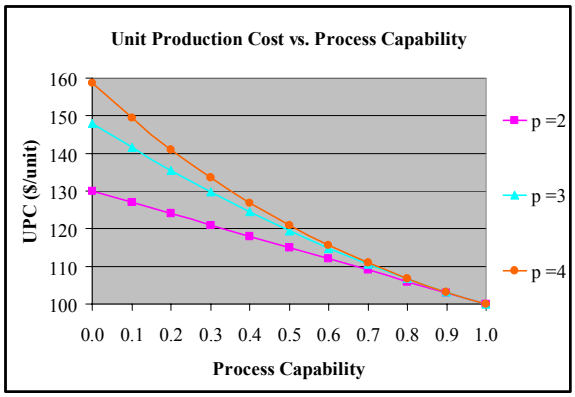

Figure 2: Unit Production Cost for Pascal with Rework

7. Appendix

The derivations of the mean and standard deviation for the Pascal distribution are not easy to find in texts on probability and statistics. As a matter of fact, in a survey of several such books, the Pascal distribution, or Negative Binomial as it is sometimes called, was not even shown. For the interested reader the mean and standard deviation of the Pascal are derived here. We begin by demonstrating that the Pascal is indeed a valid probability distribution. The Pascal distribution is defined as …

$$1)\quad p(X=k)=\left(\frac{k-1}{r-1}\right)*p^{r}*q^{k-r}$$

where $q = 1 - p$

and $k \geq r$

Now, in order for Eq. 1 to be a valid probability distribution …

$$2)\quad Sum=\sum_{k=r}^{\infty}\left(\frac{k-1}{r-1}\right)*p^{r}*q^{k-r}=1$$

Now, Eq. 2 can be rewritten as …

$$3)\quad Sum=p^{r}*\sum_{k=r}^{\infty}\left(\frac{k-1}{r-1}\right)*q^{k-r}$$

But …

Intermediate equation (see below)

So that Eq. 3 can be written as …

$$Sum = p^r * (1-q)^r = 1$$

Thus, QED, the Pascal is indeed a valid probability distribution.

Next, we derive the equation for the expected value of a Pascal distribution. The expected value, EV, for a Pascal distribution is written as …

4) $$EV(X) = \sum_{k=r}^{\infty} k * \left(\frac{k-1}{r-1}\right) * p^r * q^{k-r}$$

But Eq. 4 can be written as …

5) $$EV(X) = p^r * r * \sum_{k=r}^{\infty} \left(\frac{k}{r}\right) * q^{k-r}$$

As with the proof above, the quantity under the sum can be written as …

$$\sum_{\mathbf{k=r}}^{\infty} \left(\frac{\mathbf{k}}{\mathbf{r}}\right) * \mathbf{q}^{\mathbf{k-r}} = \frac{1}{(\mathbf{1-q})^{\mathbf{r+1}}}$$

Thus, Eq. 5 can be written as …

6) $$EV(X) = r * p^r * \frac{1}{(1-q)^{r+1}} = \frac{r}{p}$$

And the expected value of the Pascal is then shown to be the required number of successes, "r," divided by the probability of a success, "p."

Turning to the variance for the Pascal distribution, the variance is defined as …

7) $$Var(X) = E(X^2) - [E(X)]^2$$

The first term of the variance expression, $E(X^2)$, is written as …

8) $$E(X^2) = \sum_{k=r}^{\infty} k^2 * \left(\frac{k-1}{r-1}\right) * p^r * q^{k-r}$$

In order to obtain a form for Eq. 8 that is tractable to simplification, we rewrite it in the following form:

9) $$E(X^2) = r * \sum_{k=r}^{\infty} \frac{k^2}{r} * \left(\frac{k-1}{r-1}\right) * p^r * q^{k-r} = r * p^r * \sum_{k=r}^{\infty} k * \left(\frac{k}{r}\right) *$$

Next we modify Eq. 9 as follows:

10) $$E(X^2) = r * p^r * \sum_{k=r}^{\infty} \left\{ k * \left(\frac{k}{r}\right) + \left(\frac{k}{r}\right) - \left(\frac{k}{r}\right) \right\} * q^{k-r}$$

Now we combine the first two terms under the sum, and at the same time multiply numerator and denominator by "r+1." This results in the following:

11) $$E(X^2) = r * p^r * \sum_{k=r}^{\infty} \left\{ \frac{r+1}{r+1} * \left(\frac{k+1}{r}\right) - \left(\frac{k}{r}\right) \right\} * q^{k-r}$$

Consequently,

12) $$E(X^2) = r * p^r * \left\{ (r+1) * \sum_{k=r}^{\infty} \left(\frac{k+1}{r+1}\right) - \sum_{k-r}^{\infty} \left(\frac{k}{r}\right) \right\} * q^{k-r}$$

Operating upon the first summation, we can write it as …

13) $$Sum = r * p^r * (r+1) * \sum_{k=r}^{\infty} \left(\frac{k+1}{r+1}\right) * q^{k-r}$$

Intermediate equation (see below)

