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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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Inventory Control Strategies in a Recoverable System with State-dependent Product Returns

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Abstract

This paper investigates inventory control strategies for a single product manufacturing /remanufacturing system with state-dependent product returns. A certain fraction of the products in use in the market is estimated to be returned to the manufacturer every period. This relates to the relative consumption (or failure) of the product and/or propensity of individual customers choosing to return used product. A returned item is either sent into the remanufacturing process or disposed of. Stochastic customer demands are met from serviceable inventory which includes both newly manufactured and remanufactured products. The optimal inventory policies for this recoverable system are found by solving a Markov Decision Process formulation of the system. The optimal policies are then approximated into policy characterizations with practical structure that are optimal or near optimal and the effects of changes in system parameters on the optimal policies are investigated through those characterizations.

1. Introduction

In recent years, manufacturers are incorporating recovery activities into their manufacturing processes due to growing environmental concerns as well as economical benefits. The expectations of environmentally conscious consumers put pressure on companies to consider environmental issues in their manufacturing process. In several countries there exist environmental regulations (e.g. take-back obligations after usage) that make manufacturers responsible for the whole product life cycle [1]. With product recovery, the considerable value incorporated in the used product is regained resulting in energy, material and labor savings. Reuse of products also provides considerable savings in disposal costs that have increased significantly in recent years due to depletion of incineration and land filling capacities.

The challenges faced when dealing with returns in the context of production planning and inventory management have recently gained considerable attention in the literature. Two main approaches are observed in the literature regarding inventory control of stochastic recoverable manufacturing systems. One, rarely used, approach is to investigate analytically the structure of optimal control policy using dynamic programming approaches [2, 3]. A second approach is to find optimal or near-optimal values for the parameters of a predetermined control policy structure [4-11]. While widely used, the pre-determined policy is not guaranteed to be optimal. In these works, it is not indicated how far the predetermined policy is from the optimal policy.

In the work mentioned above, product returns are stochastic and they are represented using a known probability distribution. Nakashima et al. [12, 13] model the product returns in a novel

way. They represent returns as a certain fraction of the products that are in use in the market. They model the inventory control problem for this system as Markov Decision Process (MDP) with two state variables: serviceable inventory consisting of finished products, and virtual inventory consisting of products that have been sold and currently in use in the market. The optimal policy resulting from their model determines how many to manufacture in each system state subject to given remanufacturing and disposal rates. In their experimental design, they fix the remanufacturing rate and look for the best disposal rate that will minimize the total system cost, and vice versa. Note that the return fraction equals the sum of remanufacturing and disposal rates. Hence, they implicitly assume that the return fraction is controllable. However, return fraction might not be controlled by the manufacturer in most real life situations, so it might not be rational to look for its optimal value.

We consider the same product recovery problem considered by Nakashima et al. [12, 13]. However, our MDP model differs from theirs in the following aspect: we define the return fraction as a given input parameter of the model, and look for the optimal manufacturing and remanufacturing amounts (i.e. lot sizes) for each system state subject to that given return fraction. Our aim is to characterize the optimal inventory policies for this system under several cost configurations and see the effects of changes in several model parameters on the optimal policy structure and policy parameters. Policy characterization can be defined as the description of the policy in a structured way using a few parameters. Clearly, characterization of the optimal policy is important, because it makes it easier to interpret the optimal policy. The effects of a change in system parameters on the optimal inventory policy can be more clearly seen through characterization.

The paper is organized as follows: section 2 describes the recoverable system under consideration and provides the MDP formulations of the corresponding inventory control problem. In section 3, the inventory policy characterizations obtained through numerical experimentations are reported and our observations and comments on the results are provided. Concluding remarks are given in section 4.

2. Model description

The recoverable system considered is illustrated in figure 1. Two modes of supply are available in this system: manufacturing and remanufacturing. Newly manufactured items as well as remanufactured items are stored in serviceable inventory from which the stochastic customer demands are satisfied. The products in use by the customers are considered to be potential remanufacturable inventory for the company. The company estimates to receive a certain fraction of the products currently in use by the customers as returned items. Printer cartridges, single-use cameras, computers, etc. can be given as examples of returned products for remanufacturing that fits this model. No long-term storage of returned items is considered at the remanufacturing facility; hence, the returned items at beginning of period are either sent into the remanufacturing process or disposed. Manufacturing and remanufacturing operations have one-period lead time. Backordering of demand is allowed up to a certain amount, beyond which demand is considered to be lost.

<Insert figure 1 about here >

The aim is to find the optimal manufacturing and remanufacturing strategies for this recoverable system, which minimize the long run expected system cost per period. In order to find the optimal policy, the problem is

formulated as a discrete-time Markov decision process and solved using a variant of Howard's policy iteration algorithm [14] that integrates the fixed successive approximation method suggested by Morton [15] for computational efficiency. The MDP formulations are provided below.

System States

The system states consist of the serviceable inventory and the products currently in use in the market. The serviceable inventory and the products in use by the customers at the beginning of period t are denoted as I_t and J_t, respectively. Lower and upper bounds for the serviceable inventory (i.e. I_{min} and I_{max}) as well as for the products in use (i.e. J_{min} and J_{max}) are considered to enable the modeling of the problem as a finite-state problem. However, these bounds can be determined in a way so that they are not restrictive.

Decisions

The decisions to be made are the manufacture (p) and remanufacture (m) quantities given serviceable inventory and products in use in the market. Both decisions are made at the beginning of the period.

State transitions

Serviceable inventory decreases with demand d and increases with newly manufactured products (p) and remanufactured products (m). Demand during a period is met from the beginning-of-period inventory since the manufacturing and remanufacturing orders will not be ready before the end of period. Hence, the inventory at the beginning of period t+1 is calculated as:

$$I_{t+1} = \min\{I_t - d, I_{\min}\} + p + m$$

Products in use in the market decreases with returns and increases with the products sold into the market. Given that return fraction is α, the number of returns during period t is αJ_t, which is rounded to the nearest integer if fractional. The products in the market at the beginning of period t+1 is calculated as:

$$J_{t+1} = J_t - \alpha J_t + Q_t,$$
$$\text{where } Q_t = d + \left|I_t^-\right| - LS_t - \left|I_{t+1}^-\right|$$

In the above formulae, Q_t represents the number of products sold into the market in period t. d represents demand during period t. $\left|I_t^-\right|$ represents backordered demand at the beginning period t, where $I_t^- = \min\{I_t, 0\}$. LS_t represents demand lost during period t, and is calculated as:

$$LS_t = \begin{cases} I_{\min} - (I_t - d) & \text{if} \quad (I_t - d) < I_{\min} \\ 0 & \text{otherwise} \end{cases}$$

Cost function

The total system cost to minimize consists of fixed and variable manufacturing and remanufacturing cost, holding cost for serviceable inventory, backordering cost, lost sales cost and disposal cost. The following notation is used for the cost function.

S_P : setup cost for manufacturing,
S_M : setup cost for remanufacturing
C_P : unit manufacturing cost
C_M : unit remanufacturing cost
C_{HS} : holding cost per serviceable unit per period
C_{BO} : unit backordering cost per period
C_{DISP} : unit disposal cost
C_{LS} : unit lost sales cost
$DISP_t$: disposal amount during period t

LS_t : lost sales during period t

B_t : backordered demand during period t

Given that the system is in state $S_t = (I_t, J_t)$, manufacturing and remanufacturing decisions taken are p and m, respectively, and d units of demand occurs during period t, the cost during period t is calculated as:

$$C(S_t,(p,m),d) = \delta(p) + \gamma(m) + C_{HS}[I_{t+1}]^+ + C_{BO}B_t + C_{DISP}DISP_t + C_{LS}LS_t$$

where the terms represent manufacturing cost, remanufacturing cost, holding cost for serviceable inventory, holding cost for recoverable inventory, backordering cost, disposal cost, and lost sales cost (or, lost sales revenue), respectively, and

$$\delta(p) = \begin{cases} S_P + C_P p & for\ p > 0 \\ 0 & for\ p = 0 \end{cases}$$

$$\gamma(m) = \begin{cases} S_M + C_M m & for\ m > 0 \\ 0 & for\ m = 0 \end{cases}$$

$$[I_{t+1}]^+ = \max\{I_{t+1}, 0\}$$

$$B_t = \begin{cases} -\max\{I_t - d, I_{\min}\} & \text{if } \max\{I_t - d, I_{\min}\} < 0 \\ 0 & \text{otherwise} \end{cases}$$

$$DISP_t = \alpha J_t - m$$

$$LS_t = \begin{cases} I_{\min} - (I_t - d) & \text{if } (I_t - d) < I_{\min} \\ 0 & \text{otherwise} \end{cases}$$

Then, the expected cost in period t is calculated considering all possible demand values, as:

$$E[C(S_t,(p,m))] = \sum_d P(D_t = d) * C(S_t,(p,m),d)$$

3. Experiments and results

The recoverable system is investigated under several scenarios generated from a so-called basic scenario by changing the value of a single system parameter at a time. Our objective behind these experiments is to find the effect of changing an individual system parameter (i.e. return fraction, holding cost, backordering cost, disposal cost, lost sales cost, set up costs for manufacturing and remanufacturing) on the optimal inventory strategies.

For each scenario, we first find the optimal inventory policy by solving the MDP model. Then, we determine a policy characterization that has a practical structure (i.e. that can be defined using only a few control parameters) by observing the optimal policy. Finally, we evaluate the quality of that policy characterization by considering the percentage deviation of its cost from the optimal cost, which is calculated as:

$$\%\ \text{deviation from optimal cost} = \left(\frac{c}{c^*} - 1\right) * 100$$

where c represents the cost of the policy characterization and c^* represents the optimal cost.

The values of the system parameters used for the basic scenario are reported below:

$\alpha = 0.3$; S_P=\$0; S_M=\$0; C_P=\$10; C_M=\$4; C_{HS}=\$5; C_{BO}=\$20; C_{DISP}=\$2; C_{LS}=\$30; I_{min}= -10; I_{max}=30; J_{min}=0; J_{max}=100

Demand, which is a discrete stochastic variable, is represented using the following trapezoidal-shaped symmetrical distribution:

$$P(D=d)=\begin{cases}\dfrac{d}{30} \text{ for } 1\le d\le 5\\ \dfrac{11-d}{30} \text{ for } 5<d\le 10\\ 0 \quad \text{otherwise}\end{cases}$$

The values considered in the experiments for the return fraction and the cost parameters, and the corresponding policy characterizations are given in table 1. The definitions of the policy types that characterize well the optimal policies in our experiments can be found in table 2. Observations on the results of the experiments are summarized below.

When there are no manufacturing and remanufacturing set up costs, the (*L*, *M*) policy represents well the optimal policy, its cost deviating from optimal cost by 0.20% on average and 0.79% at maximum in our experiments. *L* and *M* represent manufacture-up-to and remanufacture-up-to levels, respectively. According to the (*L*, *M*) policy, if serviceable inventory at the beginning of current period is below *M* (i.e. $I_t < M$), then an amount *m* that will raise the inventory level up to *M* is remanufactured as much as the returned items currently available suffice ($m = \min\{\alpha J_t,\ M - I_t\}$). Then, if serviceable inventory position after remanufacturing decision has been made is below *L* (i.e. $I_t + m < L$), an amount *p* that will raise the inventory position to *L* is manufactured ($p = L - (I_t + m)$).

<Insert table 1 and 2 about here>

If a change in the holding cost or backordering cost occurs in the basic scenario, that does not affect the policy structure, i.e. the (*L*, *M*) policy still remains as a good approximation of the optimal policy, but the values of control parameters *L* and *M* change. As can be observed from table 1, when there is an increase in the holding cost, the values of *L* and *M* decrease in order to decrease the expected end-of-period inventory since it gets more expensive to hold inventory. When backordering gets more expensive, the values of *L* and *M* increase in order to decrease the expected backordered demand. On the other hand, changing disposal or lost sales cost does not change significantly the optimal policy, because the system bounds are not restrictive so expected disposals or lost sales in the long run under optimal policy are extremely low if not zero.

When manufacturing set up cost S_P is non-zero, the parameters *L* and *S*, representing reorder level for manufacturing and manufacture-up-to level, respectively, can be used to represent the manufacturing strategy. According to the (*L*, *S*) manufacturing strategy, if the serviceable inventory position after remanufacturing decision has been made is below *L* (i.e. $I_t + m < L$), then an amount that will raise the inventory position to *S* is manufactured (i.e. $p = L - (I_t + m)$). As can be seen from table 1, the (*L*, *S*, *M*) policy represents well the optimal policy when $S_P>0$ and $S_M=0$, with a maximum deviation of 0.51%. When remanufacturing set up cost S_M is non-zero, the remanufacturing strategy (*M*, *R*) can be used, *M* and *R* representing reorder level for remanufacturing and the minimum number of returned items required to start remanufacturing, respectively. According to this strategy, remanufacturing does not start unless there are at least *R* returned items on hand and serviceable inventory is below *M*. If those conditions are satisfied all the returned items on hand are remanufactured (i.e. $m=\alpha J_t$). As remanufacturing set up gets more expensive, the value of control parameter *M* decreases and *R* increases in order to decrease the expected number of remanufacturing set ups per period. The (*L*, *M*, *R*) policy characterizes well the optimal policy

when S_M>0 and S_P=0, with a maximum deviation of 0.26% in our experiments.

<Insert table 3 about here>

Another observation is that in the steady state situation, expected returns equal expected demand for every return fraction α. As the return fraction increases, the expected number of products in the market (E(*J*)) decreases, but in the long run expected returns remain the same and equal expected demand. So, changing return fraction does not significantly change the optimal cost. In our experiments, increasing α from 0.1 to 1.0 (i.e.10 times) resulted in a decrease of only 5.83% in the optimal cost (see table 3).

4. Conclusion

This paper investigates the inventory policy characterizations for a manufacturing/ remanufacturing system where a certain fraction of products in use in market is estimated to be returned to the manufacturer every period. Returned products are either remanufactured or disposed. The results show that the (*L*, *M*) policy can be used to characterize well the optimal policy for this recoverable system when no set up costs exist. The existence of non-zero set up costs significantly affects the policy structure. A single control parameter is not sufficient to represent well the strategy regarding the operation with non-zero set up costs. The two-parameter manufacturing strategy (*L*, *S*) and remanufacturing strategy (*M*, *R*) can be successfully used in the existence of non-zero manufacturing and remanufacturing set up costs, respectively.

In this paper, both manufacturing and remanufacturing lead times were one period. As further work, it would be interesting to analyze the inventory policies for lead times greater than one period.

5. Acknowledgements

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Table 1. Policy characterizations and their deviations from optimal cost

α	Policy Characterization	Deviation from optimal cost (%)
0.1	(L=12, M=15)	0.15
0.2	(L=12, M=15)	0.19
0.3	(L=12, M=15)	0.19
0.4	(L=12, M=15)	0.21
0.5	(L=12, M=15)	0.22
0.6	(L=12, M=15)	0.22
0.7	(L=12, M=15)	0.02
0.8	(L=13, M=15)	0.00
0.9	(L=13, M=14)	0.00
1.0	(L=13, M=13)	0.00

C_{DISP}	Policy Characterization	Deviation from optimal cost (%)
-2	(L=12, M=14)	0.12
0	(L=12, M=14)	0.17
2	(L=12, M=15)	0.19
4.5	(L=12, M=15)	0.37

C_{LS}	Policy Characterization	Deviation from optimal cost (%)
0	(L=12, M=15)	0.19
10	(L=12, M=15)	0.19
20	(L=12, M=15)	0.19
30	(L=12, M=15)	0.19

C_{HS}	Policy Characterization	Deviation from optimal cost (%)
1	(L=13, M=22)	0.30
3	(L=13, M=16)	0.34
5	(L=12, M=15)	0.19
10	(L=10, M=12)	0.10
20	(L=7, M=9)	0.06
30	(L=5, M=7)	0.15

S_P	Policy Characterization	Deviation from optimal cost (%)
0	(L=12, M=15)	0.19
10	(L=11, S=12, M=15)	0.38
20	(L=10, S=12, M=16)	0.43
30	(L=10, S=12, M=17)	0.51

C_{BO}	Policy Characterization	Deviation from optimal cost (%)
1	(L=4, M=7)	0.79
5	(L=6, M=10)	0.53
10	(L=9, M=13)	0.24
20	(L=12, M=15)	0.19
30	(L=13, M=16)	0.21

S_M	Policy Characterization	Deviation from optimal cost (%)
0	(L=12, M=15)	0.19
8	(L=12, M=15)	0.22
16	(L=12, M=12, R=2)	0.26
24	(L=12, M=12, R=3)	0.19
40	(L=13, M=10, R=6)	0.04

Table 2. Policy descriptions

Policy Type	Policy Description*
(L, M)	$m = \begin{cases} \min\{\alpha J_t,\ M - I_t\} & \text{for } I_t < M \\ 0 & \text{otherwise} \end{cases}$, $p = \begin{cases} L - (I_t + m) & \text{for } I_t + m < L \\ 0 & \text{otherwise} \end{cases}$
(L, S, M)	$m = \begin{cases} \min\{\alpha J_t,\ M - I_t\} & \text{for } I_t < M \\ 0 & \text{otherwise} \end{cases}$, $p = \begin{cases} S - (I_t + m) & \text{for } I_t + m < L \\ 0 & \text{otherwise} \end{cases}$
(L, M, R)	$m = \begin{cases} \alpha J_t & \text{for } I_t < M \text{ and } \alpha J_t \geq R \\ 0 & \text{otherwise} \end{cases}$, $p = \begin{cases} L - (I_t + m) & \text{for } I_t + m < L \\ 0 & \text{otherwise} \end{cases}$

* For each policy type, remanufacturing decision (m) is given before manufacturing decision (p). The term αJ_t, which represents returns, is rounded to the nearest integer if fractional.

Table 3. Steady-state situation under different return fractions

α	E(J)	E(Return)	Optimal cost
0.1	54.50	5.50	73.75
0.2	27.50	5.50	73.11
0.3	18.21	5.50	72.41
0.4	13.75	5.50	71.71
0.5	10.50	5.50	71.01
0.6	9.17	5.50	70.44
0.7	7.76	5.50	70.31
0.8	6.87	5.50	69.87
0.9	6.10	5.50	69.70
1.0	5.50	5.50	69.46

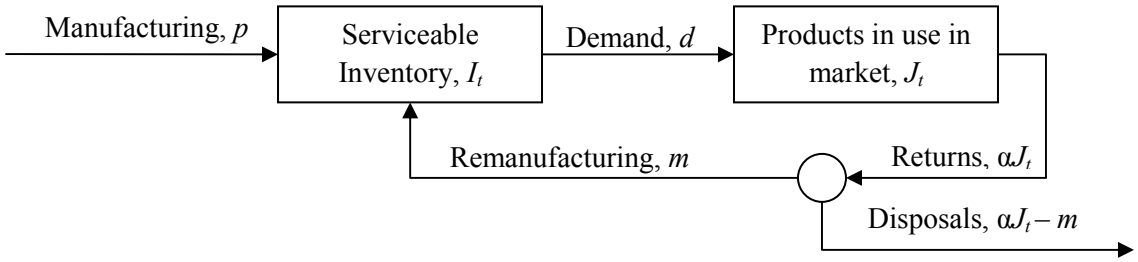

Figure 1. The recoverable system

Elements of Effective Learning: Study of Face-To-Face Versus Podcast Lectures

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Abstract

A study was performed to determine the effectiveness of podcasts as a supplemental learning aid for students enrolled in a face-to-face course. The study consisted of assigning 120 participants to one of four groups or rather conditions consisting of two different lectures (planning and time management) using either two live lectures, two podcast lectures, and different combinations of one live and one podcast lecture. Analyses were conducted comparing conditions across topic (planning and time management) as well as order (first presented topic and second presented topic).

1. Introduction

Radical improvements in learning and instruction have been made as a result of advances in technology. Student learning has also become more flexible and content sources much more accessible. Creating, sharing and knowledge capitalization is facilitated through the use of the Internet. A study was conducted to determine the effectiveness of podcasts as a supplemental learning aid for students enrolled in a face-to-face course. The study consisted of assigning 120 participants to one of four groups or rather conditions consisting of two different lectures (planning and time management) using either two live lectures, two podcast lectures, and different combinations of one live and one podcast lecture. The study results are of value in understanding the effectiveness of podcasts as well as potential uses of podcasts in an academic setting. Analyses were conducted comparing conditions across topic (planning and time management) as well as order (first presented topic and second presented topic).

There is literature on the effectiveness on online learning but there is a gap in the literature on the use of podcasts in an academic setting. There, the study objectives were to:
(a) Identify the strengths and weaknesses affiliated with a face-to-face learning environment and podcast learning environment.
(b) Gain insight into student perceptions with different learning environments.
(c) Identify from a statistical analysis if podcast or face-to-face lecture format results in a higher level of learning.

2. Literature Review

2.1 Podcasts in Education

Podcasting describes the use of an audio or video file for listening purposes, where the file itself can be played on either a portable media player or personal computer [1]. These podcasts are generally distributed via syndicated feeds such that individuals subscribing to these feeds receive the media files with little to no recurring action; however, a podcast can refer to media manually downloaded by a user as well. Podcasts may take the form of short news programs, lectures, interviews, or a mix of

media encapsulated by a narrative or subtitled text. While some teaching professionals have cited the rise of podcasts as a means to end the tradition classroom lecture environment, others consider the podcast as a means to incorporate a wider variety of material and viewpoints in the traditional classroom. This trend in campus acceptance of technology demonstrates the practicality of podcasting, or course-casting, as a means to enhance and supplement education in the college environment.

When podcasting first became mainstream, the podcast in education was often used as a supplement to meet the needs of students whose learning disabilities required a multimodal form of knowledge acquisition or as a novel method to incorporate guest lecturers into classrooms where it may not be feasible to bring a speaker to the class [5]. As more and more instructors become familiar with the creation and use of podcasting, podcasts are used in a wider variety of ways in both the traditional and nontraditional classroom. This can also be attributed to the changing demographics of those students who are now in the classroom.

Today's undergraduate students are members of Generation D, a group more tuned to the idea that technologies such as podcasting are intended for and expected to be used in higher education [8]. This group, marked by those students born between the years of 1981 and 1994, prefers interactive and dynamic media over static text; instead of traditional, more formal guidance, these students want experiential and collaborative approaches. Students of Generation D seek and utilize information in a manner unlike that demonstrated by previous generations of university students; for this group, culture and motivation, as well as learning styles and lifestyles, play an important role in information seeking, [7]. At the university level, convenience drives the adoption of such online technologies both at and away from home [6].

2.2 Podcasts as Primary and Supplementary Sources

Podcasts in higher education serve a variety of purposes and meet the needs of students with diverse learning styles [2]. Given the availability of software for audio and video creation, podcasts can be created for a low cost. The actual media that is created is relatively portable, with audio podcasts being the most portable. The busy student who commutes to and from campus can listen to a podcast of a lecture in preparation for the day's discussion or to reinforce concepts while studying for an exam.

In distance education courses where the classroom is nonexistent, podcasts can serve as a primary source of information [1]. Audio or video podcasts may be posted to an online course site, and students are expected to download and listen or view the podcast in lieu of reading pages of text. Follow-up exercises in a purely online environment include posting to a blog, online scavenger hunts of outside websites, or active participation in a message board or synchronous chat discussion. For traditional university courses where there is an

obligatory in-class requirement, the podcast serves as both a copy of the material presented during the in-class lecture and supplementary material designed to reinforce or enhance the in-class lecture. There has been concern that the podcast could be used to replace the traditional lecture, and earlier studies involving the use of podcasts in higher education specifically recommend that for the traditional student, podcasts should be used to supplement the in-class experience rather than replace it [9]. Studies involving podcasts used to supplement in-class lectures have addressed the perceived problem of lowered attendance with the availability of podcasts, and the majority of students indicate that while the podcast serves as a useful and reliable tool for review, students prefer the interactivity and routine that an in-class lecture provides [1, 3 & 4].

3. Methodology

A study was conducted to determine the effectiveness of podcasts as a supplemental learning aid for students enrolled in a face-to-face course as there is a need for more literature on the effectiveness of podcasts in an academic setting. Therefore, the study consisted of assigning 120 participants to one of four groups or rather conditions consisting of two different lectures (planning and time management) using either two live lectures, two podcast lectures, and different combinations of one live and one podcast lecture. The lecture content was the same but depending on which condition a participant was placed, the content was instructed in either a live lecture format where the same two individuals taught the material as a joint lecture consisting of a face-to-face atmosphere or a podcast to listen to which contained the same lecture material but without the face-to-face learning environment. As previously stated, four conditions existed in this study. Condition 1 consisted of the presentation on the topic of time management (podcast) followed by the topic of planning (podcast). Condition 2 consisted of a presentation of the topic of planning (live lecture) followed by the topic of time management (live lecture). Condition 3 consisted of a presentation of the topic of planning (live lecture) followed by the topic of time management (podcast). Lastly, condition 4 consisted of a presentation of the topic of planning (podcast) followed by the topic of time management (live lecture).

The first step of the study was to develop the documentation and the lecture content for the study. This involved the development of the Institutional Review Board (IRB) university documentation, pre-survey, two podcasts (one on the topic of planning and one on the topic of time management), quizzes for each of the two lectures and the post-survey. The IRB process was to seek and obtain approval to conduct a test on human participants through the IRB at the university where the testing took place. The pre-survey was given to obtain student perceptions of the different learning environments. The podcasts were created utilizing podcast development software. The participants assigned within each of the four conditions were tested by administering a quiz to determine how much of the information was learned after each lecture was given. Therefore, every participant was given a lecture on planning

and time management and given two different quizzes, one after each lecture regardless of whether it was a live or podcast lecture. The post-survey consisted of gaining insight into participant's desire of content and uses for podcasts in an academic setting. The study consisted of approximately thirty minutes for each participant due to the time involved in each participant completing a pre-survey, listening to the two five-minute lectures, completing the quizzes for each lecture and completing the post-survey. The study results are of value in understanding the effectiveness of podcasts as well as potential uses of podcasts in an academic setting.

Multiple approaches were investigated in the evaluation of the differences in learning effectiveness across lecture formats. First, the study observed the scores on two different topics (planning and time management); however, because the conditions in this study also differed in the *order* in which the topics were presented, effectiveness was also evaluated in terms of results on the first assessment and the second topic (regardless of topic). Analyses were conducted in different ways to control for differences that might occur due to practice effects and/or topic differences. Additionally, it was reasonable to conclude that variance within groups (or across individuals) that pertain to individual differences in aptitude to complete the assessments of this study might obscure the effect across conditions. In order to reduce this potential contaminant, performance on one assessment was used as a covariate in the analyses where possible.

4. Results

The results consist of the pre-survey, statistical analyses of the quizzes and the post-survey results.

The pre-survey revealed that participants ranged in age from 18-65 and 95% of the participants were undergraduate students with the remaining participants being graduate students or faculty or staff. Of the participants, 61.7% were males and 38.3% were females. The ethnicity of the participants were 53.3% Caucasian, 11.7% African American, 11.7% Hispanic/Latino and 20% Other. Of the participants, 15% have downloaded a podcast in the past and have downloaded to a laptop, desktop, ipod and/or cell phone. Of the participants, 36.7% have downloaded a PowerPoint presentation with audio in the past. Of the participants, 1.7% has downloaded a podcast in lieu of attending a class. Of the participants, 78.3% have interest in downloading podcasts for academic purposes. Of the participants, 86.7% would still attend class even if lecture content was available as a podcast. The preferences for a video or audio podcast consisted of 58.3% of the participants prefer video, 11.7% prefer audio and 30% had no preference.

The post-survey resulted in the identification of uses for podcasts in academic settings. The suggestions that came forward for either faculty or student created podcasts consist of the following categories:

- Lecture summaries
- Class Examples
- Test Review
- Visual demonstrations
- References for further reading
- Student presentations
- Frequently asked questions and answers
- Lab experiments
- Suggestions for study habits
- Slower speech for English as a second language (ESL)
- Discussion topics
- Campus news, events and information

Prior to testing the existence of any differences in learning effectiveness across lecture formats, data was analyzed to identify anomalous responses or outlying data. This assessment identified one outlier in which the respondent scored zero on one of the assessments (this respondent was removed from further analyses). Table 1 presents the overall means and standard deviations of assessment scores.

Table 1. Overall means and standard deviations

	N	M	SD
		7.7	1.2
PLANNING	120	3	0
		7.2	1.4
TIME MGT	119	4	2
		7.6	1.2
FIRST	120	6	2
		7.3	1.4
SECOND	119	1	3
		7.4	1.0
AVERAGE	120	8	8

Note: "First" and "Second" represent the score on the first topic covered in each condition regardless of whether planning or time management was presented.

4.1 Between Subjects Effects

Between group differences were determined via analysis of covariance (ANCOVA) analyses, these were conducted in order to control for relevant individual differences pertaining to learning ability or aptitude to complete the assessments of this study. Prior to conducting the ANCOVA analyses, we tested the homogeneity of regression assumption; the assumption was met across all analyses.

4.1.1 Comparison of conditions on first and second assessments

The analyses comparing learning effectiveness of lecture formats on the *first* assessment (using the *second* assessment as a covariate) resulted in non-significant differences ($F = 1.861$, *ns*). Further analysis of adjusted mean scores revealed that individuals in the live condition ($M = 7.82$, $SE = .151$) performed better than those in the podcast lecture ($M = 7.53$, $SE = .149$).

The evaluation of the differences across lecture formats for the *second* assessment using the *first* assessment as a covariate, also revealed that there was not a significant difference between the means of the conditions ($F = 2.486$, *ns*). Analyses revealed that means for the podcast format ($M = 7.51$, $SE = .176$) were higher than that of the live lecture ($M = 7.11$, $SE = .178$); see Table 2.

4.1.2 Comparison of conditions on Planning and Time Management assessments

The analyses comparing learning effectiveness on the topic of *planning* (using the *time management* as a covariate) revealed that there were not significant differences across conditions ($F = .233$, *ns*). Further analysis of adjusted means revealed that individuals in the live lecture condition ($M = 7.80$, $SE = 1.46$) performed better than those in the podcast condition ($M = 7.70$, $SE = 1.46$).

The evaluation of the differences across lecture formats for the topic of *time management* using the *planning* as a covariate, revealed that there was not a significant difference between the means of the conditions ($F = .598$, *ns*). Adjusted means on this assessment favored those in the podcast format ($M = 7.33$, $SE = .174$) over the live lecture ($M = 7.14$, $SE = .176$).

4.1.3 Between-subjects comparison of overall results

Lastly, an analysis of variance (ANOVA) was conducted to test the overall difference

(across both assessments) between subjects; those who were presented a live lecture for both topics versus those who were provided the podcast for both topics. An ANOVA was used, rather than an ANCOVA, because no suitable covariate existed. Results indicated very similar results across conditions, yielding a non-significant difference ($F = .004$, *ns*). The podcast condition ($M = 7.45$, $SD = 1.05$) was only slightly higher than the mean of the live lecture format ($M = 7.43$, $SD = 1.12$).

Table 2. Descriptive Statistics

Podcast				
	N	M_{adj}	M	SD
FIRST	60	7.53	7.57	1.25
SECOND	60	7.51	7.43	1.32
PLANNING	60	7.70	7.72	1.22
TIME MGT	60	7.33	7.28	1.32
LIVE				
FIRST	59	7.82	7.78	1.18
SECOND	59	7.11	7.19	1.54
PLANNING	60	7.80	7.78	1.18
TIME MGT	59	7.14	7.19	1.54

4.2 Within Subjects Effects

To test if lecture format influenced learning effectiveness in a within-subjects design, a paired sample t-test was conducted. Results indicated that overall there was not a strong effect for lecture format ($t = .511$, *ns*). The assessments across lecture formats were also found to be significantly correlated ($r = .35$, $p < .01$). In these analyses individuals performed better during the podcast format ($M = 7.57$, $SD = 1.69$) than they did during the live lecture ($M = 7.47$, $SD = 1.35$). See Table 3.

More specific analyses of within-subjects differences yielded contradicting patterns. In the condition in which participants experienced a live lecture on the topic of planning followed by a podcast on the topic of time management (n = 30), the live assessment yielded a higher mean score ($M = 7.63$, $SD = 1.22$) than that of the podcast ($M = 7.30$, $SD = 1.37$). However, in the condition in which participants viewed the podcast on the topic of time management followed by a live lecture on the topic of planning (n = 30), the podcast assessment yielded a higher mean score ($M = 7.83$, $SD = 1.21$) than that of the podcast ($M = 7.30$, $SD = 1.47$).

Table 3. Means and Standard Deviations

	N	M	SD
Overall (the combination of the two conditions below)			
Live	60	7.47	1.35
Podcast	60	7.57	1.69
Live (Planning) – Podcast (Time Management)			
Live	30	7.63	1.22
Podcast	30	7.30	1.37
Podcast (Planning) – Live (Time management)			
Live	30	7.30	1.47
Podcast	30	7.83	1.21

The inconsistent results may be related to the topic of the assessments or the order in which they were presented. An analysis of the differences across topic and order revealed a significant difference ($t = 2.504$, $p < .05$) and a significant correlation across assessments ($r = .396$, $p < .01$). The first topic of planning was found to have higher mean scores ($M = 7.75$, $SD = 1.19$) than that of the second topic of time management ($M = 7.28$, $SD = 1.42$). It is unclear, however, if the difference is due to the topic or the order of presentation. Expanded analyses across the entire sample ($N = 120$) suggest the topic is of greater influence; a significant difference across topics was replicated ($t = 3.685$, $p < 01$). On average, individuals scored higher on the topic of planning ($M = 7.28$, $SD = 1.42$) than they did on the topic of time management ($M = 7.28$, $SD = 1.42$). Analyses comparing the effect of order did not yield significant findings ($t = 1.164$, *ns*).

Utilizing a sub-sample (n = 60), scores on the first assessment were higher (M = 7.59, SD = 1.25) than those on the second assessment (M = 7.34, SD = 1.46). It should be noted that using the full sample of 120 does demonstrate an effect for order, where the first assessment is characterized by significantly higher scores. However, these results are skewed by the fact that 75% of the data in the first assessment was on the topic of planning. In order to neutralize this imbalance, analyses compared an equal distribution where the half of the sample experienced the topic of planning first and the other half experienced time management first. Also note that the sub-sample selected was that which would most likely demonstrate an effect if one were present.

5. Conclusion

A study was performed to determine the effectiveness of podcasts as a supplemental learning aid for students enrolled in a face-to-face course. The study consisted of assigning 120 participants to one of four conditions ranging in age, ethnicity and podcast downloading familiarity. Analyses were conducted comparing conditions across topic (planning and time management) as well as order (first presented topic and second presented topic). The following study objectives were achieved:

(a) Identify the strengths and weaknesses affiliated with a face-to-face learning environment and podcast learning environment. Further study is necessary but this particular study suggests that students prefer face-to-face when asked their preference although the statistical analyses suggests that performance is not heavily influenced with face-to-face versus podcast lecture.

(b) Gain insight into student perceptions with different learning environments. Multiple suggestions for uses of podcasts in academic settings were identified ranging from lecture summaries to student presentations to campus news.

(c) Identify from a statistical analysis if podcast or face-to-face lecture format results in a higher level of learning. The analyses conducted in this study demonstrate fairly consistent outcomes across lecture formats. While more additional research ought to be conducted to ascertain whether certain conditions or certain elements of the educational process are adversely influenced by one format or the other, the results of this study are encouraging to advocates of technology-based learning.

The study results contribute to the literature specifically in the area of effectiveness on online learning and the use of podcasts in an academic setting. Future research is necessary to determine the components that must be present within these two learning environments for effective learning to occur. Furthermore, additional research should explore different academic topics such as science, math, history, etc. to statistically determine if differences in participants' learning occur within different learning environments and compare these results with the present study results.

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Traveling Abroad? A Usability Assessment of Travel Sales Websites

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Abstract

A study was conducted to assess the usability of travel sales websites and identify recommendations for improvement from an international perspective. Testing was performed on twenty participants that were non-US citizens, between the ages of 19 and 35, recruited from a university campus. The websites tested were Expedia.com, Orbitz.com, and Travelocity.com. Participants were given general instructions and a pre-survey to determine their demographics and level of Internet experience. Participants performed the task of finding flight itineraries for their home country, car rental information, and hotel accommodations on each website. Participants were requested to locate language conversion options where available. An observation log was maintained on participants. A post-survey and debriefing session was conducted. The average testing time for participants was 30 minutes. The results include a statistical analysis, future research and practitioner take-aways.

1. Introduction

Information and communication technology (ICT) researchers and practitioners are well aware of the cultural challenges brought by a global market [13 & 14]. Internet growth enables businesses to expand their customer base to international markets. Thus, businesses benefit from the explosion of Internet usage but may be challenged by how to best meet the needs of their multi-cultural customers [3]. Barriers to International usability can be defined as anything that poses a challenge to humans interacting with technology. Examples include poor organization of a web site and language conversion issues. Current usability literature focuses on guidelines in general for the Internet. However, there is a gap in the literature with regards to usability guidelines applicable to specific types of websites. Although research has been undertaken in the development of usability heuristics for hotel sales websites and in the development of usability recommendations for booking flights on travel sales websites, there is a need for research to develop usability heuristics specific to travel sales websites to meet their international customer base or specifically international users of travel sales websites [1 & 3]. The usability heuristics developed will need to take into account globalization and the need for websites to be designed for their culturally diverse customer base. Based on previous research by Carstens and Patterson (2005), the three travel sales websites tested were selected based on their popularity as the researchers' desire were to test sites that are likely used by international students to evaluate how well the websites meet their international user community.

The objective of the study was to test multi-cultural individuals to determine the usability from an international perspective of each of the

three travel sales websites tested. However, the usability testing does not address differences among different cultural groups. The study assessed the usability of the websites from an international travel perspective and identified recommendations for usability enhancement for each site. The recommendations identified focus on how global companies can design their websites to best meet the needs of their multi-cultural customer base. The study conducted is phase three of a four-phase study which will result in the development of usability heuristics specific to travel sales websites and is discussed in the future research section of the manuscript. Participants were recruited from the university campus because over twenty percent of the students from this particular university are international students representing one-hundred countries that travel to their home country on school holidays. Formal usability testing and questionnaires were utilized for the study.

2. Literature Review

2.1 International Human-Computer Interaction

The field of international HCI has become increasingly popular with the globalization of business [3]. Even cultural barriers in verbal communication between individuals from different English-speaking countries can be difficult [9]. Barriers to international HCI are concerned with language but other factors as well since perceptions of a site are related to culture rather than the actual design of a site [6].

Usability enables users of software to easily and quickly perform their tasks [5]. Practical acceptability is the examination of the usefulness of the ICT in regards to the technology being able to carry out needed user functions [8]. Therefore, if an individual is British and uses the search feature on an American web site to find the term "organisation", the site should accommodate the language of the user even if it is not in the language of the designer of the site (e.g. Americans spell the term using a "z" instead of an "s" as in "organization"). Companies should be interested in how pleasant a customer's on-line shopping experience is as this could impact sales. The literature asserts that cultural barriers do exist and greatly vary from culture to culture [6, 12, 13 & 14]. The literature suggests common barriers to ICT consist of poor organization, hard to use features (not user-friendly), frustration, confusion, non-usable features, trust, religion, ethics, and lack of satisfaction [2, 6, 8, 9 & 12].

Several factors have been identified for websites that utilize language conversion tools [11]. In the process of language conversion, organizations typically translate text but consideration beyond text is not often given. The other features of a site that need consideration are numbers, currency, date and time formats. Images such as the Macintosh "trash" icon would not transfer well to a British individual as it could be mistaken with a postal box. Colors and metaphors should be part of localization efforts for different cultural groups such as the use of "red" in the United States symbolizing danger and in China symbolizing happiness. The flow of text may also vary for different cultural groups and therefore must be translated accordingly on websites [10].

2.2 Ecommerce Usability

For the area of e-commerce, five design features have been identified as security of data, ease of navigation, appropriate explanatory text, search tool, and product and service price concerns [15]. Other features ranked high by e-commerce users such as technical issues along with the readability, comprehension and clarity of information presented on sites [16]. Another

study identified perceived problems of e-business systems which overlap with others such as finding accurate information in a timely manner and challenges in locating the required information [7]. The study suggests issues with completing ongoing transactions and locating adequate electronic service functions to complete online transactions. Usability problems also exist in hypermedia with regard to irrelevant information, cognitive overhead and disorientation for the user. Through additional studies, challenges in terms of e-commerce usability can be identified to aid developers in the enhancement of quality of future websites.

3. Methodology

A usability study was conducted because of the need for more usability literature specifically addressing an international perspective to website usability. Therefore, the study recruited international students to identify international flight itineraries, car rental and hotel accommodations on three different travel sales websites. The usability study consisted of six steps involved in preparing and performing the usability study on travel sales websites.

The first step was to identify the tasks to test at a university in the United States. The twenty participants were international students from various countries (refer to Figure 1 in Section 4.1). The task consisted of having participants go to three travel sales websites, Expedia.com, Travelocity.com, and Orbitz.com, one at a time to find a round-trip international flight itinerary to their home country. To control for order effects, the participants were randomly assigned to one of three groups that visited each of the three sites in a different order. A 3x3 mixed factorial design was utilized for the study. Criteria were given to each participant to make sure that itineraries selected followed as closely as possible to specific dates and times. The flights selected were to accommodate one traveler. The participant was requested to identify a rental car to use for one day specifically for the day or night of arrival to their home country. Participants were requested to identify a hotel room for the first day or night of arrival to their home country. The participants were timed to identify the length of time it took to find a flight, hotel and car utilizing each website tool. After information was written down by each subject on a flight, car rental, and hotel room, participants were asked to list the available language conversion options for the two of the three websites that offer this feature. The language converter task was also timed for each participant. A pre-survey and post-survey was provided to the participants enabling the gathering of qualitative data consisting of demographic data, familiarity with the websites tested and recommendations for improvement for each of the websites.

The second step of the study was to obtain approval to conduct a test on human participants through the Institutional Review Board at the university where the testing took place.

The third step was to develop documentation for the usability test consisting of the following:

(A) Pretest Instructions: General instructions were given to participants to read prior to being given the actual testing instructions. Information on the general instructions included a thank-you to the participant for being part of the study and study environment information such as the purpose of the session, risk level for the experiment, and steps that the participant will go through as part of the testing session.

(B) Pre-Test Survey: The survey asked the participants to supply their background regarding familiarity with each of the three travel websites tested along with their Internet experience. Demographic data was also collected regarding age range, ethnic background, gender, and affiliation with the university.

(C) Participant Written Instructions: This detailed the specific instructions to be followed in the testing. For instance, participants were instructed to visit each of the websites in a specific order to identify a flight itinerary, car rental information, and hotel room for their home country. Furthermore, participants listed

all information found on available language conversion options for each of the three websites tested.

(D) Informed Consent Form: The form contains the agreement between the experimenter and the participant to be signed by both parties. The form indicates that participation is voluntary and that the participant can withdraw from participation during the study.

(E) Experimenter Form: The form contains an area for the experimenter to document the participant's comments and actions during the test. The categories on the form are the amount of time taken for each participant to identify a round-trip international flight, car rental and hotel room for each of the three websites. In addition, a category existed to record the time it took each participant to locate language conversion information on the two of the three websites with this capability. Furthermore, all experimenter's comments, user's actions, and user's comments were recorded on the form.

(F) Post Test Survey: The survey contained a questionnaire for the participant to fill out upon completion of the usability test. This additional information provided open-ended questions enabling the participant to indicate what was liked best, least, and recommendations for future improvement for each site, along with any other comments. The closed-ended questions were also included on the survey regarding an option of "Like" or "Dislike" for each of the three websites in regards to website colors, page layout of the screen and overall ease of using the website.

The fourth step involved the recruitment of participants which was performed through electronic means such as class email distribution lists and student email forums. The participants consisted of only international (non US Citizens) undergraduate and graduate students. Each participant was paid five American dollars to take part in the study. However, it was strictly voluntary for participants to participate in the study.

The fifth step involved identified how the study would be carried out. The usability testing was conducted in an office setting with only the participant and one experimenter present. A computer with Internet connection was provided for the participants to perform the study task. The twenty participants were randomly assigned to one of three groups. Each group contained six to seven participants. Since there were three different travel websites tested, each of the three groups utilized the three websites in a different order to minimize the learning curve effect. Regarding confidentiality, the data collected did not contain the names of the participants or any unique identifier of the participants. Although information was collected on a students' home country, the university testing site has multiple students from any one county and therefore data collected cannot be linked to a person's name.

The sixth step involved the analysis of the usability study data and post-survey data. A Friedman Test was conducted to determine statistical differences between the times to identify flights, hotel accommodations, and car rental information. *A factorial design was used but because of non normality and small samples an ANOVA was not used for the statistical analysis. Therefore, a Friedman test was run on the quantitative data.* If a participant could not complete a task, a +5 minute penalty was assigned in order not to skew the data. Follow-up pairwise comparisons for the times for booking flights, hotel, and a car were conducted. Traits evaluated by "like" and "dislike" identified for characteristics of each website tool consisting of website colors, page layout and ease of use were evaluated using a Chi Square analysis. Data was collected during the study through the information received from the experimenter form, pre-survey, post-survey, and debriefing session enabling researchers to identify recommendations for usability improvements to travel sales websites. The pre-survey also enabled the researchers to have background information on each participant to identify trends.

4. Results

The results of the usability study revealed many trends in user preferences of travel sales

websites. The results section contains the pre-survey results, statistical analysis and post-survey results. Recommendations for improvement to enhance usability in the design of travel sales websites were also identified.

4.1 Demographics & Internet Usage

Data consisting of participants' ethnic background is displayed in Figure 1. The age range of the participants was between nineteen and thirty-five years of age. Eighty percent of the participants were nineteen to twenty-five years of age and twenty percent of the participants were nineteen to thirty-five years of age. Of the twenty participants, eighty percent of the participants were male with twenty percent of the participants being female. Of the twenty participants, eighty percent of the participants were undergraduate students with the remaining twenty percent being graduate students. Of the twenty participants, eighteen (ninety percent of the participants) claim to have "significant experience" with the Internet and the remaining two participants (ten percent of the participants) claim to have only "some experience" with using the Internet.

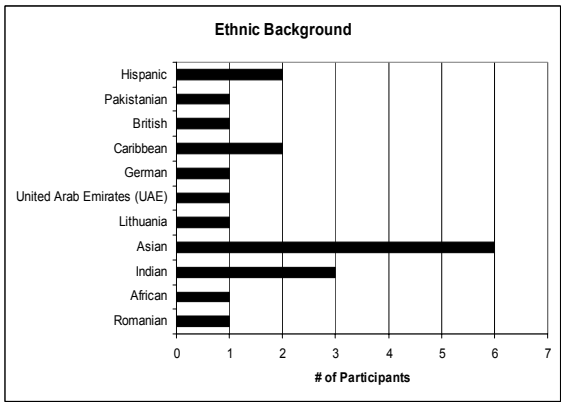

Figure 1. Ethnic Background of Participants

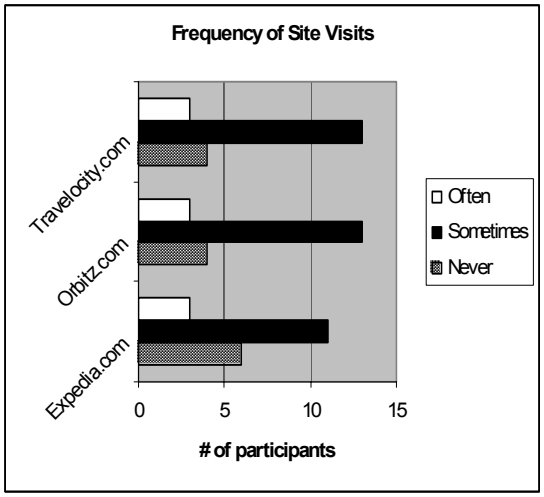

Figure 2. Participants' familiarity with the three travel sales websites

Of the twenty participants, twelve (sixty percent of the participants) have visited all three sites tested prior to the study. Figure 2 displays the frequency of visits and therefore familiarity participants had with each of the three websites tested prior to the study.

4.2 Usability Testing

The usability testing data was statistically analyzed. Since the data was non normal and the sample size less than 30, a Friedman Test was conducted to identify the results for the times after correction of +5 for the participants who could not complete a task within the study. Table 1 displays the p-values for the Friedman Test to test for significance in the times it took for participants to book a flight, car, hotel and to locate the language converter tool on the website. However, Expedia does not have a

language converter option. Since there was a statistical difference between the sites for booking round trips, a follow-up pairwise comparison was conducted to find out which sites were different resulting in a p-value = 0.166 when comparing Travelocity versus Expedia, p-value = 0.071 when comparing Orbitz versus Expedia and p-value = 0.020 when comparing Orbitz versus Travelocity. The pairwise comparisons suggest a significant difference between both Travelocity and Expedia with Orbitz. Possibly if the sample sizes had been larger, there could have been a statistical difference between Travelocity and Expedia as well. The relative average times for the tools to book a flight were Travelocity Time<Expedia Time<Orbitz Time.

Table 1: Friedman Test p-values for comparing the 3 websites

Participant Task	P-Values
Booking Round Trip Flight	0.025
Booking a Rental Car	0.703
Booking a Hotel	0.442
Locating the Language Converter*	0.593

*Comparison of the language converter was only between Travelocity and Orbitz as Expedia does not have a language converter tool.

4.3 Post-Survey

The post-survey consisted of both closed- and open- ended questions. The survey was conducted to obtain participant's feedback on specific usability features along with recommendations for improvement on each of the three websites. Tabulated statistics were identified for different characteristics of each website tool consisting of website colors, page layout, and ease of use (see Table 2). The Chi-Square test was conducted to identify significance which is displayed in Table 2. The like or dislike of the colors for the different website tools were not statistically significant. However, the page layout and the ease of use for different website tools were both statistically significant at the .05 level.

Table 2. Tabulated Statistics for Colors, Page Layout and Ease of Use and p-values.

Tool	% Liked Colors	% Liked Page Layout	% Liked Ease of Use
Orbitz	31.37%	25.64%	26.32%
Travelocity	31.37%	30.77%	28.95%
Expedia	37.25%	43.59%	44.74%
p- values	0.253	0.046	0.035

Expedia had the most number who liked the layout followed by Travelocity followed by Orbitz. For ease of use for the different website tools, Expedia had the most number who liked the ease of use followed by Travelocity followed by Orbitz.

Many recommendations for website improvement were provided by participants in the post-survey. Implementation of the recommendations could provide better service to the international user community of the three websites. An overview of the comments for each website follows.

For Expedia.com, recommendations were given to change the country title into the respective language when using the language conversion tool. It was suggested that the search results show a comparison of prices for searches on other sites similar to insurance sites displaying quotes from multiple companies. Another suggestion was to expand the car search database to contain more information to make it less limiting. Furthermore, it was suggested to increase the database for any Asian related travel. A participant also added that the language conversion tool should list "Spanish" as one of the language conversion options.

For Orbitz.com, several recommendations for improvement were provided by participants. A suggestion was to expand the international travel database to enable more options for travelers to choose. There was also a recommendation for the site to provide more information when providing search results. Another recommendation was to add "Spanish" as one of the language conversion options. A suggestion was made to make the navigation on the website more simplistic. Additionally, a recommendation was made to set-up the site more similar to Expedia.com.

Recommendations for improvement to the Travelocity.com website were also made. It was suggested that the color scheme be changed to utilize colors that aren't as dark. It was recommended that the font size also be increased. Another suggestion was to have less clutter on the site through having fewer advertisements. Suggestions were also on capturing more data and therefore providing more information on search results along with enhancing the amount of information in the international travel databases. The idea to have price comparisons revealing data from other travel sales sites as well as part of the search results was once again suggested. Adding of a website mapping feature was suggested. However, the site does contain a "Map Center" but it was a feature that the participant that gave this recommendation was unable to locate.

5. Conclusion

The objective of the study was to test multi-cultural individuals to determine the usability from an international perspective of each of the three websites tested. The statistical analysis determined that the page layout and ease of use for the websites was statistically significantly different at .05 level. Furthermore, there was a statistical difference in the times for participants to book flights on the different website tools at the .05 level. The usability testing does not address differences among different cultural groups due to the small number of participants within each cultural group. Therefore, a limitation of the study was that the differences between cultural groups could not be identified. Differences among the sites for participants liking or disliking features of a site are an interesting finding. Future research needs to be conducted to determine if the differences in likes and dislikes are a result of cultural differences among the participants or are cross cultural. A larger study that incorporated 10 or more participants per cultural group could help to sort this out.

The study results presented are from phase three of a four-phased study. The first phase of the research focused on general usability testing of the same three sites utilized in the current study. The second phase of the research focused on testing complex tasks such as finding flights, car rental information, and hotel accommodations during the holiday season on three different airline companies' sites. The third phase of the research is the current study which focused on how effective is the usability on the three travel sales websites when traveling abroad to bring in an international focus to the research. The fourth phase of the research will consist of the following four components a). Performing different analyses utilizing the data collected from phase one through three of the research; b). Validating the results of the additional analyses through performing a usability test that takes into account both simple and complex tasks with regards to international travel; c). Developing usability heuristics for designers of travel sales websites; d). Conducting a usability study to validate the usability heuristics developed.

The study revealed insight into current usability gaps that have been turned into three opportunities for practitioners to enhance the design of their travel sales website. Practitioners prior to website implementation must perform simple measures due to globalization. First, all sites should accommodate multiple cultural groups through providing language conversion tools. Secondly, companies must research different languages that their customers speak

and implement language conversion tools for these languages. Third, usability testing should be conducted to be certain that language conversion tools work appropriately. This can be accomplished through changing all the text on a screen versus just a portion of the text along with images, numbers, currency, date, time formats and the flow of text and colors when appropriate. It may be confusing to users of the site if the text is only partially converted to the desired language. Fourth, the icons used to signal that a language conversion tool exists should be placed on a website where international customers can easily see that this feature exists such as at the top of a site. With globalization in today's business environment, companies should make every effort to ensure that international customers are accommodated to ensure global success.

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DMARC: A Framework for the Integration of DMAIC and DMADV

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Abstract

In order to tackle variation and defects proactively, the initiative to achieve six sigma level of quality is being infused into the design of new products using the DFSS methodology, through systematic models such as DMADV. This research attempts to clarify the nature of DMADV and the traditional DMAIC approaches by presenting a framework, DMARC, which induces the identification and the assessment of the need to re-visit the design of an existing process or product that is deemed to be beyond generic improvement efforts. The DMARC framework integrates the classic DMAIC methodology and the DMADV model to achieve a greater long-term results and a more robust system. To exemplify the possibility of the achievement of greater results from the implementation of the DMARC framework, this paper studies a real – life industrial case that has tackled the downtime of the Launch Pad Meteorological System at Launch Pads 39A and B at Kennedy Space Center.

1. Introduction

Companies of every contemporary industry, major or minor, strive against fierce competition to stay afloat the ocean of product or service providers that cater to the quintessential customer. Even those companies that have been complacent of their position in their respective industries for a long time are realizing the threats to their dominance from advancing rivals. Managing for quality has exponentially risen in criticality as the demand in quality increased. Traditional management theories are being phased out to overcome the drawbacks that tag along.

Quality Management (QM) concepts have been adopted dramatically over the past few years to counter the rigidity of aged, classical management theories. Developing companies had realized that the primary weapon to stay in or ahead of competition is to please their customer by striving to make products or provide services that satisfy their demands or even exceed their expectations. It had dawned upon most sectors of industry, both service and manufacturing, that trying to reduce the current or persistent defects and variation was not enough to improve quality, but to tackle the problems at the root - during design. Thus, the concept of Designing for Six Sigma standards was born to take the Six Sigma methodology to new heights. Design for Six Sigma (DFSS) is implemented using models like IDOV (Identify, Develop, Optimize, Verify), TRIZ (Theory of Inventive Problem Solving) and DMADV (Define, Measure, Analyze, Design, Validate).

The traditional DMAIC model is used to solve issues dealing with current existence of defects and variation, whereas DMADV is used to design new products. In a real – life industrial environment, there might arise a case in which a project adopts the DMAIC approach to improve a process, only to realize that the best improvement gains will result from employing a Design for Six Sigma, or DMADV approach. The best solution then lies in the integration of the DMAIC model with DMADV tools and the concepts of design or re – design. Such an integration of the DMAIC and DMADV approaches, DMARC, is discussed in this research paper.

2. DMARC

DMARC stands for five phases – Define, Measure, Analyze, Re – Design, Control. It portrays a path that can be used in a case that follows a traditional DMAIC (Define, Measure, Analyze, Improve) approach in the improvement of a process, product or service but upon recognizing that the process is beyond generic improvement, considers the alternative to re – design instead. DMARC is neither a novel nor an out – of – the box concept, but a framework that explains one aspect of the DMAIC methodology. It provides an option for the consideration of the re – design of a process, product or service, which has been identified in the course of the Analyze or the Improve phase, to be beyond continued improvement efforts. DMARC integrates the DFSS approach and tools utilized in the DMADV model into DMAIC, demonstrating a shift in the nature of the mindset of the project team as it employs the re – design alternative. The framework in the form of a process flow is described in Figure 1.

This framework describes the approach of a typical DMAIC project, dealing with an existing process, product or service that has completed the Define and Measure phases and is in the Analyze phase, considering options for improvement as it progresses into the Improve phase. The analysis of Key Process Input Variables (KPIVs) and process variation leads to the development of initiatives that attempt to improve the process by elimination of the variation. When improvements made or projected do not satisfactorily achieve the goals of the project or leaves scope for persistence of variation, re - visiting the fundamental design of the process is to be considered. A design change to a process, product or service means more expenditure of resources, a shift in the nature of the project and request for support from the management and most importantly, the customer. A decision to re – design the process or product should be proposed based on numerical, statistical data. Decision – making tools, such as Analytical Hierarchy Process (AHP), benchmarking or cost – benefit analysis of a design or equipment change assist in assessing the value of such an effort in comparison to viable initiatives of improvement to the existing system. In the case of a decision to re - design being considered to be more fruitful, then the classic DMAIC model takes a different path, the DMARC path, which incorporates the DFSS approach for re – designing purposes. The Re – Design phase comprises of the Measure –Analyze – Design – Verify phases borrowed from the DMADV model. The Define phase of DMADV is not necessarily to be re – lived, as the main project objective is unchanged from the beginning of the project: to provide what the customer has asked for. In the Measure phase, the Voice of the Customer (VOC) is captured in a DFSS perspective to capture customer needs in further depth, and in alignment with the company and project objectives. The cycle culminates after the development of the new design and the verification of its abilities to achieve the desired results.

3. Decision to re - design

How do companies make the decision on whether an existing process or service can be improved upon, or it is beyond improvement such that the very design has to be looked into for change?

Initiating an effort to design or re – design requires management support and customer approval, which is acquired only through the use of numerical evidence. The benefits of undertaking such is to be ascertained through thorough study of the expenditure (financial and resources) involved and adequate comparison of the alternatives. Tools like Analytical Hierarchy Process (AHP) help determine the suitable use of redesign alternative over the improvement option.

Analytic Hierarchy Process is a multi – criteria decision making tool that was developed by Thomas Saaty[2]. It can be used to make critical decisions based on numerical evidence in the form of the comparison of alternatives against one another to select the one that carries most weight. In AHP, a hierarchic or network structure is used to simplify and represent the decision problem with its criteria and

alternatives. At each level of the network or hierarchy, pair wise comparison values of decision elements are used to determine the priority weights of the criteria. The relative weights are aggregated to obtain the final scores to see if the initiative to re – design outweighs the initiative to improve upon the existing design. A flow chart of the overview of the steps involved in the AHP process is described in Figure 2.

A generic AHP network that can be used to make the decision (based upon priority weights of the factors) on whether to pursue the re – design of an existing process or to improve upon it is described in Figure 3. The network shows the comparison of the two decision alternatives - "Improve Upon" and "Re – Design', based on selected criteria (factor(s) A, B, C and D). By weighing the importance of each criterion against the others in pairs and aggregating the relative weights, a quantified score for each of the alternatives is calculated and the one with greater weight is favored as the final decision.

4. Case study – Launch Pad Meteorological System

Since the late 1960s, Pads A and B have served as backdrops for America's most significant manned space flight endeavors – Apollo, Skylab, Apollo-Soyuz and Space Shuttle.

Of all the numerous launch pads that have been used since the advent of America's space flight endeavors, Pads A and B at the Kennedy Space Center, located in Cape Canaveral, Florida, are the operational ones from which the Space Shuttle is being launched.

Both the launch pads are equipped with a meteorological system that provides constant weather data that is used to make a decision on a space shuttle launch and landing, provide weather warnings and advisories for the Kennedy Space Center and Cape Canaveral Air Force Station Operations and many more. The meteorological system at each pad consists of equipment mounted on two 60 foot weather towers, located at Camera Sites 3 and 6, as shown in Figure 4.

NASA's Space Shuttle Program prime contractor, United Space Alliance (USA), is responsible for the management and maintenance of the meteorological system of the launch pads A and B, through its Ground Operations Engineering division.

4.1. Problem statement

It is an absolute NASA requirement that the Launch Pad Meteorological System (LPMS) be operational during all launch operations. The meteorological system experiences downtime when an unplanned event causes the system to go offline or for scheduled preventive maintenance of the equipment. Over the last few years, the LPMS saw an excessive amount of downtime due to field equipment defects. Baseline data gathered between years 2001 – 2003 (see Figure 5) from USA showed that there has been a worrying increase of system downtime, with a record high of 134 days in 2003.

The downtime data was used to determine the Overall Equipment Effectiveness (OEE), which is the amount of time the system is producing credible and accurate data.

For around – the – clock operation, the LPMS has to have an optimum OEE of 98%. Cumulative data from years 2001 to 2003 indicated an actual OEE of 71% for the three year span, identifying a need for improvement. In order to increase the OEE to an optimal level, the system downtime period required effective reduction.

Analysis of downtime occurrences showed that in 2003, 70 % of the system downtime was due to field equipment related defects resulting in unscheduled downtime for either maintenance or repairs or transducer replacements. It seemed critical that the factors for unplanned and planned downtime be studied and analyzed for providing solutions to the overall improvement of the effectiveness of the system.

4.2. The project

A Six Sigma team was formed consisting of USA's instrumentation system engineers and technicians, headed by a Six Sigma black belt, to undertake the initiative to improve the effectiveness of the LPMS in reporting accurate and reliable data with decreased downtime. The project was sponsored by the Ground Operations division of USA at Kennedy Space Center with an expected lifespan of seven months. As part of the Six Sigma culture that has been adopted by USA for problem solving and continuous improvement, the traditional DMAIC path was utilized as the approach to the project.

4.3. Major findings

The LPMS downtime reduction project had adopted the DMAIC approach to produce the best sustainable improvements through their efforts. They had set high goals to achieve, such as the increase of the Overall Equipment Effectiveness (OEE) from 71% to 90%, elimination of unplanned downtime etc. At the end of the Improvement phase the project team had reported an OEE increase of only 4 %, which was far below the expected goal. The team had recommended in the Analyze phase that in order to achieve project goals of 90% and avoid recurring maintenance problems, a design change i.e. replacement of the transducers with benchmarked models. The recommendations were not followed probably due to apprehension of the idea of re – design of the process and uncertainty of the compatibility of the replacement equipment with the current system, overshadowed by budget constraints.

The possibility of the project team having pursued the DMARC framework was discussed after reviewing the case study. Based upon the conclusions of the Define, Measure and Analyze phases, the team could have weighed the priorities of the customer and project to make a decision quantitatively, using decision making tools such as AHP, on whether to pursue continued improvements on the existing system retaining the current configuration, or the alternative, i.e. re – design of the process by testing and inducting benchmarked alternative equipment. Following the model described in Figure 3, the alternatives would be weighed against each other based on the pair wise comparisons of the importance of the customer requirements in the case of the LPMS project team (factors such as minimum risk, minimum expenditure, maximum process capability and maximum financial benefit). AHP calculations favored the re –- design alternative with an assigned value of 0.538, over the improvement option (0.462). By employing the Re-design phase, team would have used Design for Six Sigma tools and methods as they would progress through the Measure, Analyze, Design and Verify (M,A,D,V) phases that consist the Re-design path.

In the Measure phase, using Quality Function Deployment (QFD) i.e. the House of Quality (see Figure 6) the team would have translated detailed customer expectations into product specifications. In the Analyze phase, by performing benchmarking activities, the team would have compared the alternative models of the equipment to the existing ones, tested and verified the expected gains from the configuration change. An example of the projected benefits was demonstrated where the Climet 011 – 4 wind speed and Climet 012 – 16 wind direction transducers were compared with a benchmark replacement, the Vaisala WS425 wind speed and direction sensor. Figures 7 and 8 show the value stream maps of the transducer calibration cycling process, before and after the change in the equipment configuration. The maps describe the reduction of non – value added process (NVA) and the A cost – benefit analysis was performed to analyze the case in which the current models were replaced with the alternative (Vaisala WS425), then an average of $ 5400 per calibration cycle would be saved annually, eventually compensating for the costs incurred during initial investment (see Table 1) . The configuration change would also increase the OEE to, at the least, close to the project goal of 90% reflecting the drastic decrease in periodic maintenance and transducer defects due to lack

of moving parts and being newer, more reliable models. The Design phase would involve induction of the replacement equipment as prototypes, performing pilot runs to understand the behavior of the new process and designing experiments to assess the variables that impact the response variable of the process. The Verify phase would involve simulation and pilot testing of predictive models to verify that the design changes adapt to the system in real – time. If the pilot runs prove successful to have improved the system, the re – design of the process would be implemented with all necessary documentation. Control procedures to monitor process capability and process variation would be established in the Control phase to sustain the improvements achieved from the design change, thus culminating the DMARC cycle.

5. Conclusion

The DMARC approach is useful when a typical DMAIC project shifts its nature from an initiative dwelling on just improvement, to the modification or re – design of an existing process.

An initiative to re – design an existing process often, if not always, is confronted with initial skepticism and apprehensions of exorbitant expenditure, project failures etc. Some companies do realize the imperative need for the re – design of a process or product or service, but steer clear of embarking on such efforts probably due to a hefty investment price tag and uncertainty of compatibility with the current system etc. The industrial conglomeration at Kennedy Space Center is a typical example – most processes or operations affect multiple systems or even organizations in varying magnitude that any change in design of a process would have to conform to the function of many. If a process is essentially functioning, though it has errors, it becomes the responsibility of the pertaining system to weigh the importance of a modification with respect to long – term benefits. It is always preferred that a process be improved upon its current configuration and nature without a design change, but if such an initiative is projected, with quantified data, to reap long – term benefits, then an initial investment might be worth the effort. The resistance to the re – design effort has to be broken down through solid assurance of the expected gains.

In cases of persistent problems with equipment and systems, an attempt to modify or upgrade the equipment is a re – design effort that comes with benefits such as reduction of maintenance issues and increased efficiency, but also with a higher price tag and resource expenditure. Whether such an effort is worth the time and money is for the project team and customer to decide.