Now, the term in the square brackets can be shown to equal "$(1-q)^{-(r+2)}$," and as a result …

14) $$Sum = r * p^r * \frac{(r+1)}{(1-q)^{r+2}} = r * \frac{(r+1)}{p^2}$$

Referring to Eq. 6, it will be seen that the second summation in Eq. 12 equals the expected value, EV(X). Thus, Eq. 12 simplifies to …

15) $E(X^2) = \frac{r*(r+1)}{p^2} - \frac{r}{p}$

Substituting Eqs. 6 and 15 into Eq. 7 results in …

16) $Var(X) = \frac{r*(r+1)}{p^2} - \frac{r}{p} - \left(\frac{r}{p}\right)^2$

Simplifying Eq. 16 we obtain for Var(X) …

17) $Var(X) = \frac{r*q}{p^2}$ again where $q = 1-p$

There are at least two other approaches known to the authors for obtaining these results for the expected value and the variance of the Pascal: The first is to consider the Pascal as the sum of "k-1" Geometric series, each series being terminated by a single success; the second is to use a moment generating function approach. Both approaches arrive at the same results as those above. The skewness and curtosis of the Pascal distribution, the third and fourth moments respectively, could also be obtained using any of the above methods.

Equations from Article

Equation 1)

$$Y = \frac{N * [1 - (1 - c)^{p} * w^{p}]}{c * [1 - (1 - c) * w]}$$

Equation 2)

$$\mathbf{TPC} = \frac{\mathbf{c * N * \{(G - R) * [1 - (1 - c) * w] + R * [1 - (1 - c)^{p} * w^{p}]\}}}{\mathbf{1 - (1 - c) * w}}$$

Equation 3)

$$\mathbf{P(X = r)} = \left(\frac{\mathbf{k - 1}}{\mathbf{r - 1}}\right) * \mathbf{c}^{\mathbf{r}} * \mathbf{(1 - c)}^{\mathbf{k - r}}$$

Equation 4)

$$\mathrm{E(k)} = \frac{\mathrm{r}}{\mathrm{c}}$$

Equation 5)

$$\mathrm{E(k)} = \frac{\mathrm{Y}}{\mathrm{c}}$$

Equation 6)

$$\boldsymbol{TPC} = \frac{\boldsymbol{Y} * \{(\boldsymbol{G} - \boldsymbol{R}) * [1 - (1 - \boldsymbol{c}) * \boldsymbol{w}] + \boldsymbol{R} * [1 - (1 - \boldsymbol{c})^{\boldsymbol{p}} * \boldsymbol{w}^{\boldsymbol{p}}]\}}{1 - (1 - \boldsymbol{c}) * \boldsymbol{w}}$$

Equation 7)

$$\mathrm{TPC} = \mathrm{N} * \mathrm{G}\ (\$)$$

Equation 8)

$$\mathbf{UPC} = \frac{\mathbf{N * G}}{\mathbf{Y}}$$

Equation 9)

$$\mathbf{UPC = G}$$

Equation 10)

$$\boldsymbol{TPC} = \boldsymbol{N} * \boldsymbol{c} * \boldsymbol{G} + (1 - \boldsymbol{c}) * \boldsymbol{w} * \boldsymbol{N} * \boldsymbol{R}$$

Equations from Article (cont'd)

Equation 11)

$$\mathbf{UPC} = \frac{\mathbf{N * c * G + (1 - c) * w * N * R}}{\mathbf{Y}}$$

Equation 12)

$$\mathbf{UPC} = \frac{\mathbf{N * [c * G + (1 - c) * w * R]}}{\mathbf{Y}}$$

Equation 13)

$$\boldsymbol{UPC} = \frac{(\boldsymbol{G} - \boldsymbol{R}) * [1 - (1 - \boldsymbol{c}) * \boldsymbol{w}] + \boldsymbol{R} * [1 - (1 - \boldsymbol{c})^{\boldsymbol{p}} * \boldsymbol{w}^{\boldsymbol{p}}]}{1 - (1 - \boldsymbol{c}) * \boldsymbol{w}}$$

Selected Equations from Appendix

Intermediate equation between Equations 3) and 4) not numbered.

$$\sum_{k=r}^{\infty}\left(\frac{k-1}{r-1}\right) * q^{k-r} = 1 + rq + \frac{r*(r+1)}{2!} * q^2 + \frac{r*(r+1)*(r+2)}{3!} * q^3 + ... = (1-q)^{-r}$$

Equation 9)

$$E(X^2) = r * \sum_{k=r}^{\infty} \frac{k^2}{r} * \left(\frac{k-1}{r-1}\right) * p^r * q^{k-r} = r * p^r * \sum_{k=r}^{\infty} k * \left(\frac{k}{r}\right) * q^{k-r}$$

Equation 11)

$$E(X^2) = r * p^r * \sum_{k=r}^{\infty} \left\{\frac{r+1}{r+1} * \left(\frac{k+1}{r}\right) - \left(\frac{k}{r}\right)\right\} * q^{k-r}$$