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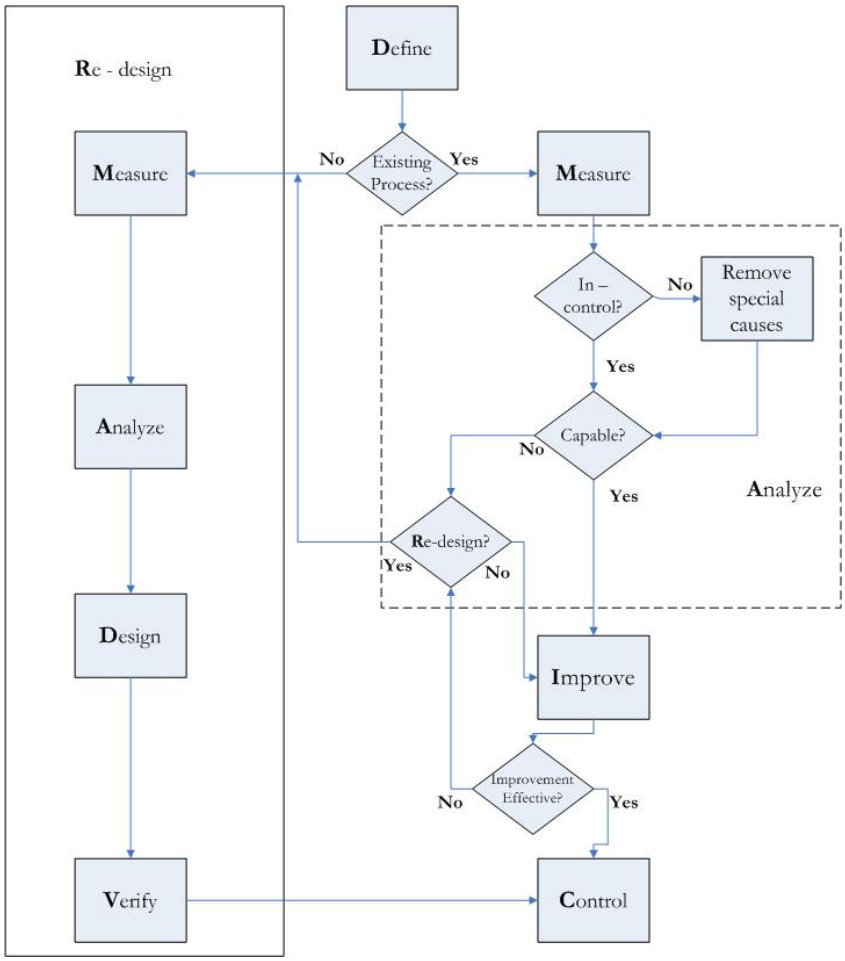

Figure 1. Flowchart of the phases of DMARC

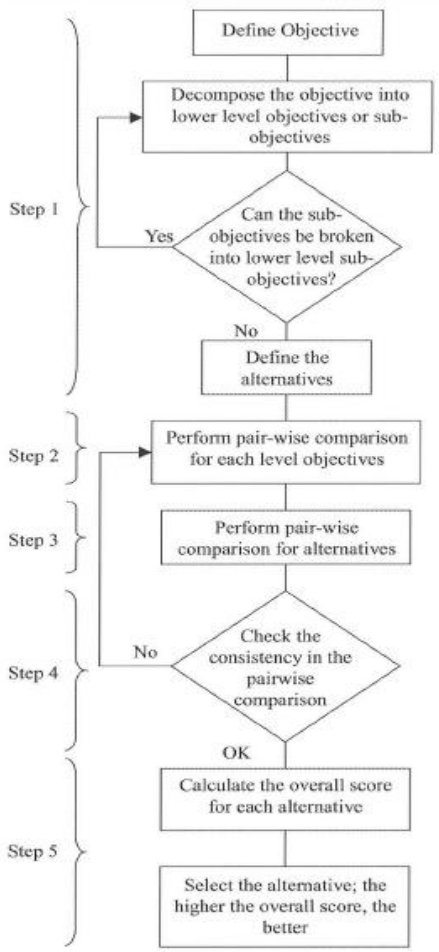

Figure 2. AHP Flow Chart [1]

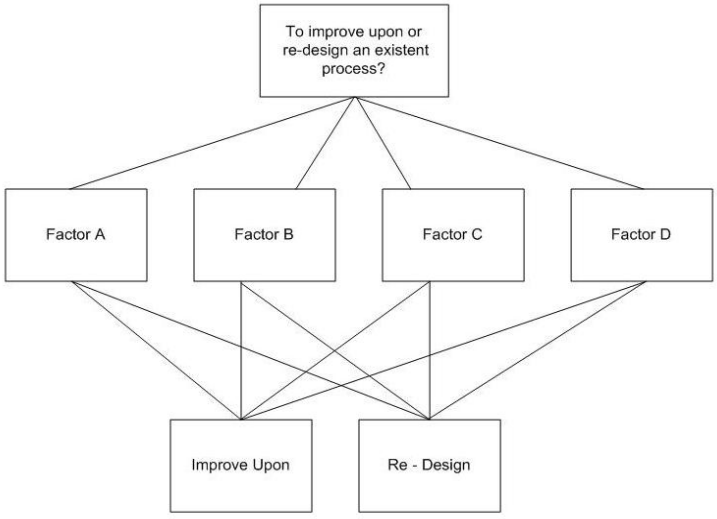

Figure 3. Generic AHP network for decision - making on re - design

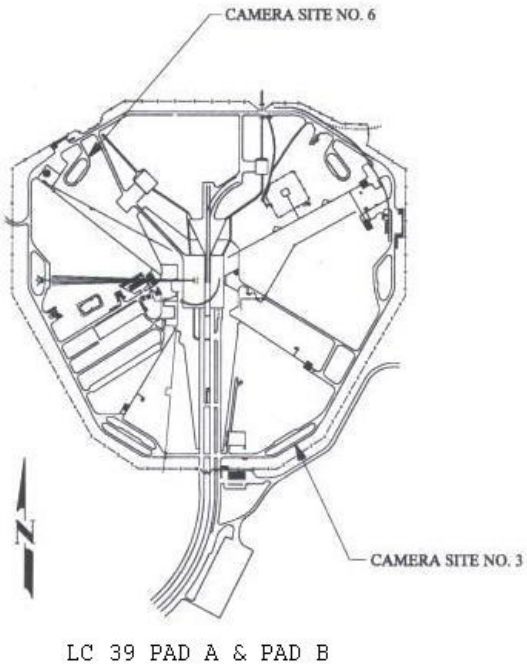

Figure 4. Location of LPMS

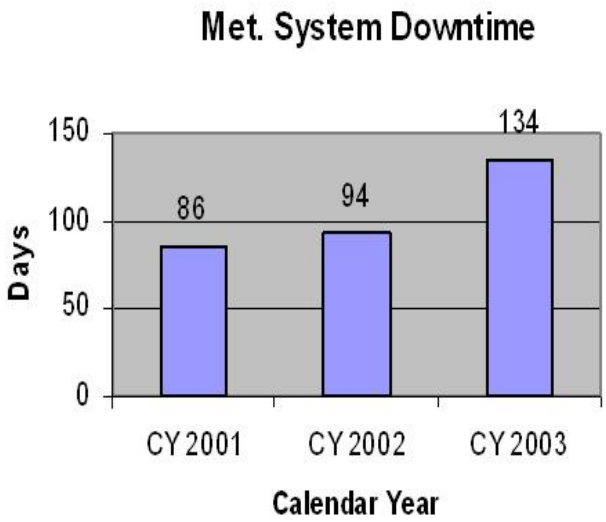

Figure 5. Comparison of Met. System downtime (in days) from 2001 – 2003

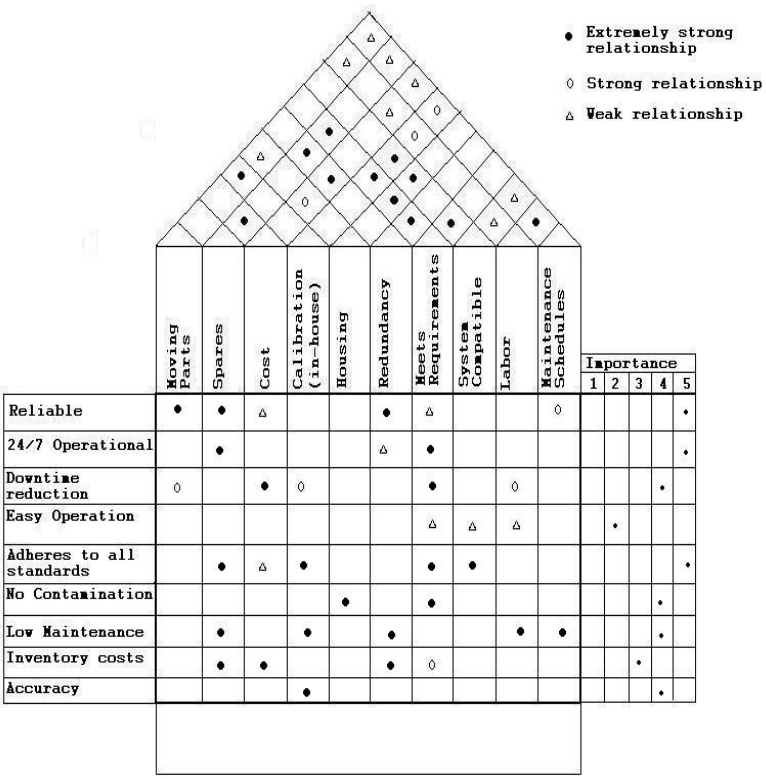

Figure 6. Example of House of Quality based on customer requirements of the LPMS

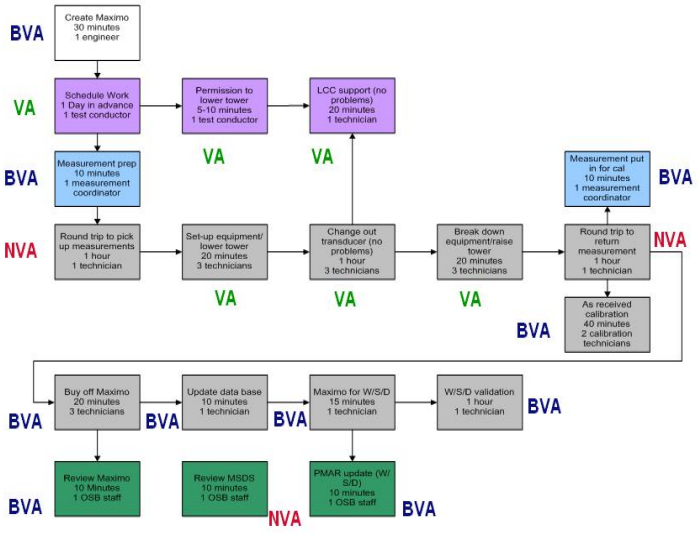

Figure 7. Transducer (Climet 011-4 and Climet 012-16) calibration cycle process map

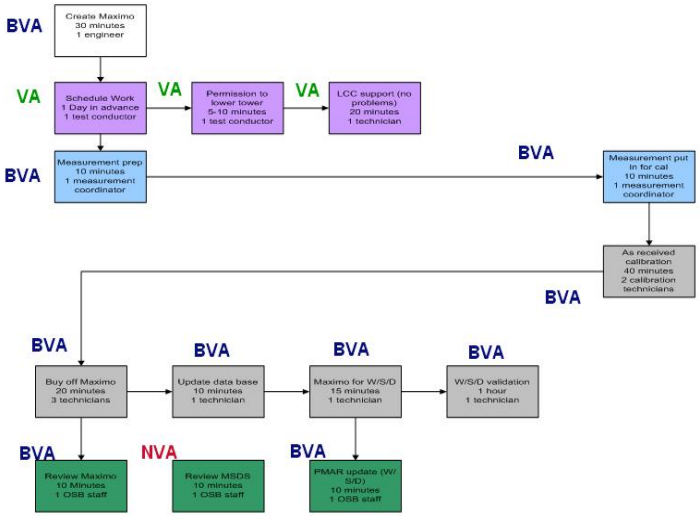

Figure 8. Transducer (Vaisala WS425) calibration cycle process map, post re - design

Table 1. Cost – Benefit Analysis of an alternative

	Equipment		
	Vaisala WS425	Climet 011-4	Climet 012-16
Purpose	Wind Speed Wind Direction	Wind Speed	Wind Direction
Quantity required (each Pad)	4	4	4
Moving Parts	None	Yes	Yes
Periodic Maintenance	None	5 months	5 months
Protection	None	Housing	Housing
Accuracy	± 3% of true value or ± 0.30 mph	± 1% of true value or ± 0.15 mph	± 1% of true value
Wind Velocity Range	0-144 mph	0 - 100 mph	N/A
Threshold	0 mph	0.6 mph	0.75 mph
Wind Direction Range	0-360 deg	N/A	0-540 deg
Unit cost	$1,800	$475	$625
Housing cost	0	$1,250	$1,250
Total transducer cost (housing and sensor only)	$1,800	$1,725	$1,875
Cal Cycle labor hours saved (out of 12) per transducer	4	0	0
Savings at $300/ labor hour per transducer	$1200	0	0

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Preparing the Contemporary Fire Officer: A National Professional Development Model

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Abstract

The success of a contemporary fire department is in large part determined by the preparation of the fire officers whose role it is to manage and lead the organization both on and off the emergency incident scene. The preparation of those who aspire to serve in these mission-critical positions is thus a subject of significant interest. While the path to preparing for professional and personal success is well defined in many fields, such as medicine, law, and accounting, it is less well defined with respect to fire officers.

The traditional routes of preparation include (1) completion of training programs, (2) certification programs, and (3) college and university courses. Unfortunately, an integrated professional development system that incorporates these three components of preparation has traditionally been lacking. Additionally, fire officer candidates have often found that preparatory activities in one arena are not "valued" in the other arenas.

This paper will examine the lack of coordination that has existed in fire officer development and the National Professional Development Model that has been developed under the Fire and Emergency Services Higher Education (FESHE) initiative of the National Fire Academy (NFA) and United States Fire Administration (USFA) to address this issue and facilitate the more effective and efficient preparation of fire officers throughout the nation. In addition to the research that the authors have conducted on contemporary fire department management, one of the authors served as Chairman of the National Fire Academy Board of Visitors throughout the development and implementation of the FESHE National Professional Development Model.

1. Introduction

The contemporary fire department provides an expanded array of mission-critical fire and emergency services within the communities that it serves. A major determinant of the capabilities and readiness of the fire department and consequently its effectiveness, efficiency and safety is the preparation of the fire officers that manage and lead the fire department members both on and off the incident scene.

In recent years the authors have engaged in research related to enhancing organizational effectiveness of contemporary fire and emergency service organizations. An integral aspect of this work has been the roles and responsibilities of the contemporary fire chief and the preparation of candidates for this position. The evolving scope and services of the contemporary fire department require that fire officers possess the technical, human and conceptual skills necessary to ensure the effectiveness, efficiency and safety of the departments that they manage and lead.

2. Professional preparation of fire officers

Most professions have a well established and understood process through which candidates prepare to enter the profession. Examples of this

would be the recognized professional preparation to become an accountant, a lawyer, an engineer, an architect, a doctor, or a nurse. Typically, a specific and coordinated system of training, education and certification is utilized in preparing individuals to enter these respective professions.

Unfortunately, this has not been the case when it comes to the preparation of fire officers. The traditional preparation routes for fire officers have included (1) training, (2) certification and (3) higher education, as separate and often distinct systems. Dr. Denis Onieal, Superintendent of the National Fire Academy, discussed this issue in a position paper designed to raise this issue for consideration and action. In this paper he identified the challenges of the current separate systems of preparation, examined existing preparation systems and articulated the importance of working towards the development of a coordinated system of fire officer preparation.

2.1. Preparation through training

An essential element of the preparation of any member of the contemporary fire service, including fire officers, is the training that is available at the local, state and national levels. Members of the fire service participate in classroom and practical training within their fire departments and at local fire training academies. Much of this training is technical in nature in such disciplines as firefighting, rescue, hazardous materials, and emergency medical services.

Additional technical training as well as management and leadership training is available through state training systems and through the National Fire Academy. The National Fire Academy serves as the lead agency within the national system of fire training and has for a number of years provided system coordination and resources through its state training partners. The National Fire Academy, located on the National Emergency Training Center (NETC) Campus in Emmitsburg, Maryland, offers more than one hundred one- and two-week residential and regional delivery courses that have been evaluated and recommended for academic credit by the American Council on Education (ACE).

2.2. Preparation through certification

While training has served as the traditional preparation route for members of the fire service, including fire officers, in recent years professional certification has gained significant recognition and participation. Through certification, fire service personnel can have their competencies in terms of knowledge and skills assessed and validated through recognized and objective processes.

Certification is a process that is related to, but distinct from training. The focus in training is on the delivery of instruction deigned to enhance a candidate's knowledge, skills and attitudes. Certification is a process designed to assess whether a candidate has the necessary knowledge and skills to successfully enact the job performance requirements of a specified generic position, such as firefighter, fire service instructor, hazardous materials technician, or fire officer.

The National Fire Protection Association (NFPA) has developed and published a series of professional qualification standards that articulate the necessary job performance requirements (JPRs) in terms of prerequisites, knowledge and skills for various positions within the fire service. These professional development standards which articulate necessary position competencies for use in both the development and delivery of fire service training programs and the development of certification systems and evaluation of fire service certification candidates address fire service positions including firefighter, fire apparatus driver/operator, fire service instructor,

fire investigator, and fire officer. The NFPA 1021 - Standard for Fire Officer Professional Qualifications articulates required competencies for four levels of fire officer: Fire Officer I (Supervising Fire Officer); Fire Officer II (Managing Fire Officer); Fire Officer III (Administrative Fire Officer); and Fire Officer IV (Executive Fire Officer).

Two national accrediting organizations, the National Board on Fire Service Professional Qualifications (NBFSPQ) and the International Fire Service Accreditation Congress (IFSAC) accredit state fire training organizations to conduct fire service certification under their auspices. A growing number of fire service personnel who have received training through local, state and national training agencies have utilized these certification systems as a validation of their competencies.

2.3. Preparation through higher education

In recent years a growing number of members of the fire service as well as those desiring to enter the fire service have enrolled in courses and degree programs offered by local colleges and universities. Numerous institutions of higher education offer associate's and bachelor's degree programs in fire and emergency services and related disciplines. A review of these programs revealed that there are 86 associate's degree programs and 25 bachelor's degree programs that are regionally accredited and reported to and listed on the National Fire Academy's Fire and Emergency Services Higher Education (FESHE) website. Associate degree programs are offered by colleges and universities in 35 states, with colleges and universities in 19 states offering programs at the bachelor's level.

States with significant fire service populations, such as California, Colorado, Florida, New Jersey, New York, North Carolina, Ohio, and Pennsylvania, have produced a greater number of available associate's degree programs. Several institutions are now offering programs on-line and through distance education. Thirteen colleges or universities, in 9 states, now offer related master's degree programs.

While many individuals interested in careers in the fire service pursue degrees in fire science or related areas, others major in such areas as business management or public administration. A college degree has become a requirement for advancement within the fire officer ranks in a growing number of contemporary fire departments.

3. Problems of traditional approach to fire officer preparation

The problems associated with the traditional approach to the preparation of fire officers derive from the fact that routinely the preparation routes of training, certification and higher education have functioned as separate systems without coordination. This often presents a perplexing dilemma to fire officer candidates and their fire departments in terms of determining which route(s) of preparation to pursue.

In essence the three separate systems of fire officer preparation represent "functional preparation silos," with each system often failing to value the other preparation routes. Sadly, this has been most prevalent in terms of colleges and universities not having the necessary articulation agreements to award credit, as appropriate, to students who have completed relevant fire service training and certifications. The significant increases in training requirements that have been mandated since the tragic attacks of September 11, 2001, and the certifications that will be required under planned "credentialing" initiatives will place further time and resource demands on fire service personnel and thus further exacerbate the existing "interoperability" that exists between fire service training, certification and higher education.

The lack of an organized system of fire officer development that is recognized, accepted and understood has yielded undesired outcomes from the perspective of both fire officer candidates and contemporary fire departments. Typical outcomes have included: personal confusion and frustration; increased preparation costs and time; excessive duplication of effort; and ultimately the failure of candidates to complete preparation as a fire officer, particularly the completion of a college degree.

4. Fire and Emergency Services Higher Education (FESHE) initiative

An essential part of the mission of the National Fire Academy has involved the development of management, leadership and advanced technical skills of members of the nation's fire service. The four-year Executive Fire Officer Program (EFOP) has become a recognized credential for senior fire officers. In 1999, the National Fire Academy leadership and staff with the strong encouragement and endorsement of its Board of Visitors embarked on the Fire and Emergency Services Higher Education (FESHE) initiative in the interest of leveraging its leadership competencies within the national fire training system to facilitate discussion and action to address the problems inherent in separate systems of training, certification and higher education. Initial participants in this collaborative initiative included coordinators of two- and four-year academic fire and emergency medical service degree programs.

Dr. Denis Onieal provided the visionary leadership to embrace this initiative, while Mr. Edward Kaplan successfully led the project and achieved recognition as the "Champion of FESHE." Dr. Robert S. Fleming, one of the authors of this article, served as Chairman of the National Fire Academy Board of Visitors during the development and implementation of the FESHE initiative and was thus afforded the unique perspective and opportunity to study and experience the FESHE experiment.

The mission of FESHE was to "provide an organization of post-secondary institutions to promote higher education and to enhance the recognition of the fire and emergency services as professions to reduce loss of life and property from fire and other hazards." The annual three-day FESHE conferences now include participation of fire and emergency services related degree programs, state and local fire service training agencies, and national fire service organizations. Ongoing FESHE activities now include standing FESHE committee meetings and state and metropolitan FESHE summits.

In a relatively short number of years, a number of significant FESHE accomplishments including the development of national professional development models, a national professional development matrix, and model curriculum and course outlines have facilitated remarkable progress towards the development of a coordinated system of fire service training, certification and higher education. Recent involvement of the major fire service publishers in the FESHE conferences and committees will ensure that the necessary textbooks to support the model curriculum and its courses are available. A theme that runs throughout all of the FESHE initiatives is fostering the necessary cultural change to reduce the incidence of firefighter line of duty deaths.

4.1. National professional development models

A major goal of the FESHE initiative was the development of a national fire service professional development model. This model has been developed and is gaining acceptance in the training, certification and higher education communities. The model incorporates training, certification and higher education. Training is identified as the "ability to do the work" with a

"focus on the road," whereas education is identified as the "ability to manage" with a "focus on the horizon." The model incorporates the four levels of Fire Officer certification as well as associate's, bachelor's and master's degrees. "Fire chief" serves as the terminal position in the Fire Service National Professional Development Model.

The successful development of the fire service model led to the subsequent development of additional related professional development models for emergency medical services and fire prevention. The same process was utilized to develop the Emergency Medical Services Professional Development Model as were the aforementioned constructs related to training, certification and higher education. The terminal position in this model is EMS executive. The development of a fire prevention model is currently in process with the terminal position of fire marshal.

4.2. National professional development matrix

A second goal of the FESHE initiative involved the development of a national professional development matrix. While the National Professional Development Model provided the conceptual framework for fire officer professional development, the professional development matrix articulates the specific information necessary to operationalize the National Professional Development Model. The matrix crosswalks required competencies and collating NFPA professional qualifications standards with training and education. College and university courses along with NFA courses and accompanying ACE credit recommendations are identified within the education component of the matrix. The training section of the matrix is designed to be completed to incorporate appropriate state and local training courses.

4.3. Model curriculum

The FESHE committees have successfully developed a model fire science curriculum for both associate's and bachelor's degrees. Each curriculum includes identified core courses, non-core courses and concentration areas. Course descriptions including learning outcomes, objectives, and course content have been developed and accepted. A growing number of colleges and universities have committed to adopting the model curriculum and its corresponding courses, thus facilitating the transfer and acceptance of prior coursework. A masters-level model curriculum is now being developed.

Each model curriculum incorporates both core and non-core courses as illustrated by the associate's curriculum. The six core courses identified in the model associate's degree curriculum are: (1) building construction and fire protection, (2) fire behavior and combustion, (3) fire prevention, (4) fire protection systems, (5) principles of emergency services, and (6) principles of fire and emergency services safety and survival. Non-core courses articulated in the model from which college or universities would select in aligning their academic program include: introduction to fire and emergency services administration, fire investigation I, fire investigation II, fire protection hydraulics and water supply, hazardous materials chemistry, legal aspects of emergency services, occupational safety and health, and strategy and tactics.

The process of reaching consensus on a model curriculum began with the associate's degree level, where FESHE committee members were asked to identify the "courses or subjects that should form the theoretical core that every graduate should have when he or she receives a fire science associate's degree. The finding of unanimous agreement on the core course areas at the 2000 FESHE Conference, spawned the development of the necessary consensus on

additional aspects of the associate's degree model curriculum, and subsequently the bachelor's degree model curriculum over the following several years. In recent years, the associate's degree model curriculum was revised to replace the original core course in fire service hydraulics, with the current fire and emergency services safety and survival course.

4.4. Fire service summits

The aforementioned accomplishments in terms of developing the professional development model, professional development matrices, and a model curriculum serve as the building blocks of a coordinated system of fire officer professional development. Fire service summits are the vehicle through which the various states and major metropolitan fire departments can successfully achieve the desired coordination between fire service training, certification and higher education within their respective jurisdictions. FESHE fire service summits are designed to facilitate the development and implementation of an organized and integrated fire service professional development system that incorporates the "valuing" of fire service training and certification by institutions of higher education offering fire service academic degree programs.

The six steps in the state fire service summit process include: (1) state discusses project with NFA; (2) convene higher education summit within state; (3) standardize fire science curriculum; (4) convene professional development summit planning meeting; (5) convene professional development summit; and (6) implement standardized competency-based professional development system. As of now one entity, the District of Columbia, has completed this six-step process, with 22 others being engaged in the various stages of this process. The state of Virginia and the City of Baltimore, Maryland have progressed to the fifth step in this process. The state of Arizona is currently engaged in the fourth step in the process. Of the remaining 19 states engaged in the National Professional Development State Adoption Process, 15 are engaged in the first step with 2 states involved in each of the second and third steps.

The time required for a state to progress through the six-step process is in large part determined by the readiness of the various key stakeholders from training, certification and higher education within the state to work together and their shared vision and commitment. Likewise, the number of colleges and universities involved within each state will potentially influence the necessary time. Evidence has shown that a realistic timeframe is probably two years, assuming the above prerequisite conditions are met. The sources or resistance and dynamics that have been found to frustrate the timely completion of the six-step model curriculum adoption process have included (1) time commitments and demands of stakeholders from training, certification and higher education organizations, (2) a lack of understanding of the FESHE initiative, and (3) developing a cross-functional approach that challenges and breaks down the traditional three "preparation stovepipes" of training, certification, and higher education.

5. Findings and recommendations

The FESHE initiative has demonstrated its merit in facilitating the development of a coordinated system of fire officer professional development. Through the aforementioned initiatives and the same visionary leadership that contributed to the success of the FESHE initiative to date, those with responsibilities for fire service training, certification and higher education within the various states have the potential of addressing the traditional dilemma of fire officer development, first within their states and eventually at the national level.

The authors intend to conduct further research as the various states engage in their respective pilgrimages to develop comprehensive and organized systems of fire officer professional development that incorporate and "value" training, certification and higher education. A potential question for future research may be whether fire service officer candidates who complete the model curriculum advance more rapidly than do those who follow a more traditional and less integrated preparation approach. An additional area of exploration would be to consider the relevance of this approach to the professional development of other professions.

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Development of a Multi-Algorithmic Platform for Traffic Incident Detection

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Abstract

The conducted work aimed at demonstrating the feasibility of using real-time traffic measurements and travel time data to develop a multi-algorithmic incident detection platform based on the California Algorithm, the Exponential Smoothing Algorithm, and the McMaster Algorithm. Once these traffic incident algorithms were applied to the available field data, set theory was then used to access the likelihood of occurrence for each identified traffic incident. The traffic data used for this research originated from the South Carolina Department of Transportation (SCDOT). It covered a period of two and half months. The data were collected by Inductive Loop Detectors (ILD) located along the State. The platform proposed by the authors should provide road authorities with quick and reliable incident detection models aimed at improving road safety by optimizing the response to traffic incidents.

1. Introduction

Roadway incidents refer to non-recurring events resulting in traffic congestion or disruptions including accidents, vehicle breakdowns, road debris, spilled loads, inclement weather, unscheduled maintenance and construction activities or other unusual or special events affecting roadways. During an incident, the normal capacity of the roadway is restricted leading to queues and delays. Incidents contribute to delays and have far reaching consequences for safety, congestion, pollution, and the cost of travel. Previous studies indicate that incidents are one of the major causes of loss of time and increases in avoidable costs in transportation networks in the U.S. For example, in 2004, it was determined that more than 60% of urban freeway congestion was caused by incidents, and that indicator was estimated to be 70% by 2005 (Schrank and Lomax, 2004). Prompt and reliable incident detection is vital in reducing incident congestion, post-incident delay, and the potential for additional incidents.

Incident management is a crucial function in the design and deployment of Advanced Transport Management Systems (ATMS) and Advanced Traveler Information Services (ATIS). It primarily includes incident detection, verification, validation, response, and clearance. Incident detection is a critical step in incident management. It affects consequent actions and determines the reliability and efficiency of the whole system. The procurement of real-time incident detection information is an integral element of and supports the realization of many other functions in traffic management. Nevertheless, incident detection is one of the weakest links in implementing advanced traffic controls.

2. Background Studies

Automatic Incident Detection Algorithms (AIDAs) have been an important part of freeway management systems from the beginnings of Intelligent Transport Management (ITS) deployment. However, several studies revealed that, in many cases, the automatic incident alarms have been disabled or are simply ignored (Parkany and Bernstein, 1995). The general reason for disabling AIDAs is their relatively poor

operational performance. Nevertheless, the size and scope of urban transportation networks under direct monitoring by transportation management centers are growing at a pace faster than the available staffing and resources levels. This trend is motivating renewed interest in the quest for reliable and accurate AIDA functionality.

From time to time, comparative analyses of AIDAs have been performed in order to find out the relative advantages of one algorithm over the others (Stephanedes et al., 1992; Dia et al., 1996). Abdulhai and Ritchie (1999) discussed the problems arising during implementing an incident detection algorithm and proposed a set of characteristics for an operationally successful incident detection algorithm. But still, the developments in incident detection algorithms seemed to be mostly at a scholastic level. In spite of the rapid development of numerous algorithms, the response of the industry seemed to be hesitant.

A survey conducted by Abdulhai and Ritchie (1999) shows that 6.3 % of the DOT's agencies ignored using AID algorithms, 12.5 % used them partially, 46.9 % preferred not to use AID at all, while only 12.5 % chose to use AID algorithms. When asked for the reasons for the limited integration of incident detection algorithms in their systems, the respondents cited three principal factors: high occurrence of false alarms, difficulty of algorithm calibration, and low detection rates. The primary and most commonly cited reason for limited use of AID is an unacceptably high rate of false alarms. The number of false alarms generated by the AIDA systems currently in use is high for operator comfort, and the distraction caused by the false alarms usually outweighs the benefits of faster incident detection. Survey respondents indicated that the problem of initially calibrating the algorithm was also a major reason for the dissatisfaction generated by this technology. Unless the algorithm is properly calibrated, it cannot be expected to function with an acceptable level of efficiency and accuracy (Stephanedes et al., 1992; Dia et al., 1996). The calibration process in most of the algorithms is complicated and time-consuming, and it requires an understanding of the details of the algorithm to a degree which is not realistically attainable by practitioners. The pattern matching, statistical and mathematical modeling based algorithms that are currently available rely mostly on heuristic and inductive modeling based approaches for calibration. Such procedures of calibration require data pertinent to a diverse set of incidents that represent all possible scenarios (Parkany and Bernstein, 1995). The accuracy of the available information determines the efficiency of the calibration. Although incidents in traffic streams are abundant, information pertaining to these incidents is often insufficient and scarce. In some instances, as it is the case with artificial neural network based algorithms, it is necessary to use simulation generated artificial incident data for calibration. Not only does this limit the accuracy of the calibration, but it involves substantial time and effort. Development of new simulation networks for the specific site of implementation is arduous. Some algorithms are capable of improving with time after implementation, through the availability of more data. But incorporation of such capabilities requires manual feedback, which in turn delegates additional tasks for the traffic personnel. There are two ways of addressing this problem. One venue would be to find ways to automate the calibration process as far as possible in the existing algorithms. If the algorithm implementation can be designed to adjust itself automatically to the existing and changing conditions of the environments and sites, it can then be deployed with some initial configuration and minimal calibration. With the passage of time, the accuracy of the algorithm would improve. There have been some efforts in this direction (Abdulhai and Ritchie, 1999). However, there is an alternative approach. If instead of the usual inductive modeling approach, a deductive modeling approach based on traffic flow theory is adopted, the algorithm would not suffer from the usual data constraints. The calibration would mostly involve operations

data (e.g. flow, speed and occupancy). This data is definitely more accessible than incident information data. Some TMCs already archive this type of data, and the rest of them can eventually do it, if necessary, at minimal costs. No elaborate simulations would then be necessary for incident data generation.

Low detection rate of incidents (i.e. the percentage of incidents that was actually detected by the incident detection algorithm) is another major reason for rejecting incorporation of AIDAs in TMCs. Since a center usually employs several technologies which work in tandem to detect incidents, the chances of not detecting an incident that is seriously affecting traffic are quite low. Therefore, although a high detection rate is very desirable, it is not considered as a critically decisive factor in accepting or rejecting the use of a particular algorithm (Parkany and Bernstein, 1995).

3. Research Objectives and Scope

The objectives of the conducted research were to review the available literature on the most common algorithms developed for incident detection, to analyze the computational as well as traffic data requirements of each of these algorithms, to shortlist a set of detection algorithms applicable to real-life traffic conditions, to implement the selected algorithms using traffic data collected from the South Carolina Department of Transportation (SCDOT), and finally to develop a scheme for the integration of the algorithms into a decision support platform.

3.1 Data Collection

Traffic data collected from 269 detector stations across South Carolina was made available for the study. Out of these, 12 detector stations, which are continuous sections of the highway, were selected. Data was obtained in terms of vehicles speed and traffic counts. Occupancy values were calculated from the data. The study focused on sections of Interstate 185, Interstate 85, Interstate 385, Interstate 77, and U.S. Route 501. Detectors were installed at the start and end sections of the road.

As shown in Figure 1, the road sections considered in the study are mostly north and south of Greenville along Interstate Highway 185, north and south Spartanburg along Interstate Highway 85, and north and south of Laurens County, along Interstate 385. Detectors installed at these sections provide information on vehicle counts. Data was collected for a period of two and a half months by SCDOT. Twelve sections of the highway were selected. The data was collected on an hourly basis. Information on the section of the road, and vehicle counts was collected and recorded. Lane occupancy was then mathematically derived from the collected data. Table 1 depicts the format in which the collected data was made available for the study.