Equation 12)

$$E(X^2) = r * p^r * \left\{(r+1) * \sum_{k=r}^{\infty}\left(\frac{k+1}{r+1}\right) - \sum_{k-r}^{\infty}\left(\frac{k}{r}\right)\right\} * q^{k-r}$$

Intermediate equation between Equations 13) and 14) not numbered

$$Sum = r * p^r * (r+1) * \left[1 + (r+2) * q + \frac{(r+3)*(r+2)}{2!} * q^2 + \frac{(r+4)*(r+3)*(r+2)}{3!} * q^3 + ...\right]$$

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Factors Related to the Student Syndrome Phenomenon in Online Courses

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Abstract

This paper presents research on graduate student access patterns to internet courses, procrastination, and time spent completing online course work. This study investigated the extent of this phenomenon in several courses in a Master of Science in Engineering Management online program. Students in the program have a wide variety of backgrounds, enabling multiple factors related to the phenomenon to be analyzed. Specifically, work procrastination (Student Syndrome) was measured as related to students' professional backgrounds, academic experience, and course performance. The Student Syndrome, modeled graphically by a hockey stick-shaped time-series curve, is characterized by the significant surge of activity toward completing a task as the task completion deadline approaches. It is commonly observed in traditional classroom settings and is also seen in the manufacturing industry as end-of-month production deadlines approach. Student syndrome was observed in all of the subjects studied, regardless of background. Students who had more academic and professional combined total work load procrastinated less. Students in the introductory and mid-level courses who procrastinated most had the poorest level of academic performance, whereas students in the capstone course who procrastinated most had the highest level of academic performance, The results of this study present a baseline for future research, such as comparing the existence of the syndrome in traditional (face-to-face) courses versus online learning setting, and provide insight beyond online education into remote and virtual teamwork, work-from-home jobs, and other deadline-focused settings.

1. Introduction

Student syndrome is described as the phenomenon where study activities get postponed until the last moment [1]. This pattern has been recognized both in academia and industry. The expansion of "work-from-home" arrangements, virtual teams and other distributed work arrangements increase concern for student syndrome affecting virtual work and collaboration performance. This study evaluated performance behaviors of the students in online courses. Since the setting for virtual work is similar to on-line courses and remote workplaces, the results provide some insight into the industrial setting.

2. Population sampling

The study analyzed student access patterns in three on-line courses in a Master of Science in Engineering Management (MSEM) program. While sampling of the working population was not randomized, student demographics showed that a wide cross-section of the working population was studied. In total, 40 students were included in the study. The subjects included US residents, as well as students from India, Columbia, Sudan, Belgium, Taiwan, Pakistan, and Bulgaria. Employment ranged from full time (majority) to part time, to unemployed, and study load ranged from one class (3 credit hours) to four classes (12 credit hours) per semester. Student age ranged from 22 to 53 years old, and time since completion of an undergraduate degree ranged from 1 to 27 years.

The variety and range of these factors offer a multi-faceted perspective on how maturity and workforce experience may relate to the student syndrome.

3. Study settings and data collection

This research measured students' study behaviors in three masters-level on-line courses. Each course was divided into eight units. Each unit was scheduled to run for about two weeks, across a four month-long semester. Each unit was set up to have multiple assignment types. Assignments included, for example, threaded discussions (similar to blogs), quizzes (identical to computer-based testing), and written assignments submitted through simple file uploading.

The online course environment was set up to record with one-minute precision when messages were posted, quizzes were submitted, or files were uploaded. The settings also recorded the total amount of time spent logged into the course site on a day-by-day basis and on a topic-by-topic basis.

These settings allowed researchers to determine when each student read an assignment, started working on each assignment, completed an assignment, as well as the total amount of time spent. The settings could not account for the time required to complete all required textbook reading. Not all assignments, however, were dependent on completing textbook reading.

4. Background

The lead and senior authors began research in 2007 to better understand the study habits of students in the MSEM program at Eastern Michigan University. The purpose of the research was to identify potential improvement opportunities for the program. Initial analysis of data that described the study habits of online students was presented at the 2008 IEMS Conference [2]. The initial research results suggested that there was significant opportunity for further study.

The results presented in this paper expand upon the results of that initial study. Specifically, this paper describes the nature of procrastination, and analyzes the degree of procrastination exhibited by students when completing assignments, as related to students' professional backgrounds, academic experience, and course performance.

The research team defined procrastination as the tendency of students to avoid working on or completing assignments until the end (or near the end) of the assignment time period and due date. This is a common definition of procrastination and is easily applied to college students. Procrastination is also widely recognized as a ubiquitous human behavior with some 20% of adults calling themselves chronic procrastinators and an estimated 50% to 95% of college students affected by procrastination [3].

Literature published on procrastination suggests that there is little difference in procrastination for different ethnicities, ages, or genders [4]. In fact, procrastination presents as a complex characteristic of human behavior with numerous possible psychosocial causes [5]. College students in particular may even experience physiological barriers causing procrastination [6]. Additionally, task design (type and relevance of assignment) has been shown to influence student syndrome [7]. Most recently, Ariely has shown the efficacy of assignment design to reduce procrastination in college students [8].

5. Findings

Analysis of the data shows that all of the students in all three courses procrastinated when doing assignments, and overall, it provides a clear picture of the student syndrome behavior pattern. This pattern is often described in conversation as a hockey stick due to its similarity in shape to the common ice hockey

stick. The overall study pattern with a best-fit curve exhibiting this hockey stick shape is shown in Figure 1. This figure represents the mean number of minutes spent each day by all 40 students in the study. The mean varied from 25.57 minutes per day during the first 11 days of each unit to 102.17 minutes spent on the day that assignments were due.

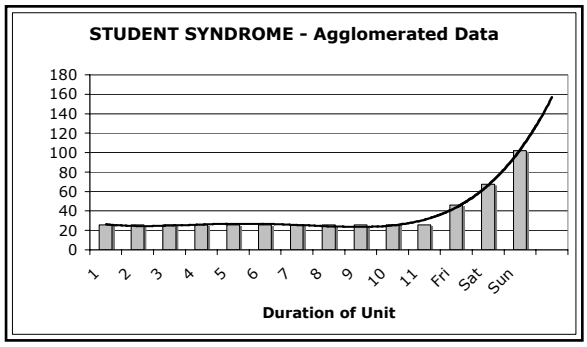

Figure 1. Student study pattern showing hockey stick shape

Consistent with previous findings, the results of this research indicate no difference in degree of student syndrome for different ethnicities, ages, or genders. Student course load was analyzed and also showed no difference in pattern between low and high course load. Course load refers to the number of classes taken by each student in the study. The mean was two classes. Students in the low course load category took two classes or fewer. Students in the high course load category took three or more classes.

Final course performance (defined as total points awarded for all assignments) showed no significant difference between low and high performers (low and high, again, referring to performance scores below mean (low) or above the mean (high)) when the agglomerated data were analyzed.

Total load (created by adding number of weekly employment hours by number of hours typical for each credit hour of course enrollment) showed a significant shift in pattern and magnitude between low (below the mean) and high (above the mean) total load for the agglomerated data as observed in Figure 2.

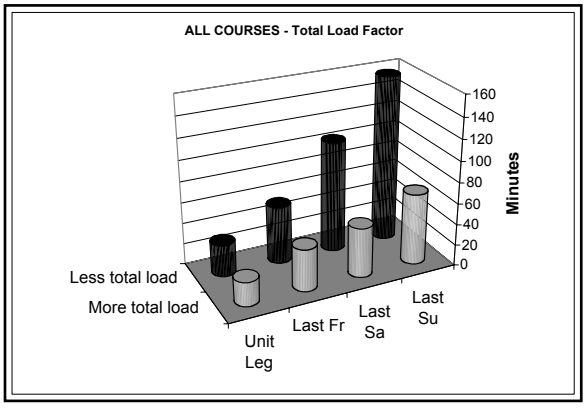

Figure 2. Student study pattern for total load

When the data were organized by each course instead of agglomerated, the results were different. These differences may provide some support for the aforementioned research that placed weight on assignment structure as an influencing factor for procrastination.

Our research showed that, on average, students from the introductory level course with lower total loads spent more time per day during the three days (in essence, the final weekend) leading up to the deadline. This is shown in Figure 3. The more consistent study pattern from students with a higher total load may have occurred because they simply had to manage their time better in order to keep up with both work and school.

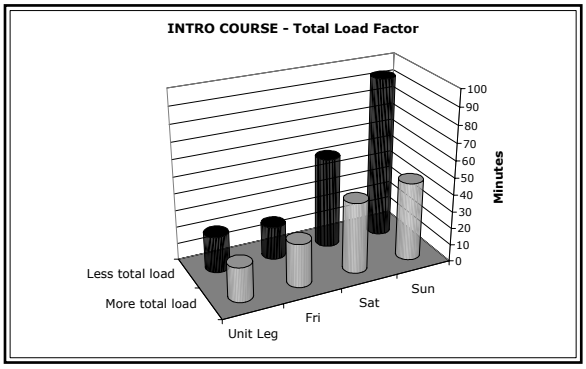

Figure 3. Study patterns in introductory course by total load

Figure 4 shows the effects of total load for students in the intermediate course. Again, students with higher total loads relative to the mean exhibited a more consistent study pattern than students with less total loads. Figure 5 shows a reversal of this pattern for students in the capstone course. It is not clear what may have caused this pattern in the higher-level course unless students with higher total workloads were simply trying to maintain a certain grade level by "cramming" during the final day before the deadline.