Figure 1. Highway Sections Considered

Table 1. Sample of Collected Traffic Data

ID	ATR_ID	Hour	Lane	Bin_0_5	Bin_11_15	Total Volume	ID1
137085	0	1	1	0	0	237	1
137086	0	1	2	0	0	150	2
137087	0	1	3	0	0	31	3
137088	0	1	4	0	0	9	4
137089	0	1	5	2	0	87	5

ID is the road identification number. Hour refers to the particular hour of the day the data was reported. There are 5 lanes considered for a particular section of the road. Bin numbers identify the number of vehicles traveling at a given speed. Total Volume provides the summation of the number of vehicles in all the Bins.

3.2 Algorithm Selection and Implementation

The following twenty-two algorithms were reviewed and studied for potential application to the available traffic data.

1) Standard Normal Deviate Algorithm
2) Exponential Smoothing Algorithm
3) Low Volume
4) Dynamic Model (MM and GLR)
5) The California Algorithms
6) Bayesian
7) Decision Logic Units-based Algorithm
8) HIOCC and PATREG
9) ARIMA
10) Multi-Layer Feed-forward
11) DELOS
12) Image Processing
13) Fuzzy Logic
14) Principal Component Analysis
15) Cumulative Sum of Occupancy
16) Probabilistic Neural Network Algorithm
17) Fuzzy Radial Neural Network Algorithm
18) Adaptive ANN-Wavelet Algorithm
19) Wavelet Energy-Radial Basis Algorithm
20) Discrete Wavelet Transform Algorithm
21) CUSUM based Algorithm
22) Support Vector Machine

Feasibility of application of the above algorithms was determined based on the nature of the data collected. For instance, the hourly basis of the data limited the use of most of such algorithms. Following are some of the major reasons that restricted the use of some of the algorithms mentioned above:

- Over saturation was not a factor to be analyzed in the data.
- Traffic data was collected on an hourly basis.
- Actual number of incidents taking place on a particular section of a road at a given point in time was unknown.
- No traffic incident data was available for fine-tuning of the algorithms.
- Lane occupancy was a factor determined mathematically, empirical values were not provided for the study.

Hence, only three of the twenty-two algorithms (listed below) matched the data requirements at hand:

1) California Algorithm #8
2) Exponential Smoothing Algorithm
3) McMaster Incident Detection Algorithm

3.2.1. California Algorithm #8

The California Algorithms (Payne and Tignor, 1978) are a set of 10 algorithms that are based on a same principle. They use a decision tree based on traffic states for incident detection. In this set, Algorithm # 8 and Algorithm # 7 are the most popular ones. The California Algorithms, developed using traffic data from the Los Angeles system, are one of the first full-scale incident detection algorithms ever created. They are normally used as benchmarks for evaluating the performance of other algorithms. At present, several modified forms of the original California algorithms exist and are implemented in several TMCs. The algorithms use 20 and 30 second occupancies and volumes averaged over all lanes at a particular station. Several variables are derived based on the occupancy values at the concerned station, the station downstream, and occupancy values at these two stations at different time points. Some of the most prominent variables are: Downstream Occupancy (DOCC), Spatial Difference in Occupancies (OCCD), Relative Spatial Difference in Occupancies (OCCRD), and Relative Temporal Difference in Downstream Occupancy (DOCCTD). These derived variables are evaluated at every time step at each station in the concerned section

of roadway, and compared to thresholds at different points in a decision tree to determine whether an incident has occurred in the system. The thresholds are determined during calibration of the algorithm by minimizing the false alarm rate for a given level of detection rate. The algorithms in this set that used derived variables based on volume and volume-to-occupancy ratios were found to be inferior to algorithms based purely on occupancy based measures. Algorithm #8 uses a persistence requirement and replaces the variable DOCCTD in the last stage of the decision tree with the variable DOCC. This is done in order to account for two observations: 1 – non-incident-related compression waves traveling upstream cause false alarms; and 2 – drop in downstream occupancies are much greater in magnitude in cases of incidents than in normal compression waves generated by recurrent congestion.

3.2.2. Exponential Smoothing Algorithm

The Exponential Smoothing Algorithm was developed using data from the John C. Lodge Freeway in Detroit. This method uses double exponential smoothing for generating a tracking variable. A tracking signal is then generated as the algebraic sum of all the previous estimate errors to the present minute, divided by the current estimate of the standard deviation. When the tracking signal deviates from zero beyond a pre-specified threshold, detection is indicated. The threshold can be computed based on either the variability of the data or likelihood of false alarms. A set of 13 traffic variables which were derived from the basic traffic variables of volume, occupancy, and speed, were used to test algorithm performance. The variables are (Cook and Cleveland, 1974):

1. Station volume
2. Station occupancy
3. Station speed (volume/occupancy)
4. Station volume-occupancy
5. Station speed-occupancy
6. Station kinetic energy
7. Station discontinuity
8. Subsystem volume
9. Subsystem occupancy
10. Subsystem speed
11. Subsystem kinetic energy
12. Volume-occupancy discontinuity
13. Speed-occupancy discontinuity

Station discontinuity, which is the difference between consecutive occupancies of the road, is first calculated, in the same manner as presented by Courage and Levin (1968), that is, by calculating the difference between the occupancies of two successive stations and comparing their values. If there is a substantial change in the values, a flag is raised. Kinetic energy computations use the surrogate for speed. Station occupancy, volume, and discontinuity were found to give better performance in terms of detection rates at different levels of false-alarms. A tracking signal is generated as the algebraic sum of all the previous estimate errors to the present minute, divided by the current estimate of the standard deviation. When the tracking signal deviated from zero beyond a pre-specified threshold, detection is indicated. The threshold could be computed based on either the variability of the data or likelihood of false alarms. In essence, Exponential Smoothing refers to the application of the moving average technique to time series data, either to produce smoothed data for presentation, or to make forecasts. The time series data themselves are a sequence of observations. The observed phenomenon may be an essentially random process, in this case, vehicle counts on two consecutive sections of the road is checked. If there is an increase in the vehicle count from the downstream occupancy section, an incident is detected. A temporal difference in vehicle count can also be considered. However, as the traffic data in this study is on an hourly basis, the spatial difference in vehicle count was considered. The variable "count" is first calculated by determining the difference in occupancy between adjacent sections of the road. If this value is greater than the given threshold value, the difference in occupancy between the two adjacent sections of the road at consecutive time intervals is obtained. This

is then compared against a second threshold value 'T2'. If this value is greater than'T2' an incident is flagged.

3.2.3. McMaster Algorithm

The McMaster Algorithm was developed using data from Queen Elizabeth Way, Mississauga, Ontario. The basic McMaster Algorithm (Persaud et al., 1990; Hall et al., 1993) is a congestion detection algorithm. It uses a catastrophe theory model for description of the flow-occupancy-speed relationship. Three regions of operation are defined on the flow-occupancy diagram– Area 1: Free flow, Area 2: Congested flow with lane occupancy less than critical occupancy, and Area 3: Congested flow with lane occupancy greater than critical occupancy. Calibration of the algorithm involves distinguishing between the congested and uncongested regions. The template for each station is calibrated separately. The minimum uncongested speed is estimated for the station. This is used to create the boundary between Area 1 and 3. A quadratic equation is then estimated to obtain flow as a function of occupancy at the station, and a constant flow value is estimated, which is to be subtracted from the function to create the boundary between Area 1 and 2.

As real time traffic-incident data was not provided by the SCDOT, a different approach was used to predict incidents. Data utilized would be divided into two sets. The fists data set consist of the data during the first 39 days, while the data for the remaining 39 days would fall in the second data set. Results of the California Algorithm are used on the first data set, to obtain the quadratic equation mentioned above. This quadratic equation is used in the second data set to predict incidents. Next, the results of the Exponential Smoothing Algorithm from the second data set would be used to determine the quadratic equation. The generated quadratic equation would then be used to predict incidents in the first data set. This approach is used to train the McMaster Incident Detection Algorithm in the first phase, and use the McMaster Algorithm in the second phase to detect incidents.

4. Implementation and Results

Implementation involved testing the functionality of the selected algorithms, i.e., the California Algorithm, the Exponential Smoothing Algorithm, and the McMaster Algorithm when applied to the available traffic data. This was carried out by coding these algorithms on MatLab files, and then developing a software interface via Microsoft Excel. Next, a probabilistic study of the results of the three algorithms was conducted. Incidents common to all three algorithms were considered to have a high probability of occurrence. Results common to two algorithms had a medium probability of occurrence, and all other results had a low probability of occurrence.

Tables 2, 3 and 4 show the number of identified incidents, at various stretches of the studied road, by the California, Exponential Smoothing and McMaster Algorithms, respectively. The mentioned probabilistic scheme was then generated using the results yielded by the three algorithms. Table 5 shows a schematic of the set theory scheme being applied to the three algorithms.

Table 2. California Algorithm 8 Results

Table 3. Exponential Smoothing Results

Table 4. McMaster's Results

5. Conclusion

In this study, twenty-two incident detection algorithms were reviewed for implementation using real traffic data provided by the South Carolina Department of Transportation (SCDOT).

Each of these algorithms was analyzed based on the data at hand. The analysis reduced the algorithms suitable for the purpose of the study to three algorithms. Each algorithm has a different perspective for analyzing data.

ATR_ID	Total Number of Incidents
194-195	6
196-197	26-
242-243	2
243-244	2

Table 5. Incident Likelihood Scheme

ATR_ID	Total Number of Incidents
194-195	5
196-197	42
242-243	2
243-244	2

ATR_ID	Total Number of Incidents
194-195	4
196-197	16
242-243	3
243-244	0

Likelihood of Occurrence	Algorithms Paired	Number of Common Incidents
High	California Algorithm #8,Exponential Smoothing Algorithm, McMaster Algorithm	1
Medium	California Algorithm #8,Exponential Smoothing Algorithm	1
	California Algorithm #8,McMaster Algorithm	3
	Exponential Smoothing Algorithm, McMaster Algorithm	2
Low	California Algorithm #8	31
	Exponential Smoothing Algorithm	47
	McMaster Algorithm	27

The California Algorithm stresses more on detecting incidents on a temporal basis. The Exponential Smoothing Algorithm analyzes data more on a spatial basis rather than a temporal basis. The McMaster Algorithm detects incidents using congestion patterns. On analyzing the three month data provided by SCDOT, using each of these algorithms, incidents were categorized based on a high, medium and low likelihood of occurrence. Each of the selected algorithms uses a different approach while analyzing traffic data. On combining the three algorithms, a multi-algorithmic approach was obtained. Such a resulting approach serves as a multi-stage filter to detect traffic incidents. The resulting platform helps in reducing the False Alarm Rate (FAR) since, depending upon the incidents common to the three algorithms, the results are analyzed through a probabilistic scheme designed to reduce the FAR. In addition, the three algorithms are significantly easy to train without employing a large set of field chosen incident data. Traffic operators' experiences on freeway traffic patterns will facilitate adaptation of the proposed approach to other sites. This stems largely from the modular architecture of the incorporated algorithms, and their general incident detection engines, as compared to dynamic based algorithms such as Image Processing Algorithms which would require more time to detect incidents.

6. Acknowledgements

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Sarbanes-Oxley and the Independent Director: Smoke and Mirrors?

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Abstract

This article reviews the research regarding a key element of the Sarbanes-Oxley legislation: that all publicly-listed companies must have a majority of independent directors. The empirical research linking independent directors and organizational outcomes is decidedly mixed. Nevertheless, having a majority of independent directors on a board is now widely recognized as an international "best practice". Three mini case studies explore the ambiguity of defining what is meant by "independent". The implications of these cases for current theory and research on corporate governance are discussed.

1. The Sarbanes-Oxley Act of 2002

In the wake of the collapse of companies such as Enron and the resulting public outcry for improved governance of US corporations, the Sarbanes-Oxley Act of 2002 was the result of an uneasy compromise between competing bills from US Congressman Michael Oxley (R-Ohio) and Senator Paul Sarbanes (D-Maryland) (Monks & Minow, 2004, p.248). The Act, along with rules changes from the Securities and Exchange Commission (SEC), New York Stock Exchange (NYSE) and the Nasdaq Stock Exchange (NASDAQ), strengthened regulations surrounding the governance of public corporations as well as significantly enhanced company reporting and disclosure requirements (Colley, et.al, 2005, p. 79).

In a very real sense, the Sarbanes-Oxley Act was an attempt to address the stunning governance failures so painfully illustrated by the failure of the Enron Board to prevent the collapse of their company (Gordon, 2003). The Sarbanes-Oxley Act, then, was an attempt to improve the transparency of financial reporting, reduce the incentives of management to manipulate financial data reporting, and to increase the ability and incentives of a firm's Board to act independently and with adequate oversight of management (ibid). It was an attempt to "fix" the recurrent crisis of corporate governance so prevalent in US firms of the late 20th and early 21st century (MacAvoy & Millstein, 2003).

Below is a brief summary of the key components of the new regulations:

(1) Listed companies must have a majority of "independent" directors.

(2) Non-management or independent directors must meet without management in regularly scheduled sessions.

(3) The Audit Committee of the Board is responsible for the fiscal integrity of the corporation.

(4) The CEO and CFO must personally certify the financial results and statement of the corporation.

(5) It is illegal for officers and directors to fraudulently influence an independent auditor.

(6) Companies must adopt and disclose a company code of ethics for directors, officers and employees. Companies must also report any material changes in these codes.

(7) Regulations surrounding the buying and selling of a corporation's securities by corporate insiders and the reporting thereof have been significantly enhanced.

(8) In general, corporations are prohibited from extending credit or loaning money any officer or director of the corporation.

(9) Corporations are required to disclose material changes in the company's financial or operational status openly and rapidly. (Colley, et.al, 2005).

What has been the impact of the sweeping Sarbanes-Oxley legislation? In general, the legislation is too new to make for a complete evaluation. At best, the current picture is cloudy. Monks & Minow (2005), for example, characterize certain facets of the reforms as "shrill" (p.249). Finegold, Benson & Hecht (2007), studying linkages between boards and firm performance, find only limited guidance for governance practices that result in more effective firm performance. Further, "Most of the governance reforms introduced have not been empirically examined…" (ibid, p. 871).

Then there is the cost. Linck, Netter & Yang (2007) find that implementing the Sarbanes-Oxley legislation imposes significance costs on corporate boards, as well as dramatically shifting the types of individuals likely to take board posts. Zhang (2007) notes that Sarbanes-Oxley events negatively affect a corporation's stock price. This result is not consistent, however, with other studies arguing that the benefits of Sarbanes-Oxley outweigh the negative impact on shareholder returns (Rezaee & Jain, 2006). Gordon (2003) criticizes the implementation of wider disclosure rules in the new legislation, and argues that any gains accruing as a result of the increased transparency may come at the expense of longer term shareholder value. Clearly, then, Sarbanes-Oxley imposes additional costs to firms and their boards, but drawing firm conclusions regarding whether the benefits exceed the costs remains the subject of further research.

The theoretical underpinnings for corporate governance research in general also remain an open question (Nicholson & Kiel, 2007). Whether the Sarbanes-Oxley reforms have shifted this elusive pattern of mixed results relative to extant theory therefore remains the subject of future research.

While a complete review of the Sarbanes-Oxley Act and the resulting regulations of the various stock exchanges such as the NYSE and NASDAQ is beyond the scope of this paper, it is important to note that the central element of these corporate governance reforms is the requirement that the companies listed by these various exchanges have corporate boards with a majority of independent directors (Crawford, 2007).

2. Director Independence

The argument for independent directors is that, by being separate from the management of a firm, the board is able to exercise better judgment, be unafraid of questioning the actions of management and able to protect the interests of shareholders. A number of researchers and practitioners have argued extensively for this independence:

> Independence is the key foundation to a properly functioning board of directors. If the board of a company is loaded with management, or a founder with a controlling stock interest, then it is possible that the directors are simply rubber-stamping the decisions of management rather than digging in to understand what is happening at the company. (Green, 2005, p. 28)

Other researchers are not so sure. They point to the continuing breakdown in managerial conduct and the corporate governance mechanisms that oversee them, and conclude that attempts to repair the governance of US corporations have fallen quite short:

> Independent directors were meant to be a means to an end. It was thought that informed, intelligent, and wise directors, of proven integrity, bound by a fiduciary standard, would effectively oversee management. Being outsiders, they wouldn't face the conflicts that, say, the chief operating officer might face, reluctant to criticize his boss and in no position to call for his ouster. The idea proved to be a mirage. Independence is an intangible concept. (Monks & Minow, 2004, p. 246).

The definition of what constitutes an independent director has been the focus of considerable attention. In general, the attempt was made separate board members as widely as possible from the management that they monitored. The original Sarbanes-Oxley Act of 2002 did not require corporate boards to be independent; it only mandated that a majority of directors have no "material relations" with the company. Audit committees of the board, on the other hand, were required to be independent (Colley, et.al, 2005).

In 2003, the US Securities and Exchange Commission approved new governance listing standards for the NYSE and NASDAQ exchanges that significantly enhanced the definition of "no material relations". The NASDAQ standards were the more stringent of the two exchanges. In addition to mandating that a majority of directors of the board be independent, the regulations articulated more precisely what conditions had to be met in order for a director to be considered "independent". An independent director:

(1) could not be currently employed or have been employed during the past 3 years by the listed company or any parent or subsidiary of the listed company, and in addition,

(2) should not have accepted any payments from the listed company or any parent or subsidiary of the listed company in excess of $60,000 in the current or any of the past 3 fiscal years,

(3) could not be a partner, controlling shareholder, or executive officer of any organization to which the company made, or from which the company received, payments for property or services in the current or any of the last 3 fiscal years that exceeded the greater of 5% of the recipient's gross revenues for that year or $200,000,

(4) could not be an executive officer of another entity where any of the executive officers of the listed company served on the compensation

committee of such other entity, if such relationship existed during the past 3 years, and

(5) could not be a partner of the listed company's outside auditor, or a partner or employee of the company's outside auditor who worked on the company's audit at any time during the past 3
years. (Crawford, 2007, p. 156-157)

A director was also ineligible if any family member failed to meet any of the above standards.

Beyond the board itself, the sharpest focus of regulators fell on the audit committees of boards. The regulations surrounding the audit committee were significantly enhanced. Beyond mandating director independence for committee members, directors were also required to demonstrate financial literacy or the ability to read and interpret financial statements (Colley, et.al, 2005). There was also a mandate to have a financial expert on this committee, generally requiring either a CPA or CFA designation, or the company had to demonstrate why no such member of the committee was present (ibid).

3. Research on Director Independence

Director independence is now widely recognized as a worldwide "best practice" for corporate governance. Practitioners and researchers cite a number of benefits to director independence: the ability to assist in disputes involving management or family members (Lippman, 2007), providing dispassionate advice (Lippman, 2007), better thoughts and ideas flowing from an independent board (Crawford, 2007), proper board functioning (Green, 2005) and a culture of professionalism distinct from management (MacAvoy & Milstein, 2003).

There are also a number of research studies that have demonstrated a linkage between independent directors and firm performance (Pearce & Zahra, 1992; Daily & Dalton, 1993). MacAvoy & Millstein (2003), for example, find a positive correlation between US corporations with active and independent boards and Economic Value Added (p. 49). It is important to note, however, that their study does not tie board performance with shareholder returns as measured by the company's stock price or some variant. Indeed, they go to great lengths to argue against stock price performance as an adequate dependent variable for their study (ibid, p. 44-48). Helland & Sykuta (2005) also note that boards with a higher proportion of independent or "outside" directors have a lower probability of being sued, and suggest that this outcome implies that independent boards do a better job of monitoring management.

The preponderance of research on independent directors, though, is inconclusive or negative. Researchers have even gone so far as to suggest that increasing levels of board independence may actually harm shareholder value:

> The many empirical studies that have examined the impact of the insider-outsider ratio on boards have found no consistent evidence to suggest that increasing the percentage of outsiders on the Board will enhance performance. In anything, they suggest that pushing too far to remove inside and affiliated directors may harm firm performance by depriving boards of the valuable firm and industry-specific knowledge they provide. (Finegold, Benson & Hecht, 2007, p.867).

This point about firm and industry-specific knowledge is also echoed by Leblanc:

> The notion that independent directors are effective is flawed, based on my data from studying boards from the inside. A common complaint I received from CEOs was "my directors don't understand my business". This became apparent during board meetings.
>
> (Leblanc, 2004, p. 440)

Brennan (2006) notes that boards are assumed to be more effective if they are independent, but suggests that a reason why they are not independent is that they are selected and appointed by management, particularly in corporations where shareholdings are widely dispersed.

> In the companies I knew, the outside directors always agree with management. That's why they are there…Because if a guy is not a yes man – no sir, he is an independent thinker – then they are dangerous to the tranquility of the board room.
>
> (Brennan, 2006, p. 586, citing Mace, 1971)

At the heart of this dilemma is what Aguilera (2005) refers to as the "independence paradox" (p. S50). Outside, or independent, directors are almost totally beholden to corporate management for the information that they require to supervise and oversee management. This information asymmetry seriously damages the ability of directors, particularly independent ones without extensive contacts at the company, to act independently and be effective in controlling board decisions (Baysinger & Hoskisson, 1990).

Academic research on corporate governance in general and regarding independent directors specifically is unable to tie the main theoretical models of corporate governance with the "facts on the ground". Researchers continue to find inconsistencies between the empirical results of their studies and the three main theoretical models of corporate governance: agency theory, stewardship theory and resource dependence theory (Nicholson & Kiel, 2007). One possible reason for this outcome is that an obsessive focus on quantitative methods, coupled with secondary data that is easily observable at a distance from corporate boards (such as meeting external criteria for independence), has obscured researchers from clearly observing the underlying phenomena that is a corporate board meeting. In keeping with Leblanc's (2004) call for the greater use of qualitative methods when researching corporate governance, the next section discusses three case mini case studies regarding director independence.

4. Three Case Studies of Independent Directors

Former employee of the company. Hewlett Packard's corporate governance guidelines call for a majority of their board of directors to be composed of independent directors.

> The Board reviews commercial, industrial, banking, consulting, legal, accounting, charitable and business relationships. An independent director must not have any material relationship with HP, directly or as a partner, shareholder or officer of any organization that has a relationship with HP, or any

> relationship that would interfere with the exercise of independent judgment in carrying out the responsibilities of a director.
>
> (HP, 2009)

Richard A. Hackborn served as a member of the board of directors through at least 2008. He joined the board in 1992. He was HP's Executive Vice President, Computer Products Organizations from 1990 until his retirement in 1993 after a 33-year career with HP. Mr. Hackborn served as HP's Chairman of the Board from January 2000 until September 2000. He was also the lead independent director of the board from September 2006 until September 2008 (HP, 2008).

> …the Board has determined that each of the non-employee director nominees standing for election, including…Mr. Hackborn…has no material relationship with HP (either directly or as a partner, stockholder or officer of an organization that has a relationship with HP) and is independent within the meaning of HP's director independence standards.
>
> (HP, 2008)

Friends of the founder. In 2003, a shareholder of Martha Stewart Living Omnimedia (MSO) filed a lawsuit in connection with Ms. Stewart's trading of ImClone stock (Beam v. Stewart, 2003). Among other allegations, the plaintiff in the case alleged that a number of directors, including the president and chief operating officer of MSO, were "incapable of acting independently and disinterestedly" with regard to board decisions (ibid, p.1).

> Defendant Sharon L. Patrick is a director of MSO and its president and chief operating officer…She also serves as the secretary of M. Stewart, Inc. which is described in the complaint as "one of Stewart's personal companies." Prior to Patrick's employment at MSO, she was a consultant to the magazine, *Martha Stewart Living*…Patrick is also a longtime personal friend of Stewart.
>
> (Beam v. Stewart, 2003, p. 6)

The plaintiff in the case also alleged that a number of the board's outside directors had business relationships before joining the board, moved in the same social circles, and attended the same weddings. In the plaintiff's opinion, these relationships, combined with Stewart's 94% voting power, hindered the board's ability to act independently of Stewart (Crawford, 2007, p. 156).

While the Delaware Court recognized that Ms. Patrick was an inside director, and had a material interest in MSO, the Court did not recognize that Ms. Patrick's friendship with Ms. Stewart was a basis for challenging her independence (Beam v. Stewart, 2003, p. 17). Further, the court dismissed all of the plaintiff's allegations that the outside directors in the case who had prior business relationships or close personal friendships with Stewart were incapable of acting disinterestedly or independently.

> In sum, plaintiff offers various theories to suggest

> reasons that the outside directors might be inappropriately swayed by Stewart's wishes or interests, but fails to plead sufficient facts that could permit the Court reasonably to infer that one or more of the theories could be accurate. (Beam v. Stewart, 2003, p. 19)

While the Court did not rule out the possibility that personal friendships were relevant to determining independence, the Court decided that the plaintiff in this particular case needed more evidence to prove the claim that the directors were unable to act independently (Crawford, 2007, p. 158).

Advisor to the company. Larry W. Sonsini is the lead partner in Wilson Sonsini Goodrich & Rosati, a large Silicon Valley law firm that employs about 600 lawyers. Mr. Sonsini also serves on the board of a number of high-tech companies that employ his firm as outside counsel. "These are companies I helped build…I am involved with them almost daily" (Lublin, 2003).

> Mr. Sonsini says being an outside counsel doesn't harm his independence as a director. "Often, my interests are aligned with the shareholders," he says in an interview. "A lawyer serving on the board does not, in itself, compromise the concept of independence because the lawyer represents the organization and must act in the best interest of the shareholder." (Lublin, 2003)

In November of 2002, Brocade Communications Systems, one of the firms on which Mr. Sonsini has a board seat, agreed to acquire Rhapsody Networks for approximately $173 million. Mr. Sonsini and several colleagues at his law firm handled the transaction. At the same time, Mr. Sonsini blessed the deal as a Brocade director (Lublin, 2003).

5. Discussion

The above cases are not intended to impugn the reputation of the individuals discussed, or to imply that their actions were anything less than legal or ethical. On the contrary, there is reason to believe that each of the individuals discussed are persons of integrity, competence and skill.

But are they independent? Within the letter of the law at the time each of these cases is discussed, the individuals qualify as independent board directors. But it is precisely the ambiguity as discussed by these cases that worry corporate governance experts. For example, if an outside director is also the company's paid outside counsel, "it's impossible to meet the spirit as well as the specific criteria for independence," says Roger Raber, president of the national Association of Corporate Directors in Washington, DC (Lublin, 2003).

Perhaps the question that really needs to be asked, then, is whether independence, as currently construed, is even necessary. Is independence even possible without removing directors with deep industry experience and replacing them with industry outsiders? Does independence destroy competence in the process, removing incentives to closely monitor the corporation, and lowering the time necessary to be aware of the actions of management? Is independence even desirable? Further, has the incentive of legislators to impose increasing standards of independence been an attempt to be seen as "doing" something, rather than actually

accomplishing the reform of corporate governance?

Management theorists would arguably respond that to remove requirements of independence from boards would be to invite the self-dealing and managerial malfeasance for which the Sarbanes-Oxley regulations were written to address. Indeed, the agency problem in corporate governance is an old one (Schleiffer & Vishny, 1997). Agency theory prescriptions of incentive alignment has resulted, however, in bloated executive compensations and stock option schemes for executives that do not pay for the observed levels of performance in their organizations. Investing heavily in the stock options of directors to align their incentives with shareholders would therefore also likely be an exercise in futility, particularly if the board has been gutted of industry relevant experience.

So where does that leave us? The following conclusions appear to be evident:

(1) The Sarbanes-Oxley regulations appear to have been hastily written on a shaky theoretical and empirical foundation.

(2) The empirical research on corporate governance does not confirm the main theoretical models of corporate governance.

(3) Director independence, while an intuitive and externally measurable construct, may not be either truly possible or truly desirable.

(4) The self-dealing and managerial malfeasance around which the corporate governance regulations, theory and research have been built arguably continues unabated.

These conclusions suggest a wide-ranging agenda for future research. First and foremost, it suggests that the crisis of corporate governance so carefully documented both here and elsewhere is much deeper than simply "agency conflicts" or "board independence". Further, our theoretical models will have to be re-examined to reflect the lack of empirical confirmation, and reconfigured to be consistent with what our empirical research suggests. The empirical research on corporate governance will need to take a much more nuanced view of corporate directors than simply "independent" or corporate insider. Finally, research methods other than quantitative modeling, such as qualitative or case-based research, will need to be employed in greater measure to capture the ambiguities as discussed in this study.

Corporate governance and the "black box" that is the corporate boardroom have come under increasing scrutiny. Without true reform and transparent, enlightened governance, corporations will continue to operate under a cloud of suspicion and hostility.

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Revamping Education to Meet Global Challenges

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Abstract

It is well known that as societies develop and mature the nature of their economic bases changes. In the U.S., for instance, agriculture gave way to the industrial revolution, which has been giving way to the information revolution. Additionally, computerization, the Web, and the ability to digitize work have enabled companies to seek workers offshore who are capable of performing higher-skilled jobs including knowledge creation and professional work.

Many U.S. community leaders, politicians, and others have decried offshoring but have not offered much in the way of solutions. It is our belief that in order to keep more of these higher-skilled jobs at home we need to develop a talented workforce with expertise in areas where demand is outpacing supply, and to become more innovative and technologically sophisticated.

In order to accomplish these we - America - need to fix the shortcomings of our education system that make it difficult to engage and prepare students in the subject areas that form the underpinning of innovation and technology - literacy in mathematics, the sciences, and reading. This paper examines these shortcomings and proposes solutions, beginning at the K-12 level.

1. Introduction

The move offshore began with many low-skilled jobs as companies sought lower labor costs. Next came many back-office and front-office jobs, once again because companies sought lower labor costs. Now offshoring encompasses many high-skilled jobs, knowledge jobs, and professional jobs. The reason for offshoring these higher-skilled jobs is not so much for lower labor costs, but because the expertise is more readily available elsewhere [2].

The practice of offshoring has been criticized by many Americans and at many levels [3]. From local government leaders to labor unions to federal government leaders, the cry has gone out to find ways to keep more jobs at home, particularly those that have resulted in closed plants in some of our more traditional industries. However, as important as those jobs are, what many people have failed to consider is that as our society matures and our economy grows, our workforce should be progressing up the "food chain" of jobs, not stagnating.

According to *The Economist* [11], what's important in a society is creating wealth, and if a country wants to create wealth, then it is necessary for that country to transition from lower-skilled jobs to higher-skilled jobs. This is important because the comparative advantage for developed economies lies in having a highly skilled workforce pursuing knowledge-intensive activities.

Although the transition can be painful, it is important that America prepares its workers to become more competitive in seeking the more highly-skilled jobs. The key to success in achieving this goal is to turn out more members of our workforce who have a high level of literacy in mathematics, the sciences, and reading because these areas form the underpinning of innovation and technology which fuel

most higher-skilled jobs [13]. If society desires to keep these high-skilled, innovative, and technology rich jobs in the hands of Americans, then our education system needs to do a much better job preparing our students. This preparation needs to begin at the K-12 level so that students will be better prepared for the rigors of college level science, engineering, and other technology related programs of study.

Toward that end, society and educators need to understand the shortcomings of our education system - starting at the K-12 level - and educators, with the support of society, need to find ways to overcome these shortcomings. In the following sections test scores in reading comprehension, mathematics skills, and science skills of U.S. students are compared to test scores of other students around the world. Prospective reasons for unfavorable differences in the test results are examined and a three-pronged solution is proposed. The role of higher education in the solution process is then discussed.

2. Comparing U.S. students to the world

In 2000, 15-year-old students from 31 countries, including 27 Organization for Economic Cooperation and Development (OECD) countries, took the first Program for International Student Assessment (PISA) test. Its focus was on reading literacy and it covered three areas: retrieving information, interpreting texts, and reflecting on texts. U.S. students scored 504 (the average was 500). This ranked the U.S. at 15th among OECD countries in the combined reading literacy scale. Finland ranked first with a score of 546 [14].

The PISA is given every three years and includes testing in reading literacy, science literacy (identifying science issues, explaining phenomena scientifically, and using scientific evidence), and mathematics literacy (space and shapes, change and relationships, quantity and uncertainty). Each time the test is given all three areas are covered, but one of them is assessed in greater depth. As noted above, in 2000, that area was reading literacy. In 2003, it was mathematics, and in 2006, it was science. This is intended to be a repeating cycle [14] [15] [16].

In 2006, the most recent PISA, U.S. students achieved the following results [16]:

- an average score on the combined science literacy scale of 489 which was lower than the average of 500 for the OECD countries and lower than the U.S. scores from 2000 and 2003 (500 and 491, respectively),
- ranked 21st on the combined science literacy scale – Finland ranked first (563),
- showed no measurable difference on the combined science literacy scale between U.S. males and females,
- an average score on the mathematics literacy scale of 474 which was lower than the OECD average of 498 and lower than the U.S. score of 483 from 2003, and
- ranked 25th on the mathematics literacy scale – Finland ranked first (548).

The results are both telling and chilling. First, U.S. students trail more than half of the OECD nations in reading literacy, science literacy, and mathematics literacy. Second, since the testing began in 2000, U.S. students have not shown much improvement with respect to students in the other OECD nations. Third, if indeed the solution to the problem of offshoring high-skilled, knowledge creation, and professional jobs lies with developing better educated students in the areas of science, engineering, and other technology-related disciplines, then we are going in the wrong direction!

According to King [7], the number of traditional male and female students enrolled as undergraduates continues to grow, but the proportion of women is increasing and is now at 57%. What is most disturbing here is that technology-based studies, including the sciences and engineering, have been traditionally sought

out by men and the number of women enrolling in college is outpacing the number of men. Further, it appears as though the number of both men and women pursuing the sciences and engineering is fewer than those demanded in the market [2]. This is one of the reasons why U.S. companies are seeking these types of skills offshore. These issues lead to two questions.

- Where have the male students gone?
- Why are U.S. students falling behind the rest of the world with regard to literacy in mathematics, science and reading?

These questions are addressed in the sections below.