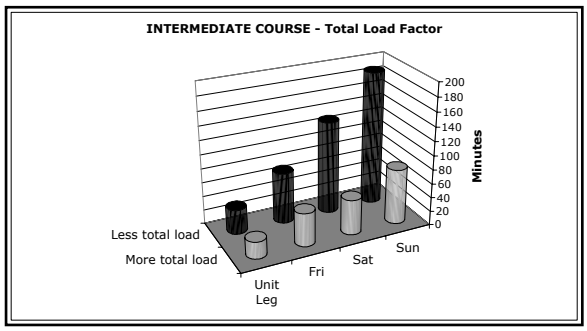

Figure 4. Study patterns in intermediate course by total load

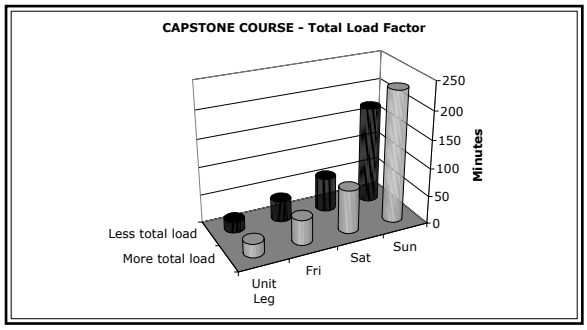

Figure 5. Study patterns in capstone course by total load

Study patterns for each course based on the final grade performance indicated that students in the introductory and intermediate courses who performed the poorest procrastinated the most. This is observed in Figures 6 and 7. Again, this study pattern was reversed for students in the capstone course as seen in Figure 8. In addition, the students in the capstone course who performed the best spent an average of 225 minutes on the final day of each assignment. This was 75 minutes more than the next highest level for the three courses. Those "extra minutes" may explain the high performance of this group despite their procrastination in starting the work.

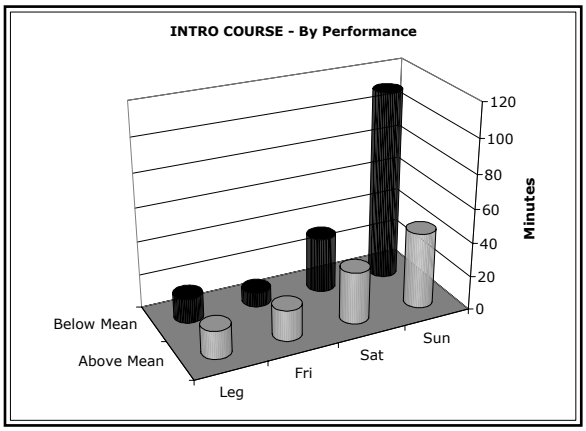

Figure 6. Study patterns in introductory course by final performance

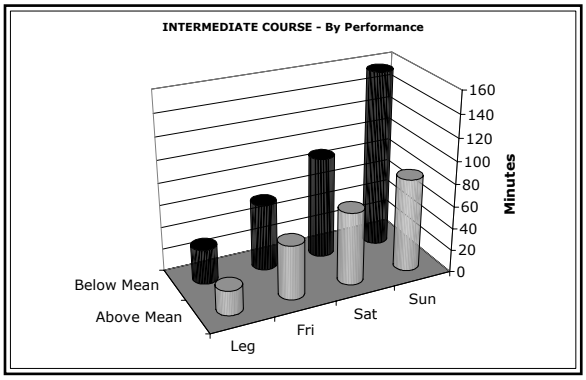

Figure 7. Study patterns in intermediate course by final performance

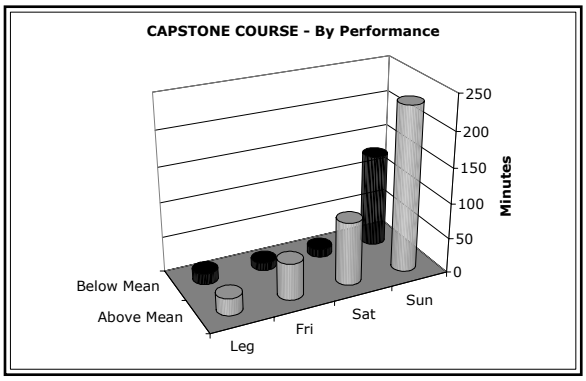

Figure 8. Study patterns in capstone course by final performance

6. Conclusion

Student syndrome is a specific form of procrastination found in college students, including graduate students who are enrolled in online courses. This feature of human behavior was observed by monitoring online students' work time each day in several online courses. A plot of time spent working on each class each day by students presented a curve that closely resembles an ice hockey stick. Consistent with the literature, all students in this study exhibited this pattern of procrastination to some extent. Some students exhibited this syndrome to a lesser extent than others. However, and most interestingly, this study found that the more experienced and mature students in the online program achieved higher course performance when they procrastinated than did less experienced and mature students. Further research may help us to understand the factors that cause this syndrome and, subsequently, lead to changes in online course delivery that will improve distance education pedagogy and, ultimately, student success.

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Using Organizational Finance as a Predictor of Information Technology Adoption

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Abstract

ATM is a switching and multiplexing mechanism operating over a fiber based physical network. It can be used to provide VPN services to businesses. Today, ATM services represent a billion-dollar business around the world. The adoption of ATM technology will probably change the current networking systems, upgrade the quality of current networks, and provide increased services. Despite the increasing deployment of ATM technology and the important role it plays in today's information technology infrastructure, little research has been found to its study with respect to social sciences. The present study examined organizational finance factor and its relationship with the adoption of ATM technology in organizations. Research results provided strong evidence that there is a statistically significant relationship between organizational finance factor and ATM adoption in organizations.

1. Introduction

Paisley [30] stated that technological change has placed communication in the front lines of a social revolution. While some companies have the opportunities and resources to take advantage of low labor costs by moving their production facilities to low labor cost countries, other companies are forced to compete in this environment by making themselves more efficient [1]. One way to improve their efficiency is to exploit modern technology [26]. As we moved from the Industrial Age into the Information Age [36], means of communication and the exchange of information and information resources have come to rely increasingly upon computer-based information technologies and information systems. The computer-based information systems brought a very basic change in human communication [34].

Currently, personal computers and workstations are commonplace in organizations. Information technology (IT) and computers have given organizations the ability to establish effective information systems for business functional areas and even share hardware, software, and data resources with business partners. The increasing power of personal computers permits multimedia, virtual reality, streaming video, instant messaging, and other applications to be conducted on computer networks and over the Internet, especially in organizations. To exchange these applications of high-speed digital bits a great deal more bandwidth is required on the network, even with further onset of compression [32]. The commonly-used Ethernet and Token Ring networking technologies can not deliver bandwidth on demand, particularly at the switching level. As more traffic is added to the network, especially voice and video, traditional technology becomes ever more incapable of satisfying the demands of business users. A solution for solving the bandwidth problem is

needed to form a unified broadband network which can deliver high bandwidth on demand.

To provide such a broadband network, a switching and multiplexing technology suitable for the design of high capacity switches is the core. As many technologies failed their promises for the requested broadband services, asynchronous transfer mode (ATM) has stood out as one technology that fulfills its promise. ATM is a switching and multiplexing mechanism operating over a fiber based physical network. According to McDysan and Spohn [24], ATM takes on many forms: provides software and hardware multiplexing, switching, and cross-connect functions and platforms; serves as an economical, integrated network access method; becomes the core of a network infrastructure; provides quality to the much-touted ATM service. ATM technology is one of the most important developments in internetworking in the last two decades. It has the potential to transform our network communication process. However the debate over the merits of such a technology is still going on [7].

Today, ATM is used to provide VPN (Virtual Private Network) services to businesses, consisting primarily of point-to-point virtual circuits connecting customer sites. ATM services represented a 2 billion dollar business in 2001. ATM is also used as the core network infrastructure for large Frame Relay networks and for some IP networks [16]. Based on the far-reaching significant position ATM possesses in networking, it can be seen that ATM will play a more important role in the building of a new utility infrastructure for communications technologies. The adoption of ATM technology will probably change the current networking systems, upgrade the quality of current networks, and provide increased services.

2. Literature Review

The theoretic framework for this study is Rogers' theory of diffusion of innovation [33, 35]. The diffusion of innovation theory is a social process in which subjectively perceived information about a new idea is communicated and rests on the premise that a new idea, practice or object has perceivable channels, time and mode of being adopted by individual or organizations [33]. The strength of the theory is that adopters and non-adopters of an innovation may be studied to identify the factors that influence their adoption behavior. They include the nature of the innovation, communication channels, and characteristics of social group, institutions or organizations. Rogers' diffusion of innovation theory is considered a suitable framework because of its potential application to information technology ideas, artifacts and techniques, and has been applied as the theoretical framework and used for a number of related studies, such as the adoption of innovations in library information systems, teaching and learning, and other information technologies [27], media literacy programs [39], telemedicine [14], e-business adoption [31], and IT innovation adoption research [15].

Despite the increasing deployment of ATM technology and the important role it plays in today's IT infrastructure, little research has been found devoted to its study with respect to social sciences. Kimberly and Evanisko [19] proposed that organizational variables have been clearly the best predictors of adoption of technological innovations. Lee and Shim [21] researched on variables and categories that are related to adoption behavior in organizational IT adoption. Roberts and Toleman [31] studied e-business adoption in organizations. Kamal [17] examined factors impacting organizational IT adoption in the private sector. Other researchers have examined organizational characteristics, such as organizational size, information systems

maturity, and their relationships to organizational adoption of technological innovations [8, 6, 9, 10, 11, 18, 19, 22, 23, 31, 38]. According to Corey and Grossman [6], significant variation in IT adoption exists across specialties (based on the findings from Health System Change's national physician survey) while practice setting and size are the strongest predictors of physician's access to clinical IT in their practices. Patterns of specialty adoption may reflect the relevance of particular clinical activities.

Beltrametti [3] pointed out that for an organization like a university a significant investment in computing is an important academic priority. It is an investment that will pay considerable dividends in the university's ability to improve teaching and future research.

In almost all universities, financial issues lie in budgeting. On what basis shall budget allocation decisions be made has long been an unsolved budgetary question. Colleges and universities today face their most significant crisis. Institutional expenses increase relentlessly and are not being offset by non-tuition income. Our colleges and universities are in an economic pincer. The increasing inability of families to cope with college costs, caps in federal appropriations, increasing competition for state funds, and the leveling off of sponsored research funding are all shrinking the revenue streams upon which schools are dependent.