3. Why are there fewer males?

In his book, *Boys Adrift*, Leonard Sax [8] discusses the phenomena of decreasing enrollment rates and the declining proportion of males in undergraduate programs. He advances five factors that are causing these phenomena:

- video games that are disengaging boys from real-world pursuits,
- teaching methods, especially in the early school years, that are turning off many boys,
- overuse of prescription drugs in treating ADHD,
- endocrine disruptors that may be lowering boys' testosterone levels, and
- devaluation of masculinity through shifts in popular culture.

While Sax provides compelling evidence for each of these factors, the focus here is on the one factor that falls within the scope of this paper; teaching methods.

According to Sax [8], children, especially boys, start school in the U.S. too soon to be able to successfully learn the material they are taught. He points out that research has shown that the development of the portion of the brain that we use for language is about two years slower in boys than in girls. That means that boys for the most part are not ready to engage in learning how to read at five or six years old.

Another of Sax's criticisms involves today's teaching methods in K-12, especially with regard to the concept of knowing. One can think of knowing on two levels; to know in the sense of book learning and to know in the sense of experiencing. In German, the word for knowledge with respect to book learning is *wissenschaft* and the word for knowledge with respect to experiencing is *kenntnis*. According to Sax, most boys prefer to learn through experiencing rather than through book learning. As an example, rather than reading about how to build a sand castle, most boys would rather just build a sand castle. The problem is that most of the learning that takes place in the early years today is focused on teaching children to read and write – *wissenschaft* rather than *kenntnis*. Boys in their early school years need to focus more on *kenntnis* than on *wissenschaft* and our school system is not set up to deal with this [8].

Another gender issue advanced by Sax [8] is that most boys tend to learn better in competitive environments that are team oriented. This is different than the environment that most girls prefer. Coupled with this is the fact that most teachers in the early school years are women who tend to teach using a style that they (females) are comfortable with. Taken together these make it difficult for many boys to become engaged in learning. If we look at the three major concerns presented by Sax - starting school too early, not enough experiential learning, and exposure to a teaching style that is less conducive to learning for boys – then the fallout is that a large number of boys are being turned off towards school very early on and they tend to stay turned off.

We can now connect the dots by examining three troubling trends. First, historically more men tend to enter fields of study that are considered rich in technology and innovation and the number of men entering college is increasing at a decreasing rate. Second, one reason that this trend is occurring is that many boys are being turned off towards school during their K-12 years.

Third, on the PISA 2000 [14], 2003 [15], and 2006 [16] exams, both boys and girls in the U.S. are lagging behind roughly one-half of the other OECD nations' students in reading, science, and mathematics literacy. These are the areas that students must excel in if they are to pursue education and careers in engineering, the sciences, or other technology-based disciplines.

4. No child left behind

In 2002, President Bush signed into law the No Child Left Behind (NCLB) bill. The purpose of the law was to increase student achievement while holding schools more accountable. It was to be particularly beneficial for disadvantaged students.

At the core of NCLB are the following [17]:

- standardized tests to see if kids meet certain national standards in math, English and science,
- schools are graded based on students' performance,
- teachers required to meet strict standards or education/training, and
- reading to be taught as early as kindergarten.

While these may seem on the surface to be admirable goals, the law has a number of shortcomings, two of which are briefly discussed below.

In light of the work done by Sax [8], teaching children to read at ages 3-5 may not be appropriate for a number of reasons, including the fact that the area of the brain used for reading is not sufficiently developed at that age. These children are still exploring their surroundings and should be allowed to play and develop social skills.

If we want to develop students who will be creative and innovators, then placing an emphasis on standardized testing may be problematic. Using standardized tests leads to "teaching to the test" rather than teaching for the purpose of learning. It would be far better to allow teachers to use pedagogies that create more learning-friendly environments and that allow students to do more exploring and project activities.

If one of the goals of NCLB is to improve student achievement, then it has failed at least on two counts. First, as evidenced by the performance of fifteen-year-olds on the PISA exam, our students are at best "run-of-the-mill" in the global environment. Second, "teaching to the test" does not appear to be a paradigm that particularly motivates students to learn or possibly even stay in school. ABC News reported in 2006 [18], that students are dropping out of school at alarming rates. They reported that 31% of high school students were dropping out or failing to graduate from America's 100 largest schools! Further, they reported that nationally, 68% of state prison inmates are dropouts. This is a sad commentary on our K-12 education system!

5. Righting the ship

In the report *Rising Above the Gathering Storm* [13] the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine proposed the four-part solution to the problems stemming from globalization shown below.

A. "Increase America's talent pool by vastly improving K-12 science and mathematics education." [13, p. 112]

B. "Sustain and strengthen the nation's traditional commitment to long-term basic research that has the potential to be transformational to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life." [13, p. 136]

C. "Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world." [13, p. 162]

D. "Ensure that the United States is the premiere place in the world to

> innovate; invest in downstream activities such as manufacturing and marketing; and create high-paying jobs based on innovation by such actions as modernizing the patent system, realigning tax policies to encourage innovation, and ensuring affordable broadband access." [13, p. 182]

While all four recommendations appear to be most helpful, the discussion in this paper will focus only on the first one.

The institutes' action plan for achieving improvement in grades K-12 focus around recruiting 10,000 science and math teachers annually by awarding merit-based 4-year college scholarships to our best high school graduates; strengthening the skills of 250,000 current teachers through a variety of training and educational opportunities; and enlarging the pipeline of students entering college programs in science, engineering, and math by increasing the number of students who pass AP and IB science and math courses [13]. While the general approach is solid, the discussion below outlines how it can be strengthened.

5.1 Start school later

In order to build student interest in math and the sciences, we first of all have to focus on retaining students in school and on making learning a pleasurable experience. In order to achieve these, we could start by delaying the start of school by two years as is done in Finland [8] so that students will begin their formal educational journey when they are physiologically and emotionally ready to do so. In the meantime, parents who either keep their pre-school children at home or utilize child care should ensure that the environment is such that their children can be, well, children! In these early years they will derive more benefit by playing and developing social skills.

5.2 Use single-gender classes

When students formally begin their studies, it may more beneficial that they do so in single-gender classes. There are a number of schools nationwide that have implemented single-gender classes and found them to be far superior to coed classes. Included in the list of schools are Westside Elementary in Spring Hills, FL; Glenwood Elementary School in Charleston, WV; Anne Bailey Elementary School in St. Albans, WV; and Woodward Avenue Elementary School in DeLand, Fl. Teachers in these classes were trained by the National Association for Single Sex Public Education which was founded by Dr. Leonard Sax [19].

In January, 2008, Kathy Piechura-Couture at Stetson Univerisy reported that in a four-year study, 4th grade boys attending coed classes at Woodward Avenue Elementary School scored 55% on the Florida Comprehensive Assessment Test as opposed to 85% for boys attending all-boys classes [19]. A study commissioned by the National Foundation for Educational Research (UK) looked at 2,954 high schools in England which used single-sex classes. It found that both girls and boys performed better in single-sex classes than those in coed classes, especially for girls at all levels of ability and for boys at the lower end of the ability scale. The study also showed that girls at single-sex schools were more likely to take non-traditional courses such as advanced math and physics [9].

Based on the many reported successes found in the literature (only a small sampling was reported here), it is recommended that school districts explore and then implement single-gender classes by performing pilot studies to work out the "bugs" and then move forward with full implementation.

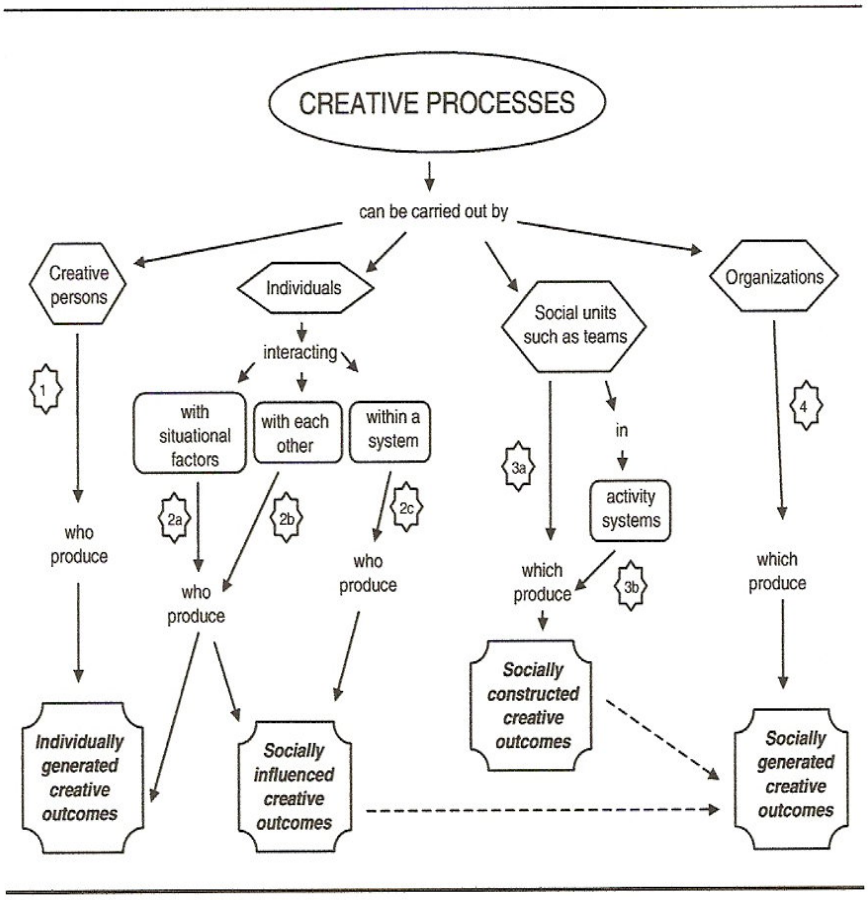
5.3 Foster learning and creativity development in K-12

Watson [10, p. 428] constructed a concept map that relates various definitions of creativity found in the literature. The map is shown below as Figure 1. The value of this map for our purposes is that it shows that individuals – in our case students –

interact with other students, within a teaching paradigm, and in the context of the teaching environment to produce socially influenced creative outcomes. The importance of this in the K-12 school years is to provide students a proper setting in which to develop their creative abilities. One approach to achieving this is through the use of group projects. Project Lead the Way® (PLTW) [1] is one such model.

PLTW requires that teachers train for two weeks to provide students with problem-centered projects in which they apply skills developed in math, science and applied technology courses. To date, this program has been used in schools that have adopted the High Schools That Work (HSTW) program of study. One key finding by Bottoms and Uhn [1] was that PLTW students achieved significantly higher math and science scores on the NAEP HSTW Assessment than similar HSTW students. PLTW has also been endorsed as a model by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine [13]. While the PLTW program may be financially out of reach for some school districts, alternative problem-centered project models can certainly be developed.

Figure 1. Social Creativity Concept Map



The discussion of creativity and learning should not be limited to technology-related disciplines. Music, art, and writing are certainly other disciplines that can indeed foster the development of creativity in students. Unfortunately, budgetary issues in a number of school districts have resulted in cutting back programs in these areas, particularly music and art. It is important, nonetheless, for school districts so affected to find ways to restore these programs.

According to a survey of 1,000 6th to 8th graders by Raytheon Corporation [12], 84% said they would rather "clean their rooms, eat their vegetables, take out the garbage and go to the dentist than sit down with their math homework." However, 67% said they wanted to do better in math and 94% said that doing well in math was important to them. Raytheon addressed this with a program called *MathMovesU* [12]. The program uses celebrities to show how they use math in their jobs which has caught the attention of many students. This type of approach could be used in science and other subject areas as well to show students the importance of these subjects in a very palatable way.

While one could speculate on a number of different approaches to stimulate learning and creativity development at the K-12 level, the most important issue is to allow teachers the flexibility to create and implement methods that will encourage students to embrace learning and foster the development of creativity [5] rather than just "teaching to the test".

6. What this means for higher education

At the university level the study of technology and of international issues is crucial. On the technology side, college courses could be upgraded to build on the higher level of math skills that would be developed during K-12. Of course we must continue to offer courses that help students build competencies in writing, oral communication, information technology, the sciences, and the arts. This knowledge forms the basis of a well-educated individual and nurtures creativity, all of which can be applied to any career endeavor. In an interview by Tom Friedman [4, p. 261] with Mike Arguello, an IT systems architect who taught at a university in San Antonio for six semesters, Arguello said that the majority of his students "… lacked the creativity, problem-solving abilities and passion for learning." This is a serious problem and we must as educators and parents find ways to solve it.

Since better trained teachers will be needed at the K-12 level, colleges involved in teacher education programs need to create new paradigms for delivering education to students. The world has changed dramatically in the last two decades, especially in how information is gathered and made available to the user. Our children are becoming exposed to these computer-based methods at a very early age. We need to find creative ways to utilize this technology to deliver our lessons so that these young folks will become more engaged in learning.

A discussion of the benefits of single-gender classes was presented in an earlier section. College and university teacher education programs will need to teach our future K-12 teachers about the differences in the ways that boys and girls learn, and expose them to the pros and cons of single-gender classes. Further, our future teachers will need to become prepared to teach single-gender classes. Teacher education accrediting agencies such as NCATE need to explore and embrace the virtues of single-gender classes and then make it part of their recommended course offerings.

If project-based, team learning is to become a focal point in science and technology-based courses at the middle and high school levels, then our future teachers must be taught how to develop effective project offerings and how to create successful team environments.

For current K-12 teachers, college and university teacher education programs need to develop short courses in these two areas that can be offered in the summer as part of

their ongoing continuing education programs, and school districts need to provide the funding for teachers to attend these classes.

7. Summary

This paper has endeavored to present (1) some important reasons for the outsourcing of higher-level jobs, (2) evidence from the PISA tests which underscore problems in our K-12 education system, (3) a three-prong solution for addressing these problems, and (4) a brief discussion of its impact on higher education. The results of the 2000, 2003, and 2006 PISA tests shows that U.S. students are trailing students in about one-half of the other OECD countries in reading literacy, math literacy, and science literacy. These areas form the underpinning of innovation and technology which fuel most higher-skilled jobs – the jobs that we are increasingly outsourcing because of lack of supply here. The reasons for our poor performance internationally can be linked to problems with our K-12 education system.

A three-pronged solution was presented which included (1) starting children in school a little later when they are physiologically and emotionally ready to learn, (2) implementing single-gender classes because evidence has shown that they work better than coed classes, and (3) using more problem-oriented projects and other appropriate approaches to stimulate learning and to encourage the development of creativity in our young students.

Finally, recommendations were made for higher education which included (1) strengthening science and engineering programs that will be receiving better prepared high school graduates, (2) preparing our future K-12 educators to teach in single-gender classes and to utilize more problem-oriented team projects and other creative methods in their classes, and (3) developing and offering similar coursework for current K-12 teachers as part of their continuing education program. We realize that there are solution elements that must also come from other sectors of society such as government, corporations, and parents, but we feel that the three-pronged solution presented here is one that we as educators can indeed develop and implement.

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Incorporating a Lean Supply Chain Methods Simulation in an MBA Operations/Production Management Course: A Pilot Study

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Abstract

In this paper the results of a pilot study aimed at assessing the perceived value of using a hands-on simulation game in an MBA operations/production management course are presented. The goal of the simulation was to reinforce lean and supply chain principles that were presented in the course. The value of the simulation was assessed by administering a pre-simulation survey followed by a post-simulation survey. The survey contained 14 items assessing lean concepts and 9 items assessing supply chain concepts. Paired t-tests were utilized and the results showed that students perceived statistically significant reinforcement of the lean and supply chain principles by participating in the simulation.

1. Introduction

The MBA program at Clarkson University is a one-year program for students who have met the foundation requirements as undergraduate business students or who have completed a 4+1 program with a participating school. For those students who have not met the foundation requirements, Clarkson offers ten, two-week pre-MBA modules to prepare them for their MBA courses. These two-week courses meet for two hours each day (28 hours total) and are very intensive.

One of the courses, the Operations/ Production Management course, is used to prepare students for the MBA courses in the operations and supply chain management areas. Topics covered include operations and supply strategy - including the Terry Hill Model [1], manufacturing process types, Six Sigma quality, strategic sourcing, lean manufacturing, inventory management, and material requirements planning.

Students who have not had work experience often find it difficult to visualize a number of these concepts. The motivation for incorporating the simulation into this course was to provide them with a hands-on tool that would help them visualize a number of these concepts, especially lean and supply chain concepts. The pilot study described here is part of a larger, multi-university study that is examining the use of such simulations, adopted from corporate lean training programs, in higher-education settings in both engineering and management [2].

In the following sections we further discuss the course and the rationale for incorporating the simulation; provide a full description of the simulation and its goals; discuss the manner and environment in which the simulation was run; discuss the hypotheses, survey instruments, and results of the data analysis; and provide our conclusions of the pilot study.

2. The OPM Course

In this section, we discuss the positioning of the OPM course in the MBA program and the history of its development. The discussion is spread over the following two subsections.

2.1 The Business Concepts Program

In 2006, the faculty in the School of Business at Clarkson University decided to reorient their one-year MBA program to attract more non-business undergraduate students. More specifically, the faculty were

interested in making the program more attractive to engineering students.

Up to that time the only two avenues available to non-business undergraduate majors interested in completing the MBA in one year were (1) complete a 4+1 program as an undergraduate or (2) take some of the foundation courses as an undergraduate and then take the remainder of the 3-hour courses during the summer prior to the start of the program. For many potential MBA students these two choices were either logistically difficult to schedule and complete, or the courses needed in the summer weren't offered.

As an alternative, the faculty created the Business Concepts Program. This program consists of ten, 2-week pre-MBA modules that would be offered during the summer. The modules are 1.5 credits each and are scheduled two at a time over a period of 11 weeks (there is a one-week break after the third set of modules). The program was launched in the summer of 2007, and has been tremendously successful in attracting non-business undergraduates. Students have stated that during the one summer they can take as few as one or as many as all ten courses in order to satisfy their foundation requirements.

2.2 The OPM Course and its Relevance

One of the foundation requirements for the MBA is completion of an OPM course with a grade of C or better. Those students who have either not taken an OPM course or who have not earned at least a grade of C must complete the requirement before taking any MBA courses. The two ways a student can meet this requirement at Clarkson are (1) take the 3-credit hour course during the spring, fall, or summer semester or (2) take the 1.5-credit hour OPM course offered as part of the Business Concepts Program. Most students since the summer of 2007 have opted for the latter choice.

The OPM course (OM580) includes topics in strategy, manufacturing processes, Six Sigma, sourcing, lean, forecasting, inventory management, and MRP. Supply chain management concepts are interwoven across these topics. This is a very ambitious set of topics to be delivered and absorbed in just two weeks! The text used in the course is a custom version of *Operations and Supply Management: The Core* by Jacobs and Chase [3]. In order to allow students to focus more on the concepts and less of the mechanics of the modeling the software package STORM® [4] was also utilized.

Two of the weaknesses in teaching a course like this in such a short period of time are that (1) there is virtually no incubation period for students to absorb the material and (2) there is no opportunity to take field trips to help reinforce the concepts. These weaknesses, among others, provided the motivation to introduce the lean/supply chain simulation in the class. The simulation will be described in detail in the following section.

All MBA students are required to take two, 2-hour core modules that require the OPM course as a prerequisite. They are *Supply Chain Management* (OM606) and *Decision Analysis and Supply Chain Modeling* (OM602). Further, those students who elect to pursue the Global Supply Chain Management Track in the MBA program are required to take two additional 3-hour supply chain courses; *Supply Chain Systems Management* (OM615) and *Advanced Topics in Global Supply Chain Management* (SB694). Most supply chain students then take *Quality Management and Process Control* (OM685) and *Supply Chain Environmental Management* (OM671) which are 3-hour elective courses. As one can clearly see, the topics covered in the OPM course are critical to the students' success in these courses! As described below, the simulation is aimed at bringing a number of these concepts alive so that the student will be able to reinforce what they hear and see in the classroom.

3. The Simulation

The game - a product of Time Wise Solutions, LLC - provides an enjoyable and participatory experience that enables students

to actually see how lean principles can be applied in a supply chain environment (see http://www.timewisems.com/time_wise_solutions.html). Students are immersed in a low volume, high mix discrete manufacturing system. They are informed that the increasingly competitive global market has customers clamoring for more variety with lower cost and faster delivery. Included in the system is one manufacturer, Time Wise, Inc. (TWI), which sells timing devices to four customers and receives parts from six suppliers.

The goal of this simulation is to make on-time deliveries of high quality timing devices to customers while minimizing costs and maximizing financial performance. Each of the four customers has a different order lead-time requirement and orders a variety of timing devices in varying quantities from the exclusive manufacturer, TWI. Time Wise employs two factory managers to assemble the timing devices, one parts warehouse manager, one finished goods warehouse manager and one accountant. The parts needed to produce the various timing devices are purchased from six suppliers. The suppliers ship parts to TWI using truckers from the Southern Truck Line with the cost of inbound freight paid by TWI. Truckers from the Northern Truck Line deliver finished timing devices to customers with the cost of outbound freight incurred by the customers. Information carriers, representing the information network, deliver orders and payments to the suppliers, and supplier invoices to the accountant. The simulation thus encourages students to think about the impact of lean ideas on material, information, and financial flows.

The game is played in three rounds. The objective of each round is to improve performance as measured by such things as on-time delivery percent, net operating profit, inventory cost, inventory turnover, and cash conversion frequency. Eighteen to twenty-eight participants are needed to play the roles of suppliers, manufacturing employees, customers, truckers, information carriers and accountant.

Before the simulation actually begins, each of the four customers uses a spinner to create orders for TWI. Identical customer orders are used in all three rounds to allow for improvements in performance to be attributed to changes in the supply chain. At the start of each round, all customers go directly to the finished goods manager at TWI to place their first order. Two of the four customers pay premium prices for fast delivery of timing devices but TWI incurs a penalty in the form of a larger discount when products are delivered late. Payments for timing devices are made directly to the accountant at TWI. The end of each round occurs with the receipt of all orders by the four customers.

In the first round, all suppliers produce to forecast. For each supplier, the roll of a die is used to determine cycle time and this time determines when a full case of supplies can be placed in finished goods. When an order is received from TWI via an information carrier, supplies are removed from finished goods and a trucker from the Southern Truck Line is summoned to deliver the case of parts and an invoice to TWI. Their travel time is determined by the distance between the supplier and TWI. In round 2, three of the suppliers begin a lean transformation replenishing to order using pull markets with TWI. Their batch sizes and cycle times are significantly reduced. The other three suppliers continue to produce to their production schedules although their case quantities are reduced due to lean improvements at TWI. By round 3, all suppliers have begun the use of lean and all have implemented pull markets with TWI resulting in continued decreases in cycle time, batch sizes and finished goods inventory levels.

The information carriers transmit information and payments between the various divisions in TWI and between TWI and its suppliers. Orders (round 1) and supplier kanban cards (rounds 2 and 3) are delivered to the suppliers from TWI; supplier invoices are delivered to the TWI accountant and payments are taken to the suppliers. Round 1 uses point-to-point truckload but in

rounds 2 and 3, shipments may be consolidated and Southern charges by the case rather than by the truckload. This reduces shipping costs for TWI.

TWI assembles nine different products; one standard Gray Pearl device that is ordered by all customers and 8 customized products (4 Blue Sapphire models and 4 Black Diamond models). In round 1, TWI produces to a forecast. In order to avoid costly stockouts, the parts warehouse manager continuously orders parts from all suppliers, stacking cases in the warehouse as necessary. The family of Blue Sapphire products is assembled in one area of the factory while the family of Black Diamond products is assembled in a second area. The Gray Pearl may be assembled in either area. The factory area managers call out to the parts warehouse whenever they need supplies. The finished goods warehouse manager fills customer orders and takes completed products from the factory.

Round 2 begins the lean transformation at TWI with the application of the lean principles of pull and flow. Both the parts and finished goods warehouses are moved closer to the factory. Production is controlled through the use of kanban cards; case quantities of parts are reduced and delivery of some parts is controlled using a kanban replenishment system.

Finally, round 3 completes the lean transformation. The parts warehouse is eliminated and supplies are delivered directly to the POUS at the factory. Work at the factory is reconfigured so that final product differentiation is delayed until an actual customer order is received.

Truckers from the Northern Truckline are responsible for transporting finished timing devices from TWI to customers. Delivery time is based upon the distance from TWI to the customer specified. In round 1, all trucks use point-to-point truck load (TL) and thus customers pay for a full truck. In rounds 2 and 3, truckers are permitted to consolidate less-than-truckload (LTL) shipments and use a single truck to deliver to multiple customers in the same region. Thus, customers are charged by the case rather than paying for a full truckload.

4. Playing the Game

The simulation is designed to be played over an eight-hour period, as part of a one-day corporate training session with discussion and lecture between rounds. Due to course time constraints the simulation was played over a 5-hour period on the Saturday between the two weeks of the course. Typically, students are given an initial briefing about the simulation and are then assigned roles. In our implementation, the initial briefing was given in class on the day before the simulation was played.

A debriefing session is held after each of the three simulation rounds. The debriefing periods are facilitated by the instructor away from the area where the simulation is played. In these debriefings, groups of students meet to tell one another what happened in the previous round and to discuss changes that might improve performance. It is important that each group have at least one representative from the supplier, customer, manufacturer and trucking units. As in real life, it is difficult for participants to know what is happening in the other areas of the game. In order to really understand the nature of the interrelationships, these discussions are absolutely necessary.

During the debriefing periods, the game is reset by helpers for the next round. This takes about thirty to forty-five minutes. An additional short break is also included after each round.

The goal of the first round is to let the students experience a poorly organized push system approach to manufacturing. In this round they readily find a number of issues that need to be corrected such as late deliveries, poor quality, chaos on the manufacturing floor, and excessive inventories in the shop as well as at the vendors.

During the second round, when the pull system approach is introduced at half of the suppliers and the manufacturing environment is somewhat streamlined, a number of the issues related to the first round are either fully or partially repaired. The students typically find additional areas for

improvement. For example, students recognize that maintaining each item in finished goods inventory is expensive, due to the variety of products.

For the final round, all suppliers have been converted to a pull system, the manufacturing environment has been further streamlined, and product differentiation is delayed. Although the activity is rather fast-paced during the third round, the issues related to the first two rounds are virtually eliminated, and students can observe the significant improvement in material, information, and financial flows. For this implementation, the final debrief was given on the Monday following the simulation.

While a smaller block of time was available for the simulation, an advantage of the course setting is that students can be asked to reflect on what they learned outside of the session. For this course, the students were asked to write a three-page paper summarizing their experiences with the simulation and the lessons learned. According to their feedback in the papers, the simulation was well received and the students felt that the extra time invested was very productive and beneficial.

5. The Pilot Study

In the pilot study at Clarkson, we were interested in examining behavioral outcomes related to student learning, which include increased self-efficacy (that is, a personal judgment of one's capability to perform a particular activity). Because it is correlated with the amount of effort an individual puts forth and their determination to complete a task, this measure is important when the subject is perceived to be difficult [5,6] and has been positively related to better academic performance [7]. We developed a pre- and post-course survey that asked students to evaluate their proficiency in specific knowledge areas related to lean and supply chain design.

5.1 Survey Design

The survey asked students to evaluate their proficiency in 23 areas, 9 related to supply chain and 14 to lean processes. Examples of the areas included are:

- Definition of a supply chain
- Understanding of the bullwhip effect
- Understanding of the value of information in a supply chain
- Understanding the concept of postponement
- Fundamental principles of lean thinking
- Benefits of lean processes
- Lean terminology (e.g., takt time, kanban, value stream mapping)
- Relationship of lean time and WIP
- Process improvement

Students were asked to evaluate each question using a 5-point scale, defining proficiency levels based on the CDIO approach [8, 9] as follows:

- **Level 1: Have no exposure to or knowledge of** (have never heard of the topic, or only in casual conversation)
- **Level 2: Have experienced or been exposed to** (have had some organized introduction to the topic, have had someone explain it to me)
- **Level 3: Can participate in and contribute to** (can participate in and contribute to a discussion about the topic, or have participated in an event where the topic was used)
- **Level 4: Can understand and explain** (have explained the topic to someone else, prepared a presentation about the topic, or written a paper about the topic)
- **Level 5: Am skilled in the practice or implementation of** (have applied my knowledge in the topic by developing solutions to a case study or other academic exercise, solving a problem in an organization, or leading an activity)

Students were asked to complete the survey prior to the simulation, and several days after the simulation was complete. The post-survey was completed before students received feedback on their written assignments.

5.2 Results

We compared student responses to the pre- and post-surveys for individual questions, as well as broadly grouped into lean topics and supply chain topics. For both surveys, 17 students participated (all of those taking the course).

Students' perception of their proficiency in each of the lean areas assessed in the survey is shown in Figure 1. In general, students' rated their pre-course proficiency at about 1.5 on the 5-point scale, corresponding to having little to some exposure to the topics. Post-course scores on each element ranged from 2.8 (for problem-solving techniques) to 4.0 (for principles of lean thinking, benefits of lean, and kanban). These values correspond to levels of proficiency associated with being able to participate in a conversation about the topic, through being able to understand and explain the

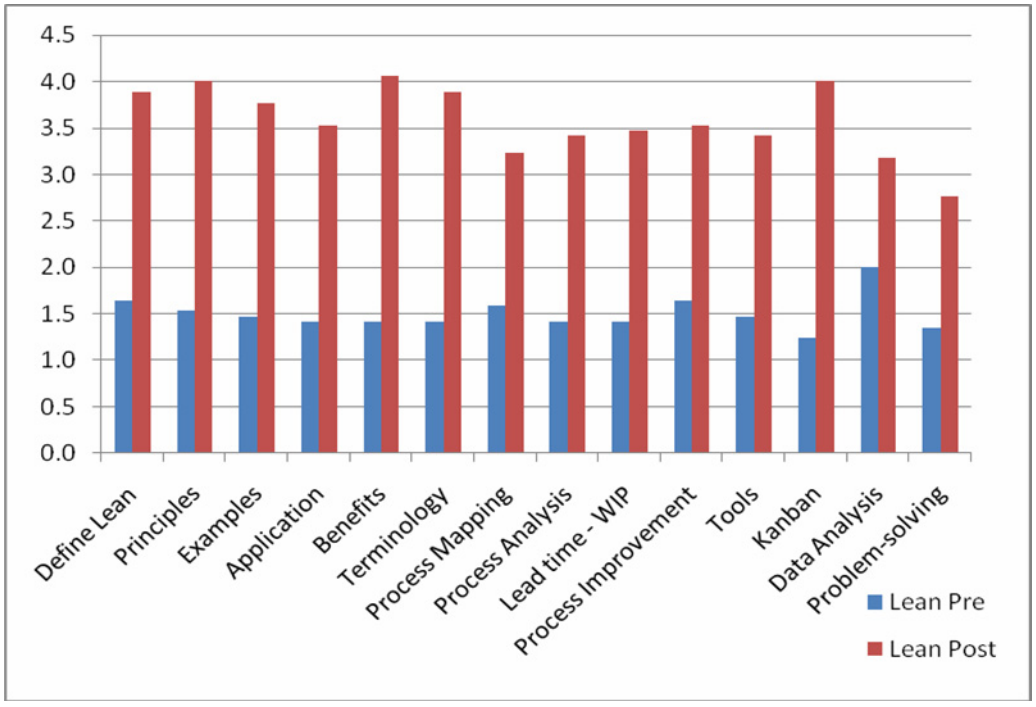

Figure 1: Students' Perception of their Profiency in Lean Process Design, Pre- and Post-Course

topic to someone else. The increase seems reasonable, providing some evidence that students' rating of their own proficiency is a reasonable metric. Topics such as process mapping, problem-solving, and data analysis were not specifically addressed as part of the simulation; the results thus are also anecdotally consistent with course coverage.

Table 1 examines the pre- and post-course scores, with the 14 lean questions grouped into a single measure. A paired sample t-test was performed to determine the significance of the increase in score. The paired sample t-test for the lean topics measure was significant (t=-13.02, p=0.000), indicating that students' perception of their proficiency was significantly higher after completing the simulation.

Table 1: Results from Pre- and Post-Surveys for Lean Topics

Measure	Lean Topics	
	Pre (n=17)	**Post (n=17)**
Mean	1.5 Minimal Exposure	3.57 Contribute to and Explain
Variance	0.41	0.26

A similar analysis was completed for questions related to supply chain knowledge. Students' perception of their proficiency in each of the supply chain areas assessed in the survey is shown in Figure 2. In general, students' again rated their pre-course proficiency at about 1.5 on the 5-point scale, corresponding to having little to some exposure to the topics. Post-course scores on each element ranged from 3.6 (understanding the bullwhip effect) to 4.1 (for defining a supply chain and the concept of postponement). These values correspond to levels of proficiency associated with being able to participate in a conversation about the topic, through being able to understand and explain the topic to someone else.

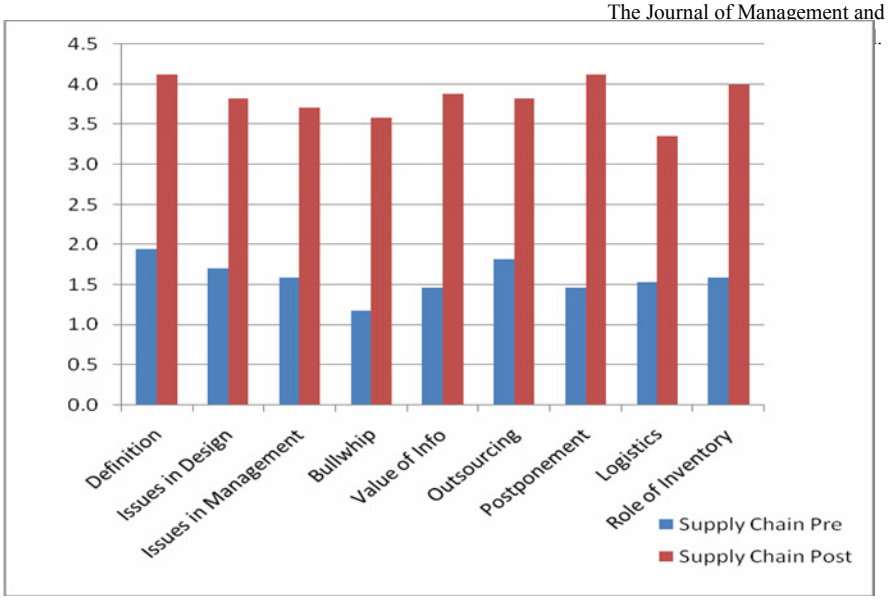

Figure 2: Students' Perception of their Profiency in Supply Chain Issues, Pre- and Post-Course

Table 2 examines the pre- and post-course scores, grouping the 9 supply chain questions into a single measure. A paired sample t-test was performed to determine the significance of the increase in score. The paired sample t-test for the supply chain measure was significant (t=-11.56, p=0.000), indicating that students' perception of their proficiency was significantly higher after completing the simulation.