Nevertheless, a large number of colleges and universities, research universities in particular, have realized that IT is a key factor in the future competitiveness of universities. The power of IT is providing new ways of conveying information and reshaping the learning process. Like it or not, the broadening role of IT tools in all disciplines means that they will demand a larger proportion of a university's budget. Systems that increase in quality always require increases in expenditures. Obviously, any technological innovations or adoptions of new technologies in an organization are, in no exception, directly affected by the financial situations of the organization.

Previous literature has shown that institutional finances have been used as predictors in a variety of studies. Morphet, Johns, and Reller [28] identified that financial resources and expenditures are related to educational output. Henson et al. (as cited in Krane, [20]) observed that when highly internationalized universities were compared to those less internationalized, the availability of funds played an important role in internationalization.

With respect to adoption of technological innovations, Bayless and Johnson [2] used cost factors in their study of critical factors in the installation of local area networks for university office systems programs. In their study, they used budget for keeping network running, among other cost factors in network design, and budget for local area network (LAN) software, among other hardware and software factors in network design, as variables. They found that conducting thorough cost analysis to determine all LAN installation costs is one of the most important factors in network design. Marcotte's [23] study of adoption of automation innovations in college libraries identified institution size and finances can be used as predictors for adoption of automation innovations.

However, no research has been found that studies ATM adoption in institutions of higher learning, nor has any research of this nature been found in other IT technologies and organizational studies. Identification of such organizational variable as university finance will provide valuable information to researchers in their study of ATM adoption in universities, as well as similar IT innovation adoptions in other settings. This paper examined the relationship between a university's finance and its ATM technology adoption to investigate whether a

university's finance factor can serve as a predictor of IT adoption. To examine the relationship, the following hypothesis was formulated: There is a statistically significant relationship between the finance factor and ATM adoption in a university. The study originally included several organizational variables such as size, type, etc. However, organizational finance and its analysis were selected from among others for presentation in this paper. Therefore data analysis and discussions will be focusing on findings of this variable and its related indications.

3. Methodology

The research design for this study was correlational since this method permits analysis of the relationships among a number of variables in a single study [4]. Universities chosen for the study were randomly selected from the population of four-year universities in the United States. The sample subjects were randomly selected from the population of university domain LAN administrators in these universities. The LAN administrators are those who are involved directly in the planning, administration, construction of university network infrastructure and LANs administration, and, most of all, adoption and implementation of state-of-the-art high-tech innovations like ATM. The preference of only university domain LAN administrators makes the selected subjects homogeneous so that more accurate data of the variables can be obtained [4].

In an institution, the percent of overall Educational and General (E & G) budget that is expended for information technology represents how much importance the institution attaches to its IT. Further, the percentage of overall IT expenditures that is expended for networking and telecommunications (N/T) reveals the institution's competitiveness in IT, which in turn represents the institution's overall competitiveness. The measurement of institutional financial variables can be institutional revenue, E & G budget, endowment, federal funding, costs, salary, etc. In IT, the measurement of financial variables can be overall IT expenditures, academic computing, administrative computing, library computing, N/T, hardware, software, salaries, wages, benefits, and other expenditures [5]. In this study, the percentage of overall IT expenditures that is expended for N/T (coded as NTBDGET in section 4.1 and Table 3) was defined as the measurement of university financial variable. The percentage of a university's overall IT expenditures expended for the university N/T budget was obtained from both CAUSE Institution Database Service [5] and a researcher developed questionnaire survey.

3.1 Data Analysis

Logistic regression was employed to study the relationship between organizational variables and the ATM technology adoption status of a university. According to Hosmer and Lemeshow [13], regression methods have become an integral component of any data analysis concerned with describing the relationship between a dependent variable and one or more independent variables. Very often the dependent variable is discrete, taking on two or more possible values. Logistic regression, in many fields, has become the standard method of analysis in this situation. The dependent variable in this study is dichotomous with an objective of describing the relationship between the dependent variable, ATM technology adoption, and the independent variable of university overall IT expenditures that is expended for N/T. Therefore, logistic regression was an appropriate statistical analysis method for this study. The data were analyzed by using Statistical Package for the Social Sciences (SPSS).

4. Findings

4.1 ATM adoption status

Of the 199 responses received, 58 universities indicated that they had adopted ATM technology, which was 29.1% of the responses. Of these 58 universities which have adopted ATM, 51.7% (n = 30) were research universities and 48.3% were non-research universities. Among the non-research universities, 22.4% (n = 13) were doctorate-granting universities, and 25.9% (n = 15) were neither research universities, nor doctorate-granting universities. The frequencies for ATM adoption are shown in Table 1.