Table 2: Results from Pre- and Post-Surveys for Supply Chain Topics

Measure	Supply Chain Topics	
	Pre (n=17)	Post (n=17)
Mean	1.59 Minimal Exposure	3.82 Contribute to and Explain
Variance	0.51	0.44

Finally, we also asked four general questions on the post test survey to gauge students' general responses to the simulation. Students were asked to evaluate statements about knowledge gained in the course related to lean thinking and supply chain principles, as well as whether the simulation played a major role in helping them to learn these principles. Answers were scored on a scale with 5=strongly agree, 4=agree, 3=neither agree nor disagree, 2=disagree, and 1=strongly disagree. As shown in Figure 3, students found both the course and simulation to be valuable, particularly in its focus on the supply chain.

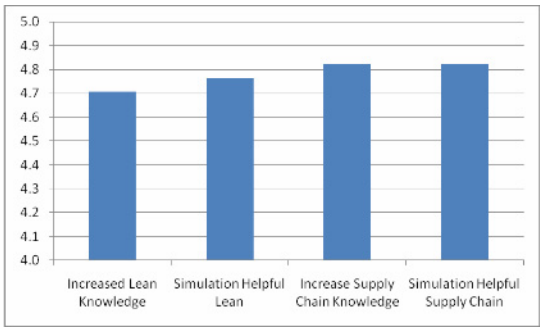

Figure 3: Students' Evaluation of the Value of the Course and Simulation in Teaching Lean and Supply Chain Principles

6. Conclusions

In this paper, we describe a hands-on supply chain simulation, developed by Time Wise Solutions, LLC, and its use in a 2-week pre-MBA module at Clarkson University. In this pilot study, our goal was to examine the effects of using the

simulation on students' evaluation of their proficiency in lean and supply chain topics. Students' perceptions of their own abilities increased significantly post-course compared to pre-course, in both lean and supply chain topics, from a level of minimal exposure pre-course to a point where they felt they could contribute to and explain the concepts to others. Students were also enthusiastic about the course, and felt the simulation was effective in supporting their learning.

In future work, we plan to compare implementations and results at four different schools where the simulation is being used, in both engineering and management settings. We are also continuing to develop assessment tools for evaluating such experiments.

Acknowledgments: We would like to thank Time Wise Solutions, LLC for providing support in the initial use of the simulation at Clarkson University. Partial support for this work was provided by the National Science Foundation's Course, Curriculum, and Laboratory Improvement (CCLI) program under Award No. 0618669. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Variables Affecting the Operational Performance of Hot Cathode Fluorescent Lamps: A Case Study

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Abstract

As a designer of circuits used to drive fluorescent lamps in environmentally hostile applications, it is necessary to study the wide range of research work carried out in the past. This paper presents the variables affecting the operational performance of fluorescent lamps not just from the circuit design point of view, but inclusive of actual lamp design parameters. The problems encountered in developing a generalized impedance model of the lamp are also highlighted. With the efficacy roughly five times that of incandescent lamps, fluorescent lamps have clearly dominated the office environment applications. The load reduction on office cooling systems is quite significant. The life of the fluorescent lamps is ten times more than that of incandescent lamps and hence maintenance costs are significantly low. Fluorescent lamps, with all their problems, are still the most practical light source available when efficiency, life, and rapid start are the prime considerations.

1. Introduction

When properly designed and driven the life of a fluorescent lamp can be on the order of ten times the life of an incandescent lamp. Given the high efficiency and long life of fluorescent lamps, why would anyone use incandescent lamps?

The basic reason fluorescent lamps are not more widely used is that they required a controlled temperature environment. If the fluorescent lighting is inside the garage, one may have noticed that the lamps do not light reliably in the winter. This is because the working fluid, mercury, has precipitated out of the gas solution, and excessive voltage is required to ignite the lamp. If the ballast in the lamp assembly can achieve the required voltage, the lamp will light intermittently [1]. As the lamp warms, more mercury evaporates into the solution and the lamp lights more reliably. This may be acceptable inside the garage, but it would not accept this sort of behavior in most products in use.

When designing with fluorescent lamps, many other concerns come to the surface, aside from the temperature and voltage requirements. Shape concerns such as length and diameter of the tube, complexity of circuitry, hazardous gas release when the lamps are broken, all raise concerns among designers and corporate legal departments. These concerns can be dealt with when sound engineering practices are followed, and a more complete knowledge of the issues is achieved [2].

Figure 1 shows the distribution of energy in a cool white fluorescent lamp. As is typical with energy conversion most of the input leaves as some form of heat.

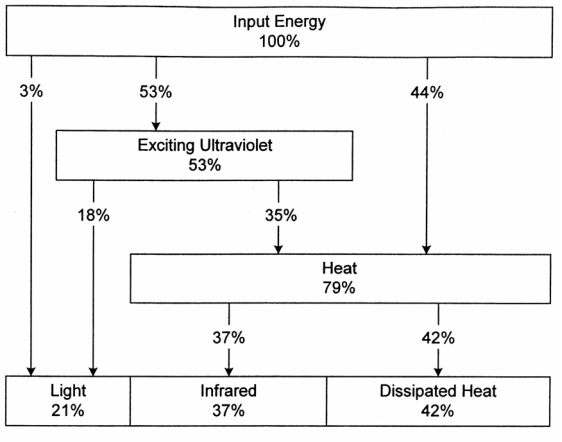

Figure 1. Energy distribution in a cool white fluorescent lamp [3]

2. Theory of fluorescent lamp operation

The following is an explanation of the components of the fluorescent lamp and their operation. It is broken down into three parts for clarity: The Gas, Ignition, and Electrodes.

The gas: The working fluid in the fluorescent lamp is mercury (Hg). The pressure is such that an optimum amount of Hg is in the gas form. Too little Hg, the lamp will not light, and too much Hg, the radiated UV collides with so many Hg atoms that an extinguishing collision is likely to occur [4].

With an abundance of mercury in the tube the pressure of Hg is determined by the bulb wall temperature. The coldest spot on the bulb wall is where the Hg will condense determining its partial pressure. The optimum mercury partial pressure is from 6-10 mTorr. This provides enough Hg in the gas form to allow uniform lighting of the tube. The impedance of the gas is lower when more Hg is in gas form, obviated by the fact that an electron travels a shorter distance to collide with another Hg atom. Unfortunately, this same fact causes the radiated UV to collide more often when more Hg is present. The goal is to provide enough Hg in gas form to allow the lamp to be driven easily, but so much as to cause excessive collision losses in the gas. Collision losses cause heating which increase the amount of Hg in gas form, causing more heating, etc. Collision losses also cause a loss of system efficiency or luminous efficacy.

Mercury ionizes at energy of 10.4eV. Two states of excitation are 6.4eV and 4.86eV, from which de-excitation yields UV of wavelengths 254nm and 180nm, respectively. Both excitation states yield UV usable by the phosphor while ionization decay produces electrons used to excite or ionize other Hg atoms. Figure 2 shows the various excitation states of mercury, and the wavelengths of the light emitted (in nm) when transitioning from state to state. Small numbers under each wavelength are from Kenty [5] and indicate a relative frequency of occurrence. Kenty's numbers relate to a 1.5 inch 40W lamp operating at 420mA with 3.5 Torr argon and 7mTorr mercury partial pressure. Clearly most of the radiating transitions come from the 6^3P_1 state and are at 254nm. Kenty showed that the metastable states on either side of the preferred 6^3P_1 state (6^3P_2, and 6^3P_0) contribute significantly by transitioning to the 6^3P_1 state, where radiations at 254nm can occur.

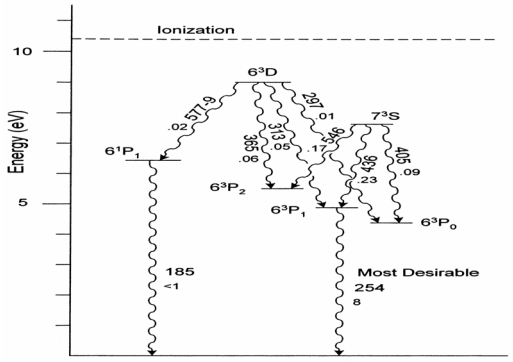

Figure 2. Radiation diagram for mercury (combined from Kenty and Waymouth [5, 6])

Figure 3 shows the effect wall temperature has on efficiency. Note that the slop is much steeper below the optimum wall temperature than it is above. As a result many lamp ballast designers set the operating point at or above the optimum to avoid the steep side of the curve.

This curve is for a 1.5" diameter lamp. Research by the author showed that this curve shifts to the right for smaller diameter lamps. For example a T-5 (5/8" diameter) lamp has its peak efficiency at closer to 52°C, compared to 40°C for the T-12 shown.

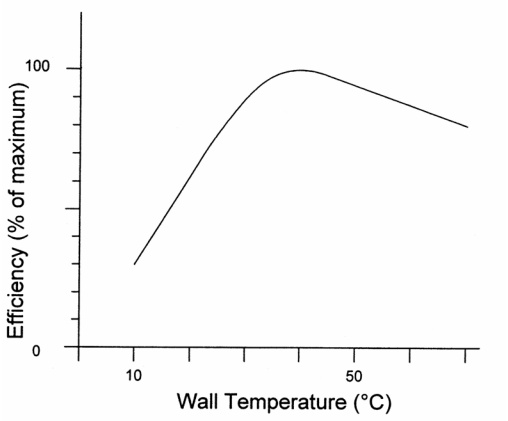

Figure 3. Efficiency vs. bulb wall cold spot temperature (from Waymouth [6])

Ignition: J. S. Townsend developed a theory in the early 1900s that, although empirical, is still the preferred method to describe initial ionization in a gas discharge tube. The theory called the "Townsend Avalanche" suggests that an electron emitted from a cathode **(**by photo emission or cosmic ray bombardment), if accelerate in a sufficient field, will strike an atom causing it to ionize. Now two electrons are in the field. These accelerate and ionize other atoms causing avalanche effect. The number of free electrons increases exponentially with distance. The measured coefficient is referred to as the Townsend "α" coefficient. The equation used to describe the electron current is thus:

$$i = i_o e^{\alpha x} \qquad (1)$$

where: i_o is the initial electron current leaving the cathode and x is the distance between electrodes in the tube.

Glow discharge: A factor important to initial ionization is "glow discharge". Glow discharge occurs when secondary emission (electrons expelled due to ions striking the cathode) causes the current at the cathode to be carried mainly by positive ions [7]. Ions strike the cathode as a result of very high potential drop immediately in front of the cathode. In fact, much of the voltage drop in a fluorescent lamp occurs in the "cathode sheath", an area extending only about 0.1 mm out from the cathode surface: the voltage drop is called the "cathode fall".

Hot cathode discharge: As the cathode is heated (due to external filament drive as well as the heat given off by the glow discharge ions striking the cathode) the cathode fall will drop to below 16 volts. Under these conditions most of the cathode current is due to "thermionic emission". Thermionic emission occurs when a material reaches a temperature where it freely releases electrons. Cathode materials are selected to optimize this property. When most of cathode current is due to these thermionically emitted electrons the discharge is called a "hot cathode discharge" [8].

Electrodes: The electrodes are the connection points where current is injected and removed from the gas column. In a DC lamp there exists an anode and a cathode, while in an AC lamp either electrode can act instantaneously as an anode or cathode [9].

The cathode: In the positive column, electrons carry 99.9% of current, all supplied by the negative glow at the cathode. At the cathode surface approximately 10% of the current is carried by positive ions and only 90% by electrons [10].

The anode: At the opposite end of the positive column is the anode. Since the anode does not emit positive ions, all the current that crosses the anode surface must be carried by electrons. Waymouth [6] suggests that the

random current at an anode surface, placed in this electron column is,

$$i_r = en_e A\sqrt{\frac{kT_e}{2\pi m_e}} \qquad (2)$$

where A is the area of the anode, n_e is the electron density, k is Boltzmann's constant, T_e is the electron temperature, and m_e is the electron mass. The total current at the anode is,

$$i_A = i_r e^{-\frac{eV}{kT_e}} \qquad (3)$$

where V is the potential between the anode and the plasma.

Figure 4 shows graphically the variation of the potential over the length of a typical hot cathode lamp. Note the nonlinear effects near the cathode and anode, becoming linear in the positive column.

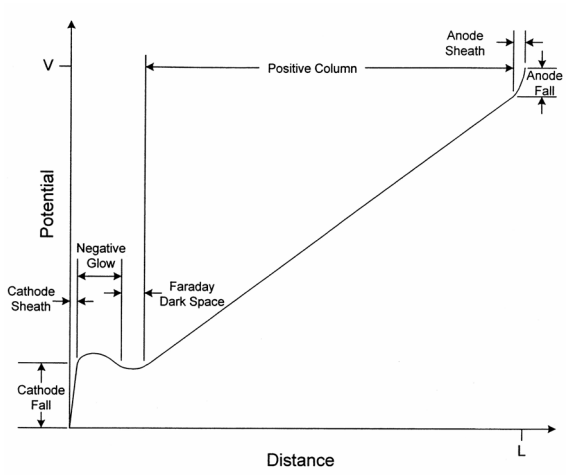

Figure 4. Potential vs. position along the arc length (from Waymouth [6])

3. Problems associated with fluorescent lamps

Lamp dimensions are critical in the design of fluorescent systems. As the length is increased the cathode/filament losses become less a factor; so, large increases in efficacy can be achieved by increasing the length of the lamp. Diameter considerations are a little less clear. Diameter is a trade off between diffusion losses and collision losses.

Diffusion losses: The center of the arc stream is typically the hottest part of the arc, carrying the largest percentage of the current. Ions tend to migrate toward the cooler portion of the gas, or toward the walls of the tube. At the walls the ions are satisfied by electrons, causing the ionization energy to be released to the walls in the form of heat. The farther the ions have to travel before reaching the walls of the tube the less the diffusion losses are, a kind of insulating effect. Waymouth [6] showed this loss to be proportional to ion-electron production frequency:

$$V_i = (\frac{2.4}{R})^2 D_a \qquad (4)$$

where: R is the radius of the tube wall and D_a is the ambipolar diffusion coefficient. The loss is thus proportional to $1/R^2$.

Collision losses: As Mercury atoms are excited and de-excited UV is released. If the UV reaches the walls then the phosphor is excited and de-excited giving off visible light. If, however, the UV encounters another mercury atom in its path it may excite the new atoms, which may: de-excite giving off desired UV, or possibly excite the atom to higher excitation level from which it radiates useless UV (non-254nm), or have a collision of the second kind and extinguish giving off heat. As the number of collisions increases the probability of an extinguishing collision occurring is increased. As Wymouth et al [11] showed, expanding on work by Kenty [5], the probability of collision related loss is proportional to the effective imprisonment lifetime (the time it takes for a particular photon to effectively excite and de-excite its way to the bulb wall)

$$T_{eff} = \frac{(k'R)^2 T_o}{2} \quad (5)$$

Where k' is the effective absorption coefficient, and T_o is the natural lifetime of the excited state. Waymouth suggested T_o was roughly 100ns and a typical imprisonment time would be 50 to 100 times T_o. But more important is the observation that as the diameter of the tube is increased collision losses also increase. This loss is directly proportional to R^2.

4. Results applied to fluorescent lamps

In spite of the problems associated with sizing and shaping fluorescent lamps, building the lamp is just the first part. The next challenge is to drive the lamp properly, achieving the desired light output, arc stability, and lamp life.

Drive: Two techniques of drive will be discussed here which allow lamps to be driven in extreme environments: direct drive, and flyback drive. Direct drive implies directly switching a high voltage through an inductor to the lamp. Flyback implies energizing a transformer, then allowing the secondary of the transformer to drive the lamp while the input drive is off.

Direct drive: This technique is essentially an offshoot of the office lighting technique of applying an AC voltage an inductor. More desirable results can be achieved if the frequency selected is in excess of the de-ionization frequency of the gas (usually around 1 kHz). Lower voltages are required and smaller magnetic can be used. If the diameter of the lamp used is to be less than the optimum 1.5", higher power supply voltage must be used. The voltage required can be from 100V to several thousand volts. With proper selection of lamps (size and rare gas pressure) the voltage can be kept to be below 1000V [12, 13].

Flyback drive: This technique uses a switch to connect a lower voltage (typically 100V or less) to a transformer primary. The energy is then transferred to the transformer secondary where the voltage raises proportional to the secondary inductance and capacitance as well as the lamp capacitance. The voltage rises until the gas in the lamp ionizes or the LC resonant peak voltage is reached. The resonant peak voltage must be designed sufficiently large to allow the lamp to ionize under worst case conditions, but sufficiently small voltage will not destroy the transformer and associated circuits should the lamp connection be broken. Again the frequency of operation should be selected such that the lamp remains ionized between cycles and the transformer remains small. Here the drive circuit can be as simple as a switch, a transformer, and a blocking diode. If the drive is single ended the filament heating can be DC referenced to ground connected to the cathode end of the lamp. The anode would then be connected to the drive transformer.

5. Conclusion

With efficacy roughly 5 times that of incandescent lamps, fluorescent lamps have clearly dominated the office environment application. The load reduction on office cooling systems is quite significant. Also, fluorescent lamp lives of 10,000 hours, as much as ten times of incandescent lamps, noticeably reduce maintenance costs.

There are, however, more efficient lamps. The efficacy of mercury metal halide lamps can be significantly greater than fluorescents. This has led to the proliferation of metal halide lamps in warehouse environments, where their deficiencies are not so objectionable. Deficiencies such as having bulb wall temperatures in the vicinity of 750^{o}C make its application impractical in small packages. Also, getting the gas up to temperature can take from several seconds to minutes. Power interruptions cause rapid cooling of the gas, leading to cold start conditions, when the interruption is longer

than a few hundred milliseconds. Another consideration is that the "burning" metal diffuses into the quartz bulb wall causing shifts in the color of the light output with age. This shift in color, although acceptable in warehouses, would be objectionable for most other lighting applications.

Although extremely difficult to model, fluorescent lamps are becoming more and more common. Fluorescent lamps, with all their problems, are still the most practical light source available when efficiency, cost savings, life, rapid start, and energy savings are the prime considerations [14].

A more valuable model would be one that focused on small diameter lamps such as T-5 (5/8" diameter) with multiple bends. These are the types typically used in LCD backlighting, where large dimming range is desirable. Simply designing a ballast does not require a detailed model, but dimming and the associated wide range of current level poses a real need for accurate modeling. Military applications, with the desired wide range of operating temperatures pose additional modeling requirements [15].

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E-Learning Product Design Using Quality Function Deployment and Fuzzy Regression

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Abstract

Electronic learning (e-learning) products are emerging with flexibility in attributes of pace, place, time and the presentation of the education. The main objective of this research is to propose a methodology for determining the target values for product characteristics of the e-learning products that satisfy customers' expectations. We initially explore the essential criteria to establish a basis for a comprehensive model for measuring e-learner satisfaction. Next, we present the quality function deployment (QFD) framework to allocate resources and to coordinate skills and functions based on customer needs. Differing from earlier QFD applications, the proposed methodology employs fuzzy regression analysis to determine the parameters of functional relationships between customer needs and product characteristics, and among product characteristics themselves. Since fuzzy regression is a viable alternative approach for finding the values for these relationships, it improves the applicability of QFD as a decision support tool for determining the target values for product characteristics to be considered. A real-world application illustrates the proposed methodology.

1. Introduction

The globalization drastically changed the relationship between the customers and the product or service providers. The providers can no longer impose on the customers the products or services they are to use. Rather, the customer chooses the products or services that he/she requires. As a result, both manufacturing and service companies have intended to introduce their own new product/service development and improvement mechanisms to assure the quality of their products and services. This was unavoidable since they are part of a globally competitive market and they have to survive and maintain their market shares. One of these strategic quality management tools is the quality function deployment (QFD), which simply intends to analyze customers' needs (CNs) to guarantee satisfaction.

In this work, our main objective is to propose a mechanism to improve the e-learning products so that the customers' satisfaction is ensured. We apply our decision methodology to evaluate several e-learning applications in Turkey. We initially explore the essential criteria for a successful e-learning environment. These criteria establish the basis for a comprehensive model for measuring e-learner satisfaction. Then, we introduce our QFD framework to allocate resources and to coordinate skills and functions based on CNs. This methodology enables us to easily develop the appropriate services for the customers. It neglects aspects with little or no meaning to customer; giving more importance to aspects meaning a lot. The main contribution of this study over previous QFD applications is that the proposed methodology employs fuzzy regression analysis to determine the parameters of functional

relationships between customer needs and product characteristics, and among product characteristics themselves. Fuzzy regression analysis used in this research addresses the problem of subjectivity and vagueness in determining the relationships between customer needs and product characteristics, and the dependencies among product characteristics. Since fuzzy regression is a viable alternative approach for finding the values for these relationships, it improves the applicability of QFD as a decision support tool for determining the target values for product characteristics to be considered while designing an e-learning program, and thus, providing a roadmap for e-learning product developers.

The remaining part of the paper is structured as follows: Section 2 presents the e-learning concept, and summarizes the main steps of the QFD and fuzzy regression along with related research. In Section 3, the decision methodology that is based on fuzzy linear regression and optimization is presented. In Section 4, the proposed framework is illustrated through an e-learning program study in Turkey. The last section presents concluding remarks driven from the case study.

2. E-learning

The European Commission defines e-learning as the use of new multimedia technologies and the Internet to improve the quality of learning by providing access to resources and services as well as enabling remote exchanges and collaboration.

Levy [11] reveals that the dropout rates from e-learning courses are 25%-40% and more dramatically, the dropouts from online training centers exceed 50%, compared to 10%-20% in on-campus courses and 10% in standard on-site training. Multimedia extensions of e-learning materials, such as video, audio, chat rooms, discussion boards, instant messaging and e-mail, all offering effective interaction for e-learners are used as a precaution to draw and keep their attention alive [2]. The preparation of these materials usually requires substantial effort because traditional course materials should be initially processed to be suitable to put on-line, which not only includes the digitalization of contents, but also making use of the new multimedia tools. Nevertheless, technology must not be considered a goal in itself, but rather a means towards better and easier learning. It is becoming common ground that a good e-learning course does not solely rely on technical aspects but also on pedagogical aspects [1]. In this paper, we use the QFD methodology to consider the pedagogical aspects (customer needs) and technical aspects (product characteristics) together.

In recent studies, authors have analyzed the e-learning procedure and proposed several essential criteria. Wang [17] measured the e-learner satisfaction with a questionnaire considering evidence of reliability, content validity, criterion related validity, convergent validity, discriminant validity, and nomological validity. Hwanga et al. [6] divided the evolution criteria into three categories: (1) criteria for evaluating the design of student interface, (2) criteria for the quality of instructional contents, and (3) criteria for evaluating the assessment functions. Mahdizadeh et al. [12] designed a questionnaire for teachers to identify factors shaping their opinions about e-learning environment. This paper concentrates on the e-learning initiatives in Turkey, which are relatively new and suffer from limited access to broadband connections.

2.1. Quality function deployment

The application of QFD starts with the first of its four phases, namely the house of quality (HOQ). In this work, we focus on this particular step. The following phases just use the outputs of the previous phases as the inputs. Thus, the main idea is the same for the remaining phases.

For a comprehensive review on QFD, the reader may refer to Chan and Wu [4]. As depicted in Figure 1, HOQ consists of seven elements.

(1) *Customer needs* (*CNs*). They are also known as voice of the customer, customer attributes, customer requirements or demanded quality. They provide a guideline for the providers on product/service attributes that the product should possess.

(2) *Product characteristics* (*PCs*). They are also referred as the voice of the company, design requirements, product technical requirements, engineering attributes, engineering characteristics or substitute quality characteristics. CNs define the goals for the QFD process, whereas PCs provide the means to achieve these goals.

(3) *Relative importance of the CNs*. Due to limited resources, the providers should concentrate on the most important needs while disregarding relatively unimportant ones. Moreover, the diversity of the CNs usually prohibits satisfaction in all of the CNs, simply because they could be in conflicting nature. As a result, the providers require methods to prioritize the CNs.

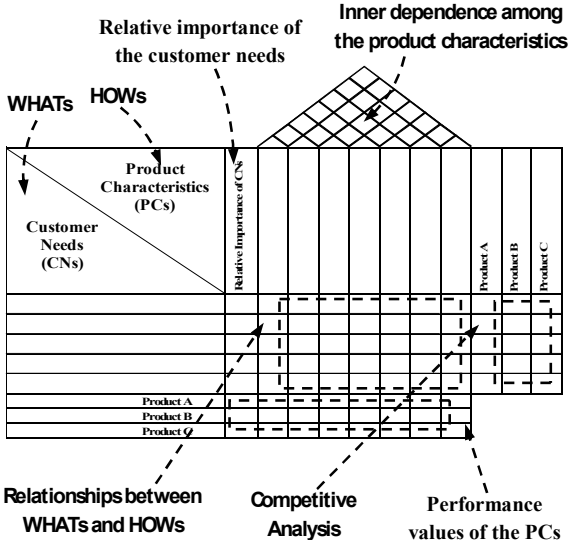

Figure 1. House of quality

(4) *Relationships between WHATs and HOWs*. The relationship matrix indicates to what extent each PC affects each CN and is placed in the body of the HOQ. This step is crucial as it is used to make the transition from the CNs into PCs. The determination of the strengths of these relationships is a subjective process. However, in this study we require just to define whether a PC is related with a CN and strength of these relationships is determined using fuzzy regression analysis. Consequently, we have provided a more solid and objective framework with minimum knowledge requirement.

(5) *Inner dependencies among the PCs*. The inner dependencies among PCs given in the HOQ's roof matrix measure the extent a change in one feature affects another. Similar to the relationships between WHATs and HOWs, these are also determined using fuzzy regression analysis.

(6) *Competitive analysis*. During the competitive analysis, the company's product or service position among its main competitors is identified, underlining company's strengths and weaknesses in terms of CNs. These findings along with the performance values of PCs for each provider are used to determine target values for PCs.

(7) *Overall priorities and performance values of PCs*. The performance values of PCs and the PCs' final ranking is usually used as the input for an optimization process.

QFD has been utilized in the field of education. Jaraiedi and Ritz [8] explored ways to improve the advising process as well as to improve the teaching process. Pitman et al. [13] and Hwarng and Teo [7] developed procedures using QFD to measure customer satisfaction in academic institutions. The main goals of these earlier studies are to identify the needs of the students, to prioritize these needs, and to take the necessary actions to satisfy them. Similarly, we employ QFD to satisfy the quality characteristics desired by the students through designing the best e-learning product.

2.2. Fuzzy regression

Fuzzy linear regression, which was first introduced by Tanaka et al. [15], is founded on possibility theory and fuzzy set theory. Fuzzy regression has been reported as a more effective tool than statistical regression when the data set is insufficient to support statistical regression, human judgments are involved, and the degree of system fuzziness is high [15].

In this study, fuzzy linear regression is selected as a tool for parameter estimation of functional relationships owing to its aptness to deal with human expert knowledge which is an important source in e-learning product selection. First, the ratings for factors such as "easy to understand", "credibility", and "easy to use" that are listed among customer needs are generally represented by expert judgment. Likewise, the fuzziness inherent in the relationships between customer needs and e-learning product characteristics, and the dependencies among e-learning product's characteristics can be effectively expressed using expert judgment.

In several studies, fuzzy set theory has been used to consider imprecision and vagueness in determining the importance of customer needs and addressing the relationships between customer needs and engineering characteristics in QFD [3, 9]. Few researchers have addressed the development of procedures for setting target levels for product characteristics using fuzzy regression and fuzzy optimization [5, 10].

The target values for e-learning product characteristics can be determined by solving the following formulation.

$$\begin{aligned} &\max z(y_1, y_2, \ldots, y_m) \\ &\text{subject to} \qquad (1) \\ &y_i = f_i(x_1, x_2, \ldots, x_n), \quad i = 1, 2, \ldots, m \\ &x_j = g_j(x_1, x_2, \ldots, x_{j-1}, x_{j+1}, \ldots, x_n), j = 1, 2, \ldots, n \end{aligned}$$

where y_i denotes the customer perception of the degree of satisfaction of the i^{th} customer need (i = 1, 2, …, m), x_j is the target value of the j^{th} e-learning product characteristic (j = 1, 2, …, n), f_i represents the functional relationship between the i^{th} customer need and the e-learning product characteristics, and g_j denotes the functional relationship between the j^{th} e-learning product characteristic and other e-learning product characteristics. The objective function of formulation (1) can be expressed as

$$z(y_1, y_2, \ldots, y_m) = \sum_{i=1}^{m} w_i \left(y_i - y_i^{\min} \right) \Big/ \left(y_i^{\max} - y_i^{\min} \right) \quad (2)$$

where w_i is the relative importance weight of the i^{th} customer need and is defined such that $0 < w_i \le 1$ and $\sum_{i=1}^{m} w_i = 1$, and $y_i^{\min}$ and $y_i^{\max}$ represent the minimum and the maximum possible values, respectively, for the i^{th} customer need.

The information provided in the HOQ can be used to estimate the parameters of the functional relationships f_i and g_j. Since the relationships between customer needs and e-learning product characteristics and the interactions among e-learning product characteristics are imprecise, fuzzy regression emerges as a robust alternative approach for serving this purpose.

A fuzzy linear regression model is defined as follows [15]:

$$\tilde{y} = \tilde{A}_0 + \tilde{A}_1 x_1 + \tilde{A}_2 x_2 + \ldots + \tilde{A}_n x_n \quad (3)$$

where $\tilde{y}$ is the fuzzy output, x_j are the real-valued independent variables, and $\tilde{A}_j$ are the fuzzy parameters expressed as symmetrical triangular fuzzy numbers with centers α_j and spreads c_j, respectively, having the membership function given as

$$\mu_{\tilde{A}_j}(a_j) = \begin{cases} 1 - \dfrac{|\alpha_j - a_j|}{c_j}, & \alpha_j - c_j \le a_j \le \alpha_j + c_j \\ 0, & \text{otherwise} \end{cases}$$

Fuzzy linear regression determines the fuzzy parameters, $\widetilde{A}_j$, such that the estimated output has the minimum total spread while satisfying a target degree of belief H, where $0 \le H < 1$. The H value is determined by the decision-maker and is referred to as the measure of goodness of fit of the estimated fuzzy linear regression model to the data set. In order to determine the fuzzy parameters, $\widetilde{A}_j$, the linear programming model given below is solved [16]:

$$\min Z = \sum_{j=0}^{n}\left(c_j \sum_{k=1}^{s}\left|x_{jk}\right|\right)$$

subject to (4)

$$\sum_{j=0}^{n}\alpha_j x_{jk} + (1-H)\left(\sum_{j=0}^{n} c_j \left|x_{jk}\right|\right) \ge y_k \text{ , } k = 1, 2, ..., s$$

$$\sum_{j=0}^{n}\alpha_j x_{jk} - (1-H)\left(\sum_{j=0}^{n} c_j \left|x_{jk}\right|\right) \le y_k \text{ , } k = 1, 2, ..., s$$

$$x_{0k} = 1, \; k = 1, 2, ..., s$$

$$c_j \ge 0, \; j = 0, 1, ..., n$$

where x_{jk} is the value of the j^{th} independent variable for the k^{th} observation (here, the value of the j^{th} product characteristic for the k^{th} e-learning product alternative), and y_k is the value of the dependent variable for the k^{th} observation (here, the customer perception of the degree of satisfaction of the customer need for the k^{th} e-learning product alternative). The aim of formulation (4) is to determine $\widetilde{A}_j$ in a way to minimize the total fuzziness under the condition that each observation y_k has at least H degree of belonging to its fuzzy estimate, i.e. $\mu_{\tilde{y}_k}(y_k) \ge H$ for k = 1, 2, …, s. When no fuzziness is considered in the system parameters, only the center value estimates obtained from formulation (4) are used in formulation (1) while the spreads are ignored [10].

3. The proposed framework

In this section, a modeling framework that integrates quality function deployment and fuzzy linear regression is presented to determine the target values for e-learning product characteristics. The methodology in this article addresses the problem of evaluating customer satisfaction and designing best performing product in the market. It consists of three main steps as depicted in Figure 2.

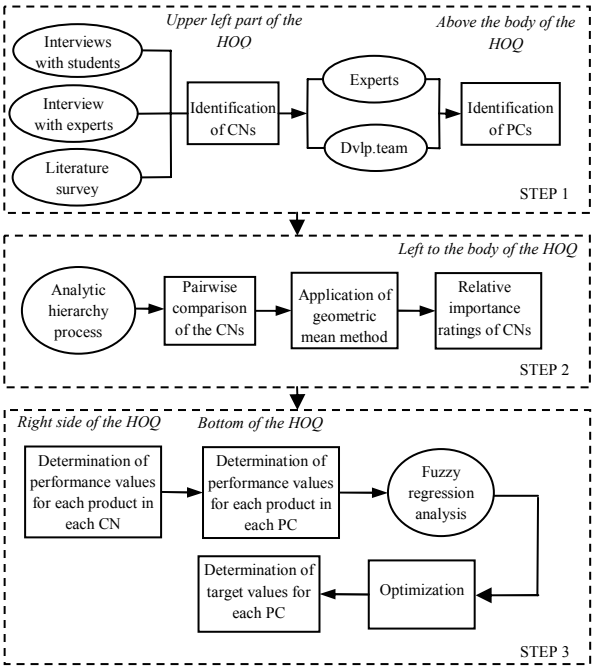

Figure 2. Representation of decision methodology

Step 1. The QFD process starts with the identification of the customer needs. The CNs have to be collected in terms of customers' perceptions and linguistic assessments. The organized customer phrases are placed in the upper left part of the HOQ. Additionally the PCs, the means of the company to satisfy these CNs, are also identified in this step and placed under the roof of the house of quality.