Table 1. Frequencies for ATM Adoption Status

	Adopted		Non-Adopted		Total
	Freq.	Percent	Freq.	Percent	
Rsrch	30	51.7	16	11.4	46
Dctrt	13	22.4	23	16.3	36
Nthr	15	25.9	102	72.3	117
Total	58	100	141	100	199
Ttl %	**29.1**		**70.9**		**100**

4.2 Speed, bandwidth, and efficiency improvement

About 93% (n = 54) of the universities, which had adopted ATM, reported that their networks' speed, bandwidth, and/or efficiency had been improved since they adopted ATM. Only about 7% (n = 4) of the universities did not indicate speed, bandwidth, and/or efficiency improvement on their networks since they adopted ATM. Table 2 shows the frequencies for the speed, bandwidth, and/or efficiency improvement.

Table 2. Frequencies of Improvement

	Freq	Percentage
Improved	54	93.1
Not Improved	4	6.9
Total	58	100

5. Logistic regression results

Nested models were used to analyze model variables. Logistic regression coefficients for the nested models are listed in Table 3. According to Norusis [29], logistic coefficient can be interpreted as the change in the log odds associated with a one-unit change in the independent variable. Logit (the log of odds) is represented by coefficient value β. Since it is easier to think of odds rather than log odds, the logistic model uses *Exp (β)* (exponential function of coefficient) to represent odds, which can be interpreted as by increasing the value of independent variable's coefficient from 0 to 1 the odds are increased by a factor of the value under *Exp (β)*. If the independent variable's coefficient value β is positive, this factor will be greater than 1, which means that the odds are increased; if the β value is negative, the factor will be less than 1, meaning that the odds are decreased. Based on this rule of thumb and the coefficient values revealed in Table 3, several models were created, nested, and analyzed. Interpretations of these nested models are stated individually. Due to the paper size restriction, only Model 3 and 4 of the nested models will be listed for comparison and discussion in this paper.

Chi-square tests the null hypothesis that the coefficient in the current model, except the constant, is 0 [29]. This is comparable to the overall *F* test for regression. If the Model χ^2 is statistically significant beyond p = .05, it indicates that the predictor variable contributes no chance to the probability of explaining the dependent variable [25]. Model 4 yields a Model χ^2 of 53.953 relative to two degrees of freedom, which is statistically significant ($p < .05$). Compared to Model 3, Model 4 improves the goodness-of-fit (59.618 - 53.953 = 5.665) (5 - 3 = 2). As a result, Model 4 is better than Model 3 because variable MT1 further improves the fit

by $\Delta \chi^2 = 5.665$ relative to two degrees of freedom (See Table 3).

In Model 4, the p-value for NTBUDGET (independent variable IT Expenditure for N/T Budget as stated earlier) is less than .001. This allows us to conclude that, regardless of other variables, there is a significant relationship between ATM Adoption and NTBUDGET. The odds ratio for NTBUDGET is 1.0540, which indicates that, net of other variables, the odds of adopting ATM for universities with a higher NTBUDGET are 5.4% greater than for universities with a lower NTBUDGET.

Table 3. Logistic Regression Coefficients

Variables	Model 3		**Model 4**	
	β	Exp (β)	β	Exp (β)
ENRLMT	.00002	1.0000	.00002	1.0000
UTYPE	1.6505***	5.2095	1.5204**	4.5740
NTBDGET	.0528***	1.0542	**.0526*** **	**1.0540**
MT1			.6980*	2.0098
MT2			.3479	1.4161
Model X^2	53.953		59.618	
Df	3		5	
Signif.	.0000		.0000	
*p<.05; **p<.01; ***p<.001				

6. Conclusions and discussions

Based on the results of statistical analysis, the research hypothesis that there is a statistically significant relationship between university finance and ATM adoption in a university is accepted. We can positively state that statistically there is a significant relationship between university finance and ATM technology adoption in a university.

The research results suggest that universities with higher IT expenditures for N/T budget are 5.4% more likely to adopt ATM than universities with lower IT expenditures for N/T budget.

From a managerial standpoint, administrators in the early-adopter universities or organizations need to realize that they are knowingly or unknowingly on the forefront of IT innovation adoption because of their advantageous status in technological, financial, and human resources. Keeping their leading positions in IT adoption is as significant as their leading positions in the industry or academic standings because it may be one of the major factors that they can sustain their current positions. IT vendors, on the other hand, can benefit from the research findings by realizing that organizations with better IT expenditure are often early adopters of cutting-edge information technologies, such as ATM. They ought to preserve a well-balanced targeted marketing strategy based on their in-depth understanding of their current clients and their potential customers to establish larger and long-lasting markets for new IT innovations.

Organizations which have adopted ATM technology may be prepared for adopting new ATM related products as well as the post adoption management and maintenance. At the same time, they may need to cope with the outcome change in their organizational structure as a result of the new IT adoption.

Given the seminal and exploratory nature of the study, further studies of the determinants of ATM technology adoption and the adoption of other IT innovations may want to investigate into additional organizational variables, such as organizational type, organizational structure, information systems structure, managerial support, etc. [12] so as to yield more valuable and enriched information for guiding IT and information system implementation practices in organizations.

7. References

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