Step 2. The list of the CNs is usually too diverse for the company to deal with simultaneously. Even if it is not the case, the limited budgets are forcing the companies to

make tradeoffs in these CNs. At this point, there should be a mechanism to rate these CNs against each other and prepare a relative importance rating. Our proposed methodology overcomes this problem by utilizing the analytic hierarchy process (AHP).

Step 3. Fuzzy linear regression is used to estimate the parameters of the functional relationships between customer needs and e-learning product characteristics, and among e-learning product characteristics themselves. For the base case, H value is set to 0.5 as in a number of previous works on fuzzy regression [5, 10, 15]. When the data set is sufficiently large H could be set to 0, whereas a higher H value is suggested as the size of the data set becomes smaller [16]. Target values for product characteristics are determined using formulation (1), and thus, a roadmap is introduced for e-learning product developers.

4. Case study

In this study, we have selected e-learning programs of three private and three state universities in Turkey, namely Anadolu University, Bahcesehir University, Beykent University, Gazi University, Maltepe University, and Sakarya University, to apply our decision methodology. These programs are represented as *Univ* 1 through *Univ* 6 in a way to respect anonymity. The aim is to develop an e-learning program that will satisfy the customers.

Step 1. As mentioned in previous sections, QFD is apt to design customer oriented products/services. The methodology starts with the identification of the CNs, which are determined based on related research and face to face interviews with students, using questionnaires, interviews, and e-mails. Questionnaires and interviews were administered to extract relevant information on participant perceptions of, and attitudes towards e-learning programs. Follow-up interviews with students and the instructors were also gathered at the end of the research to understand their reflections regarding the programs. Initially background information on using the Internet is obtained. Then, statements are collected about self-evaluations regarding curriculum, implementation, self-performance, and so on, indicating levels of agreement or disagreement on a 5-point Likert-type scale, with 5 indicating strong agreement and 1 indicating weak agreement. Students were asked to describe the difficulties they encountered in using the interfaces. Students were also asked about the most positive features of e-learning, and about the benefits of using the Web. The collected and organized information are transformed into customer phrases and the PCs related to these CNs are placed in the HOQ given in Figure 3.

Step 2. This step involves the computation of importance ratings of the CNs using pairwise comparisons. The relative importance of the CNs is determined by asking the following question: 'Which CN should be emphasized more in developing an e-learning product, and how much more?'. The relative importance weights of the CNs are determined using the AHP [14]. The result is given below:

$$\mathbf{w} = \begin{pmatrix} 0.062 & 0.107 & 0.282 & 0.297 & 0.043 & 0.057 & 0.151 \end{pmatrix}^T$$

Step 3. The parameter estimations obtained by employing fuzzy linear regression are summarized in Table 1. Using the data for the e-learning product design problem and parameter estimations obtained by fuzzy linear regression, formulation (1) can be rewritten as

$$\max z = 0.0155\, y_1 + 0.0268\, y_2 + 0.0705\, y_3 + 0.0743 y_4 + 0.0108 y_5 + 0.0143 y_6 + 0.0378 y_7 - 0.25$$

subject to (5)

$$y_1 - 0.2404\, x_1 - 0.6538\, x_2 - 0.5385\, x_4 + 0.4231\, x_9 = -0.5385$$
$$y_2 - 0.6500\, x_1 - 1.4000\, x_3 + 1.4000\, x_4 = 2.6000$$
$$y_3 - 0.1250\, x_6 - 1.0833\, x_8 = 0$$
$$y_4 + 0.3750\, x_5 - 0.1250\, x_6 - 1.0833\, x_8 = 0.5000$$
$$y_5 + 0.1429\, x_3 - 0.5714\, x_4 - 0.0714\, x_7 = 2.1429$$

$y_6 + 0.4167\, x_3 - 1.0000\, x_4 = 1.0000$
$y_7 - 0.1250\, x_7 - 1.0000\, x_9 = 0$
$x_2 - 1.0000\, x_7 = 0.5000$
$x_4 + 0.2500\, x_6 = 3.6667$
$x_6 - 0.4000\, x_4 + 0.6000\, x_7 + 0.4000\, x_8 - 0.8000\, x_9 = 1.2000$
$x_7 + 0.6667\, x_2 + 0.5000\, x_6 - 2.0000\, x_9 = 0.8889$
$x_8 - 0.5000\, x_6 = 2.0000$
$x_9 - 0.2500\, x_6 - 0.7500\, x_7 = 0$
$1 \le x_j \le 5,\ j = 1, 2, ..., 9$
$1 \le y_i \le 5,\ i = 1, 2, \ldots, 7$

In the above formulation, the first seven constraints correspond to the relationships between customer needs and e-learning product characteristics, the following six constraints model the interactions among e-learning product characteristics, and the final set of constraints represents the minimum and maximum possible values for e-learning product characteristics and customer needs.

Table 2 presents the results of the above linear programming model. For example, we can observe that z value of *Univ* 1 is 0.5263, which is less than the optimum value of 0.6409. Consequently, in order to improve the customer satisfaction degree, *Univ* 1 has to improve its performance in "Offering related links, references (x_1)", "Conducting course evaluation tests (x_2)", "High qualified professors (x_6)", "Personalized advisor support (x_7)", "Credible in conventional education (x_8)" and "Encourage discussion and feedback (x_9)" by trading off performance values in "Clearly defined sections/subsections (x_3)", "Attractive multimedia implementations (x_4)" and "Payment alternatives (x_5)". Similar evaluations could be made for the remaining e-learning product alternatives.

Table 1. Fuzzy linear regression center and spread values (α_j, c_j) for $H = 0.5$

	Intercept	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
y_1	-0.5385	0.2404 (0.1346)	0.6538		0.5385					-0.4231
y_2	2.6000	0.6500 (0.1000)		1.4000	-1.4000					
y_3	0						0.1250		1.0833 (0.3333)	
y_4	0.5000					-0.3750	0.1250		1.0833 (0.3333)	
y_5	2.1429			-0.1429	0.5714			0.0714 (0.1429)		
y_6	1.0000			-0.4167 (0.1667)	1.0000					
y_7	0							0.1250 (0.2500)		1.0000
x_2	0.5000 (3.0000)							1.0000		
x_4	3.6667						-0.2500 (1.1667)			
x_6	1.2000 (1.6000)				0.4000			-0.6000	-0.4000	0.8000
x_7	0.8889		-0.6667				-0.5000 (0.1111)			2.0000
x_8	2.0000						0.5000 (1.0000)			
x_9	0 (1.0000)						0.2500	0.7500		

Table 2. Solution for the linear programming formulation (5)

z^*	y_1^*	y_2^*	y_3^*	y_4^*	y_5^*	y_6^*	y_7^*	x_1^*	x_2^*	x_3^*	x_4^*	x_5^*	x_6^*	x_7^*	x_8^*	x_9^*
0.6409	3.6783	5.0000	3.2979	3.4229	3.8570	3.1443	3.3403	5.0000	3.8326	2.6353	3.2425	1.0000	1.6970	3.3326	2.8485	2.9237

5. Conclusions

This paper presents a novel decision framework for e-learning product design. Determining product characteristics of e-learning products that are aligned with customers' expectations necessitates a comprehensive model, which makes the necessary trade-off between customers' requirements considering the relationship between customer needs and product characteristics and the dependencies among product characteristics. QFD provides the necessary means for incorporating these relationships into the decision framework. Moreover, fuzzy regression analysis used in this research addresses the problem of subjectivity and vagueness in determining the parameters of functional relationships between customer needs and product characteristics, and among product characteristics themselves.

												Competitive Analysis					
E-learning Product Characteristics / Customer Needs	Relative importance ratings of customer needs	Offering related links, references (x_1)	Conducting course evaluation tests (x_2)	Clearly defined sections/subsections (x_3)	Attractive multimedia implementations (x_4)	Payment alternatives (x_5)	High qualified professors (x_6)	Personalized advisor support (x_7)	Credible in conventional education (x_8)	Encourage discussion and feedback (x_9)	Univ 1	Univ 2	Univ 3	Univ 4	Univ 5	Univ 6
- Completeness (y_1)	0.062	X	X		X					X	4	3	3	3	4	2
- Easy to understand (y_2)	0.107	X		X	X						3	5	3	4	3	4
- Credibility (y_3)	0.282						X		X		3	3	2	4	3	4
- Price (y_4)	0.297					X	X		X		3	2	2	5	2	4
- Easy to use (y_5)	0.043			X	X			X			4	4	4	4	5	3
- Visually attractive (y_6)	0.057			X	X						3	3	4	4	4	2
- Provides personalized learning support (y_7)	0.151							X		X	3	4	2	3	4	2
E-learning PCs' Performance Values	Univ 1	3	2	3	4	3	1	3	2	2						
	Univ 2	3	4	4	5	4	4	4	2	4						
	Univ 3	4	3	3	3	4	2	4	3	3						
	Univ 4	2	3	2	2	1	2	2	3	2						
	Univ 5	3	5	2	3	1	1	3	3	3						
	Univ 6	4	3	3	4	2	2	4	4	3						

Figure 3. House of quality for designing an e-learning product

Since fuzzy regression is a viable alternative approach for finding the values for these relationships without requiring the rigid assumptions of statistical regression, it improves the applicability of QFD. As a result, the proposed methodology can be considered as a sound alternative decision aid to establish the target values for e-learning product characteristics and the maximum achievable values for customer requirements. For further study, the proposed methodology can be extended by performing sensitivity analysis w.r.t. *H* values for the fuzzy regression model.

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Developing an Enterprise Integration Strategy using an AHP-Delphi Approach

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Abstract

Selection of an optimal Enterprise Integration (EI) strategy is an important problem in realizing the strategic goals of an organization. It is a multi-criteria decision making problem involving multiple participants often times with different views. The authors posit the utility of analytic hierarchal process (AHP) coupled with a Delphi technique can improve the decision making processes by incorporating and weighting the various priorities from different players ultimately leading to consensus selection. The use of the AHP-Delphi model is formulated and applied in this context and validated by a real world case study involving a state governmental agency (SGA) embarking on the selection of an EI strategy. The use of the proposed model in this context is novel but represents a scientific and systematic approach to decision making thus minimize risks and optimizing the benefits generally associated with the selection of EI.

1. Introduction

In recent decades, we have witnessed organizations both in the private and public sector heavily investing in information technologies (IT). From all indicators, this trend will continue. IT, especially the internet has changed the business landscape. Organizations are competing and creating new opportunities in global markets with global partners and consumers. Business users and customers are now demanding high quality services and lower prices, both at the same time. This presents major challenges to an organization's ability to remain competitive. The dynamic nature of the new business playground means the development of new strategies. To be competitive, businesses must be agile and have effective service delivery. This often requires rapid sharing of information among business processes both intra and inter organization. Enterprise integration (EI) is an emerging technology that promises to assist organization with achieving this goal. EI aims to link separate business processes giving them increased leverage [1]. Thus it is not surprising that in a recent survey of top CIOs, EI ranked in their list of top 10 priorities for 2009 [2, 3]. For many top executives, EI is now a business necessity. Failure to implement EI may be detrimental to business. However, implementation of an EI strategy is not an easy task. Past researchers have cautioned that EI should only be undertaken when a thorough evaluation of organization's requirements is completed [4].

In this paper, we provide a systematic framework for analysis in the selection of an EI strategy. Selection of an EI strategy is a multi-

faceted problem. It involves more than the choosing a vendor. It is important to consider the organization's vision, requirements and constraints; the technical merits and limitations of the chosen strategy and huge costs. Costs include money for the technology, time and resources.

In spite of all the interest in EI very little research has been conducted on providing a framework for EI implementation. Most of the EI research has been centered on the development of the technology to enable integration. Janssen argues that organizational issues and stakeholders interests should be addressed in the selection process [5]. Thus there is a need for the development of a framework in the selection of an EI strategy that incorporates a compendium of factors [6].

We have developed one such strategic framework, AHP-Delphi. Analytic Hierarchy Process (AHP) developed by Saaty [7] was chosen for its ability to incorporate multiple factors with different relative weights. This gives the decision makers the ability to prioritize the importance of one factor over another. It has been used in numerous problems for vendor selection thus it is not a far to see that it may be applicable in this situation. To further improve the results on using AHP within this context, we applied a Delphi technique. The Delphi technique improves the process by first, allowing selection of requirements considered by the participants.

The paper proceeds with a discussion on EI, followed by factors influencing integration, methodology and a case study.

2. Past Research

2.1. Enterprise Integration

Frye and Gulledge [8] defined EI as *"alignment of strategies, business processes, information systems, technologies, and data across organizational boundaries to provide competitive advantage"*. Lack of this alignment is source of many organizational problems and the process of achieving this integration involves all managerial and technological factors that enable cross-functional process integration [8]. Integration can be approached in various ways and at various levels, such as, physical, application, business and can also be achieved through enterprise modeling approach or any methodological approach aimed at achieving consistent enterprise-wide decision making [9]. EI has also been classified on whether it involves integrating applications within organization or integrating applications and processes outside organizational boundaries. Inter-organizational enterprise integration, attempts to integrate business processes between enterprises (B2B), such as Supply Chain Management systems (SCMs), or electronic purchasing processes (e-procurement), whereas Intra-organizational integration is the integration of applications within the organization, attempting to integrate custom applications and packaged systems [10]

According Spackman and Speaker [11] there exists a large number of integration architectural approaches, but generally, there is slight variations between these approaches, and thus can be classified into four categories namely simple association, central hub, message bus, service integration and hybrid approach.

During early stages of integration project planning, determination of integration architectural approach is among the most important and challenging design activities. Decision made during this process impacts negatively or positively most of the subsequent development activities, and consequently overall success and quality of the resulting system. Many of subsequent decisions such as determination of integration technologies to adopt depends on outcome of architectural approach selected. This decision process involves making architectural tradeoffs of each

approach so as to meet organization architectural requirements [11, 12]. This decision activity is usually complicated by the fact that it involves different actors who are involved in decision making process and who have different quality goals, criteria and perception about certain alternatives. The activity is further challenging as it comes in early stages of project lifecycle, hence hard to reason about the consequences of the design decisions made [12].

2.2. Factors influencing integration approach

Enterprise integration projects are strategic investments, and should be closely linked to organization vision, goals and strategies. These projects involve high expenditure, risk and have a great impact on most of organization's aspects. Various organizations develop and implement integration projects motivated by completely different integration drivers. The initial rationale for implementing integration project influences problem definition, methods of achieving goals and other subsequent activities [13].

Lam et al [14] categorized integration drivers into two categories - Organizational drivers and project drivers, while Puschmann and Alt [15] identified five integration drivers – Software drivers, financial drivers, internal drivers and external drivers. Other organizations are driven to integration initiatives based on the perceived benefits such as [16]: Organizational, operational, technical and strategic.

These drivers and benefits should be taken into consideration when an enterprise is devising and evaluating different integration strategies [4, 5, 16].

As EI involves an attempt to connect a number of different types of software products, the selection of integration approach should not only be based on functional and business requirements, but should also take into consideration non-functional (also referred as quality attributes) and other technical requirements. Non-functional requirements describe properties that a system should posses. Quality attributes are defined by stakeholders and greatly influences adoption of a particular integration approach. Quality attributes should not be overlooked, as by doing so could lead to a poor system quality, unsatisfied stakeholders and eventually unsuccessful investment [12, 17]. Spackman and Speaker [11] proposed a Software Quality Attribute Trading (SQUAT) technique, which takes into consideration known software qualities attributes to evaluate integration approaches and technologies. Silveira and Pastor [10] developed enterprise application evaluation tool by further characterizing and describing international software quality evaluation standard (ISO-9126) for integration tools. Some of these quality attributes includes; adaptability, platform Neutrality, scalability, security, reliability, modifiability, performance, interoperability, maintainability, flexibility and testability

In general, selection and evaluation of integration approaches should take into consideration multiple factors, which include business, organizational, project and technical related factors, as shown in figure 1.

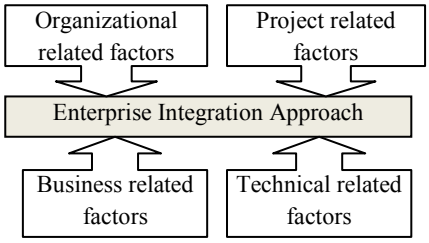

Figure 1: Factors influencing integration approach

3. Methodology

Evaluation and selection of integration approach is a complex and challenging process. It includes multiple criteria and involves multiple actors in decision making. Thus, the problem cannot just be solved by applying

traditional techniques. The problem requires an elaborate and systematic approach that would allow actors involved in this process to evaluate different alternatives while considering multiple factors, and expressing their preferences on these factors. In general, the evaluation and selection approach must:

- Allow participation, interaction and consensus of different actors involved in the decision process
- By allowing these participants to express their preferences on different factors and alternatives
- Allow identification, evaluation and ranking factors (attributes) that would be considered most important to the organization
- Allow identification, evaluation and ranking different alternatives that would properly address organization problem
- Have a way of letting decision makers see justification and logic behind the final decision

With these points in mind, this paper proposes use of analytic hierarchy process (AHP)- Delphi technique.

The AHP-Delphi methodology presented in this article consists of the following seven steps; (i) Problem formulation and factor identification; (ii) Forming evaluation panel; (iii) Defining evaluation Criteria; (iv) Structuring problem hierarchy; (v) Pair-wise comparison; (vi) Aggregating and normalizing results; (vii) Calculate globe weight and rank alternative. (See figure 2 below)

To illustrate the AHP-Delphi approach, this paper will consider an actual case study at one of state government agency (referred herein as SGA).

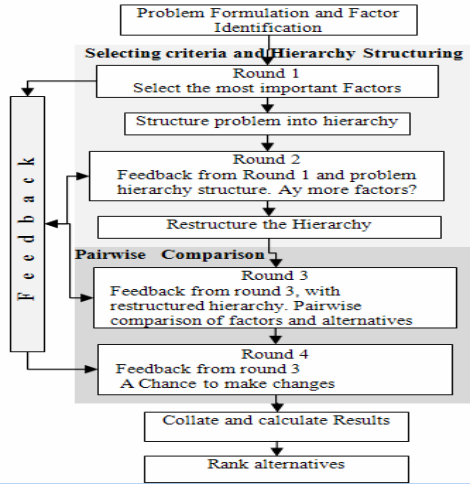

Figure 2: AHP-Delphi evaluation framework

4. Case Study

Many organizations in public sector continue to face IT challenges especially those related to integration. According to National Association of State Chief Information Officers (NASCIO), most of state chief information officers' (CIOs') priorities involve integration related issues [3]. This is evident at SGA, which is constantly seeking solutions to streamline its operations. SGA is composed of several organizational functions. Many of these functions use different systems to support their day-to-day operations. Unfortunately, many of these information systems exist within technical and functional walls of separation that creates barriers to integration and sharing of data. In some cases, data must be manually produced in one system and then manually entered into a second system. The result is inefficient business processing. For this reason, the agency has taken several integration initiatives as one way of addressing its strategic goals of effectiveness, efficiency and service improvement. Despite these efforts, the SGA continues to face integration challenges, as it continues to apply short-term integration solutions. SGA consists of a large number of facilities, stores, and maintenance operations, many at different locations. Thus, as an example to demonstrate challenges and integration efforts at SGA, this study will

consider one project at the agency that is seeking for a solution to integrate systems supporting financial management and supply chain, purchasing, and inventory management at its facilities and maintenance operations. In other similar integration projects, SGA has successfully applied traditional integration approaches such as building direct interfaces between applications, replicating data between databases or consolidating the databases, flat file transfer etc. But for this particular project, such approaches cannot be applied, due to several issues. First, one of the system is been upgraded to a later version and the other is scheduled for an upgrade at a later time. Secondly, these two systems must also be integrated with other enterprise systems such as Geographic Information System (GIS), engineering systems and with state financial management system, which is under different platform with that of SGA. Thirdly, the accounting code data format is different between the two systems i.e. lack of data uniformity.

Thus, the management is seeking for a different approach, that would not only integrate these two systems, but one that would also allow future integration with other systems. The approach must also provide sound, cost effective and long-term solution that is efficient and meets all of the stipulated needs of the agency. As results, some high level integration approaches have been suggested by different managers within the organization. The approaches suggested consisted; (1) Implement a Service oriented based integration (2) Buy a Vendor based Enterprise Integration Application (EAI) adapter. (3) Implement a single enterprise system such as ERP that would either replace these systems or integrate them.

Deciding on which approach to commit the SGA presents a great challenge to the management, as these approaches are perceived to have different integration benefits and qualities attributes. There is therefore a need to evaluate the presented approaches. To evaluate these approaches, an AHP-Delphi approach is proposed. The process involved the following stages;

Stage 1: Preparation: In this phase, review of integration approaches and the factors considered in evaluating these approaches was conducted. Also a panel of four members consisting of IT planning manager, two project managers and IT analyst was established. The members selected were believed to be knowledgeable about the integration subject and organizational requirements.

Stage 2: Selecting factors and structuring problem hierarchy: - The stage consisted of the first and second Delphi rounds. In the first round, the panel was presented with brief description about the problem, proposed alternatives and a list and description of factors that maybe considered in evaluating these alternatives. The panel was requested to select and justify, factors that they would consider important in evaluating the presented alternatives. They were also requested for additional factor that may have been excluded from the list. From this round, the group identified eight technical factors and five management factors that should be taken into consideration, and thus forming the evaluation criteria. With factors identified, the problem was structured into hierarchy. In the second round, the group was presented with anonymous feedback from round one, where they were presented with results from other members. The members were requested whether to reconsider their judgments'. The group was also presented with proposed problem hierarchy. The results from this round were similar to the result from round one, and thus, consensus on evaluation factors and final hierarchy structure formed as shown in figure 3.

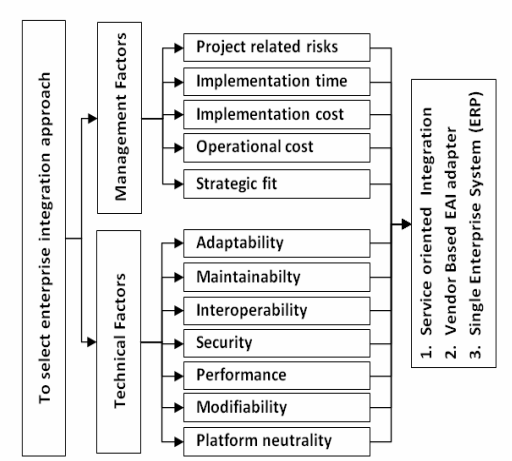

Figure 3: Decision hierarchy of Integration approach selection problem

Stage 3: Pair-wise comparison: - In this stage, pair-wise matrices were developed, that included all the combinations of criteria, sub-criteria and alternatives relationships. The matrices were implemented using the AHP Microsoft excel template, in which also, a way of checking consistency was built-in. The stage involved two rounds (round 3&4) of modified Delphi. In round three, the participants were presented with instructions on how to use excel-AHP template and the final problem hierarchy developed in the previous stage. Using Saaty's 1-9 scale [7], the participants were requested to compare the alternatives, criteria and sub-criteria according to their relative importance with respect to the parent element (criterions with respect to goal, and integration alternatives with respect to criterions). In some pair-wise comparisons, participants may find it impossible to determine appropriate weight, maybe due to lack of enough exposure to the subject, hence, participants were advised to treat such comparisons by assuming the two elements in question to be equally strong i.e. assigning them weight 1.

The results from this round indicated diversity in pair-wise comparison, and thus a fourth round was necessary to improve consensus.

The fourth round was set as the last one, and the panel was presented with round three results and asked whether they would like to make any changes in their pair-wise comparisons. Some revised their pair-wise weightings, resulting to a degree of consensus improvement. The pair-wise matrices and final results from different participants are presented in tables 1,2, 3, and 4.

Table 1: Pair-wise comparison on Criterion (factors) against objective

		P1	P3	P3	P4
Technical	Management	2	1	2	2

Stage 4: Aggregating results: - factor preferences varied from one panel member to another, hence; there was need to aggregate results for all participants. This was achieved by computing geometric mean method (GMM), using formula 1, below. The GMM procedure was preferred over arithmetic mean due to its ability to dampen very high or low values, which might bias arithmetic mean, and hence less affected by extreme values.

$$GM = \left(\prod_{i=1}^{n} a_i\right)^{1/n} = \sqrt[n]{a_1 \cdot a_2 \cdots a_n} \qquad (1)$$

Where a_{ij} is quantified judgment by participants on a pair of factors and i, j = 1, 2…, n

Table 2: Pair-wise Comparison on Management factors for different panel members

		Panel Members (Pi)				
Management factors		P1	P2	P3	P4	Aggregated
1st Factor	2nd factor					
Project related risk	Imp. Time	2	1	1	3	1.57
	Imp. Cost	2	½	1	2	1.59
	Oper cost	1	½	1/3	1	0.69
	Strategic fit	1	1/3	½	¼	0.58
Imp. Time	Imp. Cost	1	½	1	1	1.00
	Oper. Cost	1/3	1/3	¼	1/5	0.28
	Strategic fit	1/3	¼	1/3	1/5	0.28
Imp. cost	Oper. Cost	½	1/3	1/3	1/4	0.30
	Strategic fit	¼	1/5	1/3	1/5	0.24
Oper.cost	Strategic fit	¼	1	1	1/2	0.79

Table 3: Pair-wise comparison for integration alternatives with respect to factors

	Alt1/Alt2				Alt1/Alt3				Alt2/Alt3			
Factors	P1	P2	P3	P4	P1	P2	P3	P4	P1	P2	P3	P4
Project related risk	½	1	1	1	2	3	2	1	3	2	1	2
Implementation time	¼	1/3	½	1	1	2	1	2	4	3	2	1
Implementation cost	1	½	1	1	3	2	1	2	3	3	2	2
Operational cost	1/3	½	1	½	¼	1	½	1	1/3	1	½	1
Strategic fit	2	3	1	2	5	3	3	4	3	2	4	3
Adaptability	3	2	1	1	5	3	2	3	3	1	1	2
Modifiability	½	1	1	½	1	2	1	2	1	1	2	3
Scalability	3	2	2	1	4	3	4	3	3	3	2	3
Performance	½	½	1/3	1	½	½	1/3	1	½	½	1	1
Security	1/3	½	1	1	¼	1/3	1/3	½	1/3	1/3	¼	1/3
Interoperability	3	1	1	2	5	3	2	4	3	4	2	3
Maintainability	1/3	½	½	1	¼	½	1	1/3	1/3	1	1	½
Platform Neutrality	2	3	2	2	6	4	3	4	4	3	2	2

Alt1: - Service oriented integration
Alt2: - Vendor Based EAI adapter
Alt3: - Single Enterprise System e.g. ERP
P1, P2, P3, P4 - Panel members 1, 2, 3 and 4

Table 4: Pair-wise comparison on Technical Factors as provided by panel members

Technical Factors						Aggregated
Adaptability	Modifiability	1	1	2	1	1.19
	Scalability	1	½	1	½	1.00
	Performance	½	1/3	½	1	0.58
	Security	¼	¼	½	1/3	0.33
	Interoperability	½	1	1	1	1.00
	Maintainability	½	½	1	1	1.00
	Platform Neutrality	1	1	1	1	1.00
Modifiability	Scalability	1	½	1/3	1	0.69
	Performance	1/3	½	1/3	½	0.33
	Security	¼	1/3	¼	1/3	0.33
	Interoperability	1	1	½	½	1.00
	Maintainability	½	1	1/3	1	0.69
	Platform Neutrality	1	½	1	1	1.00
Scalability	Performance	½	1/3	1	1	0.69
	Security	¼	¼	1/3	½	0.33
	Interoperability	1	2	1	1	1.19
	Maintainability	1	2	½	1	1.26
	Platform Neutrality	1	1	½	2	1.26
Performance	Security	½	1/3	½	1	0.58
	Interoperability	2	1	1	1	1.19
	Maintainability	2	1	½	1	1.26
	Platform Neutrality	2	1	1	2	1.41
Security	Interoperability	4	2	3	2	2.63
	Maintainability	3	2	2	2	2.21
	Platform Neutrality	4	2	2	2	2.38
Interoperability	Maintainability	1	1	1	1	1.00
	Platform Neutrality	1	1	1	1	1.00
Maintainability	Platform Neutrality	1	½	½	1	1.00

Stage 5: Calculating factor priorities, and ranking alternatives - In this stage, an AHP tool was used to calculate factor priorities and ranking alternatives, using aggregated results from previous stage. The factor priorities and alternative ranking results are presented in table 5 and 6. More on AHP procedure can be found, in reference [7]. But in general, calculating priorities or relative weights involves calculating vector of priorities and normalizing the results. Elements of each column are divided by the sum of that column (normalizing the column), and then eigen vector is obtained by adding elements of in each resulting row to obtain row sum, and dividing this by the elements in the row, obtaining priority or relative weight. The overall priorities are calculated by multiplying the priorities of the factors within a group by the priority of that factor's group (which are calculated in same way)

The value scores for alternatives (in table 9) are obtained using formula 2

$$Vi = \sum_{y=1}^{k} W_z T_{iz} \qquad (2)$$

Where V*i* is value score for alternative i, and W_z is weight priority for factor z ($1 \leq z \leq k$) and T_{iz} is relative weighting of alternative *i* supports factor z

Table 5: Alternative ranking based on value Score

Rank	Alternative	Technical	Management	Total Value Score
1	Service Oriented Integration	0.222	0.144	0.366
2	Vendor Based EAI adapter	0.201	0.133	0.334
3	Single Enterprise System	0.218	0.082	0.300

Table 6: Local and global (overall) factor relative weights (priorities)

	Local	Global
Management Factors	0.359	
• Project related risk	0.174	0.06
• Implementation time	0.0950	0.03
• Implementation cost	0.0931	0.03
• Operational cost	0.292	0.10
• Strategic fit	0.347	0.12
Technical Factors	0.641	
• Adaptability	0.096	0.06
• Modifiability	0.079	0.05
• Scalability	0.109	0.07
• Performance	0.155	0.10
• Security	0.261	0.17
• Interoperability	0.099	0.06
• Maintainability	0.104	0.07
• Platform Neutrality	0.097	0.06

5. Results Discussion

By use of AHP-Delphi evaluation approach, a systematic approach is applied in selection and evaluation of integration approaches. The case study result, as shown in table 5 and figure 4, ranked service oriented integration as most appropriate approach to commit SGA.

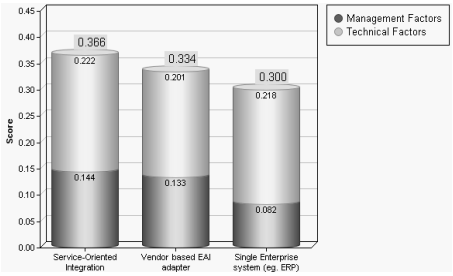

Figure 4: Alternative ranking with criteria and overall value score

The AHP analysis does not only help to determine the best alternative, but also shows reasons behind decision, through factor priorities as show in table 6 and figure 5. The analysis further allows decision makers and stakeholders see how alternatives relatively support different factors, as shown in radar chart in figure 6. The case study results presented, showed that the participants slightly favored technical factors over management factors in their decisions (see table 6). Security was a major factor influencing the final decision, scoring 17%, followed by strategic fit with 12%, and performance and operational cost both scored 10%. These results are indicated by table 7 and figure 5.

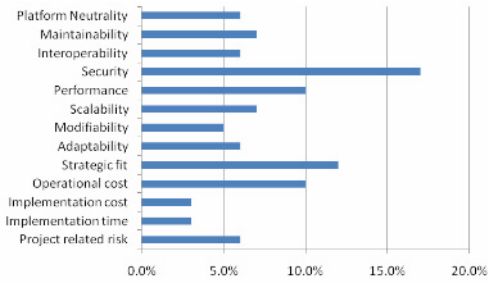

Figure 5: Chart showing factor importance (priorities) on selection problem

The analysis further showed that, members felt that single enterprise system such as an ERP relatively supports security more than other alternatives. It was further observed that Single enterprise system was deemed to bear more project risks, but better in maintainability and a tie with Vendor based EAI in operational cost. Service Oriented integration was felt to be better in supporting most factors, scoring high in platform neutrality, scalability, adaptability and strategic fit. These results are illustrated by the radar chart in figure 6.

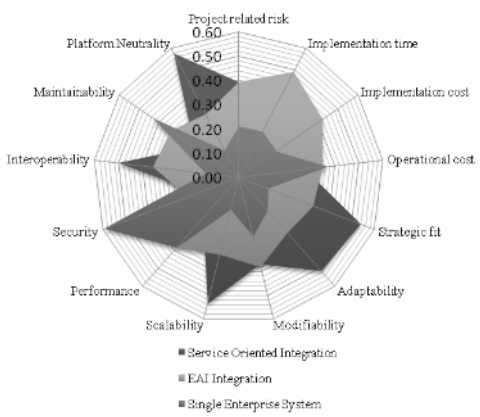

Figure 6: Radar chart showing how different alternative support factors

6. Conclusion and future work

Decisions related to EI approaches and technologies are unstructured and complex, due to consideration of a multi-set of factors, and involvement of different stakeholders. This paper demonstrated an AHP-Delphi evaluation approach, which systematically considers multiple factors and improves the AHP decision process by incorporating Delphi technique. The Delphi technique improved the process by first, allowing selection of requirements considered by the participants. Many factors included in the problem hierarchy mean more pair-wise comparison, and this may affect the process ability. The Delphi feedback also helped in improving consensus in the decision making process.

The use of the AHP-Delphi approach allows EI selection to be logically and systematically structured within the context and vision of the organization's strategic vision. It enables decision makers to consider the strengths and weakness of each EI strategy against various criteria and sub criteria. By adopting this approach it is easier to arrive at a consensus with proper documentation for such a complex decision.

From the results of the case study and calls by past research [6], we can conclude that the development of our AHP-Delphi evaluation tool for the selection of an EI strategy will improve the EI implementation decision making process. This approach should be extended in decisions throughout the enterprise integration lifecycle. If additional factors are emergent, they can easily be incorporated into this model. Likewise this model can be used to involve participants from in and out of the organization. It was observed that, there is need for a framework or benchmarking different integration approaches on how they support different factors.

Additional testing of this model is encouraged in different environments. Additionally, sensitivity analysis to determine the optimal number of players for decision making should be determined. Past research involving AHP has indicated three to seven decision makers.

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A Simulated Death and Complications Program for Engineering Management Graduate Assistants

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Abstract

The Death and Complications (D&C) conference, also known at many institutions as the Morbidity and Mortality (M&M) conference, is a standard component of surgical education. It provides a forum where both faculty and residents can examine surgical complications, identify ways to improve, and implement new practices to avoid adverse outcomes. Several years ago, Dr. Colletti from the University of Michigan's Medical School consulted with Dr. Tillman from Eastern Michigan University's Engineering Management program regarding applications of lean systems for medical education (paper presented at the 2006 IEMS Conference). During that project, Dr. Tillman learned of the use of the D&C conference for medical education and realized that it could be used in a very similar manner with Eastern Michigan University's (EMU's) Engineering Management program's graduate assistants, PhD students and fellows, and faculty as a tool for learning more about realities of an academic profession, generating teaching and research ideas, and continuous improvement of the Engineering Management masters and PhD programs. This paper will describe: (a) the specific methods used for scheduling and running D&C conferences for the Engineering Management program at EMU; (b) typical topics for discussion; and (c) its multiple benefits for faculty, students, and the program.

1. Introduction

This paper describes how the Death and Complications (D&C) conference, a teaching activity normally used in graduate medical education, has been modified and applied as a teaching tool for graduate assistants, PhD students and fellows, and faculty in the Engineering Management program at Eastern Michigan University. During this activity, student and faculty meet and freely discuss teaching and research ideas, as well as practical solutions to problems that are occurring during the conduct of the courses in the Engineering Management Program. .

2. The D&C conference in graduate medical education

Surgical residents are "surgeons in training." They have graduated from medical school, possess an M.D. degree, and are seeking additional training to become Board Certified in a surgical discipline, such as General Surgery, Cardiothoracic Surgery, Urology, Orthopedic Surgery, or Pediatric Surgery, as a few examples (this list is by no means all inclusive). Surgical residencies generally require an additional five to eight years of training after medical school. While these individuals are M.D.'s, the additional training they are receiving will eventually allow them to practice independently as a surgeon.

A surgical residency training program has both didactic and practical components. The

practical components include simulation, as well as "on the job training." Surgical residents are always supervised by surgical faculty, but are also directly involved in the evaluation and care of surgical patients and participate in surgical procedures. Participation in surgery progresses in a graduated fashion. First and second year residents participate in simple operations, while mid-level residents participate in progressively more complex cases. Residents who are in their final year of training participate in the most difficult and complex cases.

The D&C conference, also known at some institutions as the Morbidity and Mortality (M&M) conference [1], is a standard educational and quality assurance component of all surgical residency training programs. The goals and objectives of this conference are to discuss surgical complications in an open, analytical, and educational fashion [2,3]. Surgical faculty and surgical residents, as well as medical students who are currently rotating on the surgical services, are all required to attend. In cases where a patient death has occurred, especially if an autopsy was performed, faculty and residents from the Pathology Department will also attend, specifically to present and discuss the autopsy findings. These conferences usually take place on a weekly basis and all surgical complications that have occurred during the past week are listed for potential discussion [2-4]. A faculty moderator is then responsible for choosing the cases to be discussed in detail. Typically, the surgical resident who was involved in the surgical procedure that resulted in the complication is responsible for presenting the patient's medical history and pertinent findings on physical examination, the surgical procedure that was performed, the complication that occurred, how that complication was identified and treated, and the patient's overall outcome since the complication. The resident is also responsible for doing a review of the literature pertaining to this specific complication to determine best practices; the findings from the literature are also presented. Additional discussion and critique then takes place in order to determine whether a better plan of treatment could have occurred and whether a change of practice should occur in the future [5,6]. This entire discussion occurs with a focus on education and quality improvement [7]. Commonly, causes for complications or bad outcomes are classified into several categories, including technical errors, communication problems, or "system" problems [2,3]. In general, the focus of the conference is on the identification of problems, correction of those problems, and an overall goal of improvement in patient outcomes.

3. EM PhD GAs and Fellows at EMU

The Engineering Management (EM) masters program at EMU is available both fully online and face-to-face on campus, and it also serves as a concentration area for EMU's PhD in Technology program. The EM masters and PhD programs have experienced impressive enrollment growth rates, as shown in Figure 1.

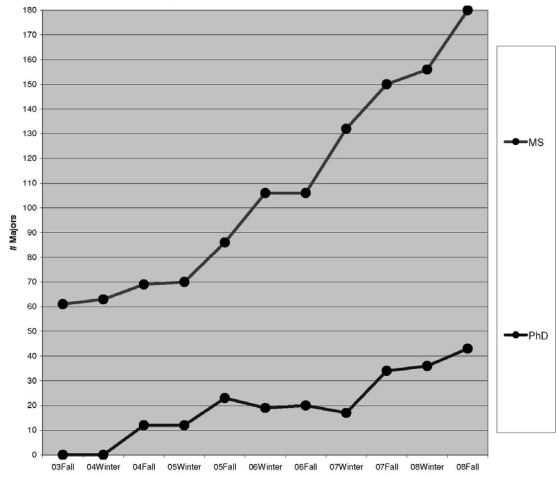

Figure 1. EM MS and PhD program growth

The EM masters program serves both as a feeder and a teacher training program for the EM PhD program. Graduates of the EMU EM masters program make excellent PhD Graduate Assistants (Gas) and teaching Fellows because

they have already had previous experience as masters students in the EM classes that they may teach as PhD students. Rather than hiring additional full-time tenure-track faculty, the growing demand for instructors in the EMU EM masters program has been met by employing more GA's and teaching Fellows from EMU's rapidly enlarging PhD program. Qualified PhD students will initially be awarded a GA position with grading and part-time teaching responsibility; they may then may be promoted to a higher-level Fellowship position, with more pay and full-time teaching responsibility. In many ways, this "teacher training program" is similar to a graduate medical education residency training program. Just like residents at a teaching hospital, GAs and Fellows in EMU's EM program are given successively higher levels of teaching responsibility and authority, doing some things right—and some things wrong—along the way.

The D&C conference method works very well in surgical residency training programs as a forum where both faculty and residents can examine surgical complications and poor patient outcomes, identify ways to improve, and implement new practices to avoid repeating mistakes. The EMU EM faculty have adopted this same system for the EM program's GAs, Fellows, and faculty for the same purpose. EM program faculty, GA's and Fellows usually meet late in the afternoon prior to evening classes, weekly in the Fall semester when new GAs start, and bi-weekly in the Winter semester. Meetings are called and run by the EM program coordinator.

4. Typical topics for discussion

To encourage openness among participants, EMU's EM program D&C meetings follow a minimal and flexible agenda, and maintain a somewhat informal, friendly team atmosphere. However, typical of an effective business meeting, these meetings often start with a presentation of quantitative program performance metrics and qualitative student feedback, whenever newly gathered information becomes available. It is helpful and motivational for the team to discuss reasons for good program performance, and it is also helpful for everyone to discuss possible reasons behind program performance problems.

Following this, GAs and Fellows are asked to present a short work report, describing what they did as part of their GA or Fellowship duties since the last meeting. This helps to assure that they are being assigned a fair amount of work to do by their faculty supervisors, and helps to make sure that they are completing their work assignments.

Then, faculty, GAs, and Fellows alike, take turns presenting any "Deaths" or "Complications" that they may be having in the classes that they are teaching--meaning either very serious problems (which we call "Deaths"), or smaller problems (which we call "Complications") that they have recently encountered in their classes. This portion of the meeting has to be handled very carefully, so as to encourage everyone to openly admit to problems and mistakes [3]. Initially, it can be very difficult for people to admit problems and mistakes to a group of their superiors, subordinates, and peers. Over time, however, in the protected and mutually-supportive environment of these D&C meetings, people do become more open in the spirit of learning from each others' mistakes, and gaining ideas for improvement. Not only do these discussions result in ideas for new and better teaching methods, they also often result in ideas for educational research that can be conducted by the PhD students and faculty members.

If there are no "Deaths" or "Complications" to discuss during a particular weekly meeting, we will hold an open question and answer session, where PhD students can ask questions of faculty, or of each other, regarding teaching,

conducting research, or studying as a PhD student. The faculty are very willing to offer their "sage" advice, however, this is also an opportunity for more senior PhD Fellows to give advice to the newer, less experienced GA's about how to be successful as an instructor, student, or researcher in the PhD program.

5. Benefits to faculty, students, and the EM program

D&C meetings are a lean kaizen tool for continuous quality improvement in surgery education programs, and likewise, for in EMU's Engineering Management program.

In the EMU EM program, D&C meetings have fostered an environment of trust and team work among faculty, GAs, and Fellows, which has resulted in an open sharing of problems and ideas for improvement. These discussions have generated many ideas for (a) new and better methods of instruction, (b) appropriate, and sometimes novel, ways to handle problem students, (c) course and program curriculum improvement, and (d) educational research that can be conducted by PhD students and faculty.

As a result, the quality of EMU's EM courses and program have improved, as have students' learning experiences. EMU's EM students are successful at achieving their course and program learning objectives, and quality of student feedback is high. Of course, the bottom-line is that the program performance metrics show significant enrollment growth, which would not happen if students were not happy with this program.

6. Conclusion

Just as EMU EM program's GAs and Fellows are learning practical methods from their D&C meetings to help them become good instructors and researchers, the faculty are sharing and learning ideas from each other, as well as from the GAs and Fellows, to become better instructors and researchers. With the right players, attitudes, and leadership, it can be a mutually supportive and beneficial arrangement for everyone involved.

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The Journey of a Leading B2B e-Commerce Network Provider: From Pioneer to Sufferer to Survivor

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Abstract

E-commerce was in many ways revolutionized by Ariba Inc, a leading independent company in the sphere of business to business (B2B) commerce network providers. In the universe of corporations, many bright meteors, like Commerce One, didn't shine too long. However, the interesting evolution of Ariba, from a pioneer to a sufferer to a survivor, has taught us much about survival in the competitive B2B software industry. They are one of the few companies to not only survive the burst of the dot-com bubble, and to this day to remain a successful company. In this paper, we will examine how Ariba, a promising startup company during the Internet boom of the 90's was able to overcome hardships, survive market and industry downturns, and continue to thrive in such a competitive industry. We will also review major events and innovations that helped the company to grow and succeed rather than to fail.

1. Introduction

Ariba, Inc. was born during the dot-com bubble, a star amid countless other e-commerce companies. The company has been evolving constantly, in cooperation with leading companies in the industry, in order to deliver E-commerce platform products to its customers/clients. Its value chain model has been able to develop business relationships further than anticipated, the results of which made it a top 40 Fortune 500 company.

Ariba has overcome many obstacles, including lawsuits, changing customer requirements, and organizational restructuring, however still managed to remain a leader in its specific niche area. They have done so by delivering solutions and services that meet customers' expectations, and have been able to cope with intense competition by keeping up with today's technologies as well as developing solutions for tomorrow. Ariba was founded in Sunnyvale CA, in September 1996, by seven men, the most influential individual being Steven Krach. Krach's early career accomplishments included being one of the youngest vice presidents General Motors [5]. Having struggled with the procurement process in his time there; it became a precursor and impetus for the birth of Ariba. Krach and his associates brainstormed and came up with the idea of automating the purchasing of common supplies and services. A seemingly simple idea, but one with a huge demand and potential.

After three months of intensive research, which included meeting with 60 Fortune 500 companies, Ariba had a prototype developed and ready for their initial marketing campaign. Having signed software licensing deals with Cisco Systems, Advanced Micro Devices and Octel Communications, prior to software completion, the pieces were put into place for the launch of their product. Among the early competitors to Ariba were Commerce One, Oracle, I2, and PeopleSoft, Inc. The objective was to become a powerhouse company with the means and resources to provide procurement software and network consulting services, enabling corporations to manage their spending more effectively. This included essentially all non payroll expenses associated with running a

business. Ariba offered their clients real-time data by providing information over the Internet. These applications were used in conjunction with the *Ariba Supplier Network* to purchase goods and services [12]. Ariba is customer driven, and offered full support, including technical support, implementation, training, and consulting. E-payment and service agreements were made with American Express and Bank of America. All of these were considered large and bold undertakings for a young startup company at that time. In June of 1999, Ariba went public at a modest $23 per share, however traded as high as $259 per share at times later that year [8]. A stunning success for a three year old company which had yet to turn a profit, it benefited from being a "first mover" in the business. However, other Internet start-up companies were beginning to offer similar software and services. Over time, smaller companies began emerging with websites that provided a place to manage procurement, some with lower costs and fees. Facing challenges in the market, Ariba began to be faced with difficult challenges and had to make major decisions in order to stay in business.

Ariba finally saw a profit of $10 million in December of 2000, which also included the completion of three acquisitions. Soon after, in 2001, the economy began to weaken in a downward spiral and Ariba's stock plummeted 95% in just nine months, making a business overhaul necessary [15]. Ariba decided to take drastic cost-cutting measures, cutting about a third of their staff. Because of their specialized and niche product line, their business was able to continue and survive the setbacks faced by other Internet software companies. Krach resigned as CEO in 2001, but stayed on chairman and appointed a CEO that would later cost the company much money and negative publicity. The bursting of the dot-com "bubble" marked the beginning of a relatively mild yet rather lengthy early 2000s recession [3]. In time, Ariba, along with the rest of the B2B business community ran into two big problems. First, the brick-and-mortar Old Economy was stable and could adjust more readily to economic downturns. Secondly, companies were interested in saving transaction fees by using alternate means of such as word processors instead of using costly B2B networks. However, they were less interested in cutting their savings in terms of transaction fees [14].

Still, Ariba persisted and would once again regain its position as a leader in the B2B procurement industry. The firm made adjustments where necessary to still deliver the goods to their clients, without sacrificing their own bottom line. According to the current CEO, Bob Calderoni, Ariba is well positioned in the spend management market and will continue to grow in the current tough global economy.

The following sections explore the external and internal factors that affect the company's struggles and challenges.

2. External factors

2.1. Severe competition

Simply being a dot-com business survivor, however, would not ensure its continued existence and profitability, and Ariba was at risk of losing business to the likes of other competitors such as SAP and Oracle. SAP, a German enterprise resource planning software maker, joined this market and signed on with Hewlett-Packard for a product called mySAP.com e-business solutions. In addition, it built a marketplace for chemical and pharmaceutical firms by educating them on mySAP.com, and with the result of installing a large SAP user base among Fortune 500 companies.

Nevertheless, Oracle had already anticipated a shift in the market and made plans to capitalize on it. Right now, the procurement sector is dominated by leading software companies Ariba and Commerce One. But as the slowdown in the U.S. economy continues, Oracle is hoping the opportunity for companies like Ariba will start to shrink as users look to more established ones, like Oracle, for an all around e-commerce package [1]. Ariba had in fact provided Oracle with an opportunity to gain market share when it cut a third of its workforce and announced reduced earnings during economic recent downturns.

Ariba recognized that to remain competitive, it had to address the problem of hidden costs associated with the products they sell, in addition to the price they charge for the software itself within the supply chain, especially when the product was in the later stage of its cycle. When a company does not paying attention to the hidden costs of new software implementation, it can creep up and well-intentioned efforts can be result in the form of financial penalties [20].

By August 2008, the market for supply chain management (SCM) software has grown. Worldwide spending on SCM solutions reached $6 billion in 2007, which was up 17.6% from 2006. SCM Technologies are well-positioned to address the economic realities facing worldwide markets where costs are skyrocketing while competition and customer demands are intensifying [7]. A number of the SCM solution vendors are merging, and expanding their capabilities within the realm of supply chain technologies. In comparison, Ariba's 2007 revenue was $160.3 million, which significantly trailed behind Oracle and SAP, who reported $955.2 million and $1,334.4 million in revenue, respectively, showing that the threat of these products cutting into Ariba's bottom line is a real one [2].

2.2. High-priced software

Without a doubt, e-procurement is rising substantially among the nation's largest 500 companies. Well-financed corporations are willing to invest in Internet software and technology that can reduce the inefficiency associated with the purchasing and buying processes. The use of this software can help companies to track spending and make sure they purchase products in accordance with contracts they have negotiated with suppliers. In fact, businesses that spend billions each year on supplies can often save tens of millions in costs by implementing such technology. However, it's only the large firms that can devote the time and money to installing such systems, which frequently required that suppliers link to such systems as well. Since the software is generally expensive and can be complicated to install on the customer's system, for small- and medium-sized businesses facing an uncertain economy, investments of this magnitude are can be difficult to justify.

Ariba took advantage of this situation, and in 2005 announced a strategy to sell its software and services to smaller companies on an on-demand basis, so they can buy supplies more efficiently online, as well. Ariba reshaped its software system so its customers can plug into Ariba's software through the Internet instead of installing it on their own systems. One major benefit of this approach, Mr. Calderoni said, is that Ariba can sell software to procurement managers and others in charge of spending, without involving the company's information technology staff.

2.3. Regulator's investigation

In early 2003, Ariba became under investigation by the Security and Exchange Commissions (SEC). The reason for the investigation was linked to Ariba's accounting errors, doubtful partner deals, and questionable payments items including chartered airplanes. Among the specific allegations were that Ariba failed to record a $10 million payment from Chairman Keith Krach to former chief executive Larry Mueller as an expense. The restatements are unusual because the chairman -- not the company -- covered the expense [18]. Then three weeks later, Ariba had decided to do the same for $1.2 million in chartered jet services that was considered as Krach's compensation to Mueller, who subsequently left Ariba in July 2001. The problem is that United States laws and regulations require that payments by a principal holder to executives be treated as expenses paid on behalf of the company.

In addition, Ariba reported an additional $7.5 million to its expenses. In 2000, Ariba acquired TradingDynamic Inc., Tradex Technologies Inc., and SupplierMarket.com, and it reclassified stock options, or goodwill, that it gave to employees of these accompanies as a compensation expense. So by combining all of these expenses, the results were 18.7 million of

added expenses. Ariba was aware that the regulator had begun an informal inquiry into its accounting practices after the firm said it would restate its earnings for 10 quarters [10].

2.4. Unhappy customers

Ariba was subject to bad publicity after sending out automated emails to mid-size suppliers announcing their accounts had been upgraded to Premier level status. The email listed premier supplier benefits as well. However, the email also informed them that as a Premier Member, they were now required to pay associated annual fees. Many of the small and mid-size companies viewed this as a marketing ploy and felt they should not all of a sudden pay fees associated with their membership [7].

3. Internal factors

3.1. Adaptations to a competitive environment

At the height of the e-procurement frenzy, two companies dominated the B2B space: Commerce One and Ariba. With the near-collapse of the original B2B procurement model, both companies sought new niches. Commerce One moved towards web services in an attempt to seek viable markets. Ariba, meanwhile, emphasized enterprise spending management [16]. Ariba strongly believed that a software firm's role is to be a software tool provider. As the B2B world divided into industry sponsored exchanges and independent marketplaces, Ariba avoided involvement in managing its customers' exchanges. Conversely, Commerce One believed that software makers had to do more than simply provide software tools. They had formed strategic partnerships with its customers and helped manage their online marketplaces [13]. It also directed its customers towards an international trading network in order to build critical mass and facilitate e-commerce between them.

As a new CEO, Calderoni monitored the external environment, where a fundamental shift in the marketplace existed, and responded promptly to adjust the company's product offering. He believed that B2B e-business had a direct and indirect impact on all functional areas, and those linkages with a company's supply chain system was critical. In effect, Ariba was changing its focus from e-procurement, to offering products that can increase customer satisfaction by solving a variety of "spend-related" problems faced by corporations [6].

With the concept of division of labor as a microeconomic view, Calderoni added a purchasing system, general ledger, and field system into Ariba's line of products. The added features in the company's products were favored by Ariba's existing customers in the auto, chemical, and manufacturing industries due to the ease of system comparability. The need to transfer data from legacy systems enabled these customers to remove outdated and inaccurate data from their systems and which also helped to improve relationships with their customers.

3.2. Acquire to advance

According to Krach, a major component of Ariba's business model is partnering followed by organic growth and acquisition, and so the company continues to follow this basic approach to help ensure the firm's success. Ariba acquired companies that had the technology and resources they needed to survive, instead of taking the time to develop them in-house. By acquiring Agile Software, a leading provider of Internet-based B2B communication technology, Ariba was able to add collaboration capability to its services, allowing its customers to communicate and coordinate product supply, design, and other specialized electronic-commerce functions. Mr. Calderoni implemented an aggressive acquisition strategy that significantly expanded Ariba's technology offerings and service capabilities, and positioned the company as a recognized leader in its market. One goal was to secure top Fortune 10 companies and Global 500 companies as customers [11].

In 2004, Ariba acquired Alliente Inc. and FreeMarkets Inc. to link their spend management software with its existing capacities as a B2B procurement hub. The acquisition of FreeMarkets increased Ariba's offerings by

providing global supply management software and services. This acquisition also positioned Ariba as a serious contender in the automotive industry, adding General Motors Corp., Daimler-Chrysler AG and Ford Motor Co. to their customer base. By acquiring Alliente, Ariba expanded its *spend management* and procurement capabilities to include a procurement out-sourcing provider [9].

In December 2007, Ariba announced that it had completed the acquisition of Procuri, Inc. a privately held provider of on-demand supply management solutions, rounding out Ariba's offerings that help companies automate the procurement process. According to Ariba CEO Bob Calderoni, more than 70% of Procuri's 300 customers have under $5 billion in revenues. As a result, this deal also gave Ariba greater access to midmarket customers [4].

3.3. Consulting adds value

Calderoni believed that Ariba has survived by expanding beyond software that focused mainly on transactions, to encompassing additional facets of the buying process. Calderoni hired hundreds of consultants to advise companies on how to buy goods and services cheaply, using Ariba's software. Although consulting is less profitable than selling software, Calderoni predicted he can successfully combine the two as an integrated set of offerings. While consultants coach Ariba's clients on how to use the software effectively, Ariba's clients can also reply on Internet-based purchasing systems to help them buy direct materials that are core to their company's manufacturing processes.

In order to extend Ariba's consulting services, which in 2004 accounted for nearly half of the company's $323 million in sales, Ariba made consultants available via email and phone for a fraction of the price that is charged to the larger companies who require dedicated consultants through in site visits [17].

3.4. Emphasis on the customer

In 2001, investors were looking for a change in leadership at Ariba after the firm missed revenue and earnings projections by a wide margin. Ariba moved Keith Krach out of the CEO position, filling the post with the company's President and COO, Larry Mueller. Mueller entered the position with a new strategy: to halt the company's current plans to enter new markets, and instead opting to add new features, including electronic payment and invoicing, to its existing e-procurement and auction applications. Mueller heightened the focus on improving e-procurement applications by making heavy investments in existing e-procurement and sourcing platforms; and building technology around the key interactions that enterprises have with trading partners.

Mueller remained focused on bolstering Ariba's role as a traditional B2B transaction platform. Ariba announced plans to invest heavily in its Ariba *Commerce Services Network* and its network-centric applications, including *Network Connect*, which allowed non-Ariba customers to come into the Ariba services network and conduct business or procure services. The company also organized its development, sales, and marketing staff to focus on specific industries. According to Mueller, "Customer ROI is the focus." A focus on international expansion has boosted revenue from outside the US from 10% in the third quarter 2000 to 25% in the same period for 2001 [22]. Ariba is trying to rebuild its fortunes as public marketplaces that use its technology are struggling - some economists feel this is due to the fact the industry just isn't ready for e-commerce.

Since joining the company in 2000, new (and current) chairman and CEO of Ariba, Mr. Calderoni has successfully transformed Ariba from a narrowly focused e-procurement vendor to a comprehensive spend management solutions provider that companies of all sizes rely on to transform the way they do business globally. Under Mr. Calderoni's leadership, Ariba has led the way in developing and delivering innovative solutions that combine technology, commodity expertise and services to help companies

streamline the procurement process and drive bottom-line results.

4. A short SWOT analysis

4.1. Industry perspective

Almost all businesses depend on the enterprise wide solutions to optimize their business operations and minimize their operating costs. This creates the pressure for developing new solutions constantly and continuously. In the present digital economy, businesses operate through e-Commerce in order to gain a competitive advantage, not only by improving the efficiency and effectiveness of existing business processes, but also by enabling constant adaptation to a rapidly changing competitive environment. The distinguishing characteristics of this industry are: rapid development/introduction of cutting-edge software technology, in-depth understanding of enterprise-oriented solutions, advanced procurement solutions, expertise in developing and managing large-scale electronic initiatives, research and development for innovation of new and improved solution products, integration with suppliers and buyers, and customization of solutions to fit customer needs. Key technological innovation and development and the ability to constantly improve the product is thus the main driving force for the industry.

The formation of B2Business companies has resulted in helping corporations to embrace the changes and opportunities of the Internet age. The key success factors for B2B firms is to leverage the e-commerce platform to automate and integrate the internal and external commerce processes of buyers, suppliers, internet exchanges, and value added service providers, delivering a global e-commerce infrastructure that provides cost savings and revenue opportunities for business of all sizes. The *Strategic Group Map* analysis for the computer service industry reveals that there is a strong competition between the B2B firms who are leaders and visionaries (Oracle, SAP, Ariba and etc.) and have the high ability to execute the solutions as a per customer requirement [21]. Individualized solutions is an ever increasing vital component of each and every business, as each customer or client has a pool of pressing need relevant to their corporation's financial goals and objective. There are challengers, who are mainly new players in the market. But because of the long learning curve of top players, these challengers contribute to the medium quality market. At times the speed in which this change takes place can be overwhelming, but the ability to create and withstand such business pressure is one key to providing solutions. This will reshape the industry depending upon the individual firm's business strategy and their ability to innovate and deliver a solution.

4.2. Marketing perspective

Ariba maintains corporate relationships by working with industry leaders and other system integrators, e-commerce solution providers, content providers, and application service providers. To provide solutions to their clients, Ariba maintains strategic alliances with leading firms. The benefits Ariba derives from its alliances are enormous. The global e-commerce revolution is entering a new phase. The early consumer-focused e-commerce winners created the Internet business model, but it will be their B2B successors that realize the full potential of the new electronic economy. B2B is already the fastest growth area in the superheated new Internet economy and carries with it a potential almost beyond measure. Just think of the overwhelming cost saving capabilities of doing complex business operations via an internet connection. Added to this is the fact that video email and conferencing are growing at a rapid rate, with some providers charging no fee whatsoever to broadcast one on one, one to a group or group to groups conferencing and training.

Ariba will enter a critical phase over the next few years as they put newly struck alliances and stratagems to work, thus facilitating their potential and growth in an ever expanding world. It would be foolhardy at this stage, with e-commerce still so volatile, to speculate about who will wind up on top. But one thing is certain: B2B e-commerce is such a complex proposition that not one software company can

do it all, from making programs that run a company's online procurement systems to powering online auctions and enabling exchanges that allow buyers and sellers to manipulate the supply chain. This is why the decisions are made by Ariba on which strategies to pursue and on which partners can best help it realize its game plan. Therefore, it would be safe to predict that Ariba has the foresight and innovative spirit to reach out and develop integrated planning solutions that firmly fit into the overall global environment.

4.3. Company perspective

With incredible technology growth and its global demand, came the opportunity for Ariba to expand and acquire a more precise goal and target. Ariba painted a vision of a world in which spend management would be affordable and available to all types of companies, and released an initial set of integrated, on-demand solutions designed to make this happen [22]. In keeping this promise, Ariba would make on-demand products and subscription-based purchasing software and services available to meet the needs of those mid-market customers not wanting to make huge upfront investments. This strategy of meeting the needs of various types of clients was in some way risky, but Ariba has thrived on making strategic, yet controversial decisions throughout the years. Having gone through ups and downs during the years, they still managed to regain a leadership position even though markets and needs have evolved and changed. Overall, they have been able to provide customers with superb services and innovative products, and reliability is what keeps old customers, and helps to bring in new customers.

How could Ariba remain a pioneer in a specific market segment and be able to maintain its successful status for so long? Taylor Stansbury, executive vice president of Products & Operations at Ariba, Inc. answered this question when he wrote about the 10 tips for evolutionary success [19] [23]. Included in these tips were some very simple ones such as *listening to customers*, where satisfying all customer's needs is a priority; *involving everyone*, which meant every department of the company needed to be involved in decisions and any change and not just one particular department; and *acquiring to advance*, which made acquisitions of companies purely strategic in order to enhance ones resources. Other principles included the need to *innovate incrementally*, which meant pushing new products but not to the level that some firms do, opting instead to upgrade products so that customers are always buying something better, even if it's just an enhancement of something previously used. *Evaluate regularly* means to constantly go over the market's needs together with new technologies to make decisions; and *stick with it*, which means to persevere in your strategy because it usually takes longer to achieve one's goal than is usually expected or planned.

These are all exceptional principles to follow, but in business, there is never a guarantee of success. Successful companies also need a must be surrounded by a committed and devoted management team, supported by well-trained employees. Are these together a recipe for success? We may never know for sure, but taking advice from a company which has been successful since its start, weathered some very tough times, and was able to survive and stay above the rest before seeking out the next realm of opportunity, is certainly an approach that appears to be sound.

5. Conclusion

A number of the challenges Ariba faced from its start to the present time allowed them to evolve over time. Ariba has been able to face these challenges head on and continue to be the leading B2B software provider. During the collapse of the dot-com era Ariba suffered a blow economically, as did others in the industry. However, they were able to adapt to their ever-changing environment and build upon their core competencies, managing knowledge that formed the basis of their competitive advantage.

It is interesting to note that while many firms who came up around the time of Ariba and offered competing solutions, Ariba is one of the

few that has survived and thrived, using continually new strategies to stay in business, providing a better customer experience, and utilizing advances in technology and ideas that no other companies dared to try. Ariba has been, and remained a pioneer and a leader in an exceedingly competitive and changing marketplace. Due to increased globalization and deregulation, for a company to succeed, it must have leverage over the impact of competitive forces. Ariba has done a great job in setting themselves apart from their competitors by strategically aligning themselves with their partners, and also expanding its service offerings to a wider range of customers.

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Economic Feasibility of Utilizing Multivariate Control Charts

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Abstract

This research is aimed at quantifying the economic consequences of utilizing the Hotelling's T^2 multivariate control chart as an alternative to the traditional Shewhart's $\bar{x}$ chart. Economic design models for the $\bar{x}$ and T^2 charts are utilized in constructing an incremental cost function to examine the cost and worth of switching from the $\bar{x}$ charts to a T^2 chart under specified levels of process and chart parameters. It is shown that the switch to multivariate T^2 chart results in economic savings under all levels of the process and chart variables considered.

1. Introduction

Since the pioneering work of Shewhart in 1931, control charts have been successfully used to monitor process performance over time. They have been a foundation for maintaining and achieving new unprecedented levels of quality. However, these are generally classified as univariate charts that can only be used to monitor a single characteristic of a stationary process. Advancements in technology and increased customer expectations have raised the need to monitor multiple variables simultaneously. This requires the utilization of multivariate control charts, enabling engineers and manufacturers to monitor the stability of their systems. Under these conditions, additional expenses are usually incurred to train users on multivariate analysis and control techniques. The original work in multivariate quality control has been attributed to Hotelling (1947). His work led to a number of multivariate techniques presented in the literature. However, the economic consequences of implementing these techniques as alternatives to the Shewhart charts have not been studied. In this paper, an incremental cost model is constructed to help estimate the cost and worth of switching from Shewhart $\bar{x}$ charts to the Hotelling T^2 chart. The following section offers a review of the literature pertaining to the economic design of control charts. Section 3 represents an incremental cost function that can be used to estimate the economic value of selecting one alternative over the other. The sensitivity of this function to changes in some process and chart parameters is investigated in Section 4.

2. Economic Models

Designing a control chart has economic consequences, which depend on the selection of the sample size, sampling frequency, and width coefficient of the control limits. These design parameters are mathematically related to three cost categories. Namely, the cost of sampling and testing, the cost associated with investigating out-of-control signals and correcting the process, and the cost of producing nonconforming units. Duncan (1956) was the first to propose an economic model for designing the $\bar{x}$ chart. He defined the net income as the difference between the total income and total cost. Duncan assumed that a single assignable cause, with an intensity of λ occurrences per hour, results in a shift of $\pm \delta$ in the process average. Duncan's

contributions were the stimulus for much of the research that followed in this area.

Knappenberger and Grandage (1969) proposed another model for the economic design of the $\bar{x}$ charts. Their model differs from Duncan's in that there is no constraint on the number of assignable causes that can occur. In addition, they assumed that the costs of investigating both real and false alarms are the same. The expected total cost per unit of product E(C) consists of three elements and is expressed as:

$$E(C)=(a_1+a_2.n)/K+(a_3/K)\mathbf{q}\boldsymbol{\alpha}^t+a_4\boldsymbol{\phi}\boldsymbol{\gamma}^t \quad (1)$$

The first element in Equation 1 represents the expected cost per unit associated with carrying out the charting procedure, where a_1 is the fixed cost per sample, a_2 is the per-unit cost of sampling, n is the sample size, and K is the number of units produced between successive samples. The second element represents the expected cost per unit associated with investigating and correcting the process. Where a_3 represents the expected cost of investigating a signal and correcting the process, $\mathbf{q}$ is a row vector representing values of the probabilities q_i (the probability of rejecting H_0 when $\mu = \mu_i$), and $\boldsymbol{\alpha}^t$ is the transpose of the row vector representing the steady-state probability that the process is in state *i* at time *t*. The third element in Equation (1) represents the expected cost per unit of producing a defective product, where a_4 is the cost of a defective unit, $\boldsymbol{\phi}$ is a row vector of the conditional probabilities of producing a defective unit given μ_i, and $\boldsymbol{\gamma}^t$ is the transpose of the row vector representing the true state of the process at time *t*.

Utilizing Equation (1), Montgomery and Klatt (1972) represented an application for the economic design of the T^2 control chart. They employed a single assignable cause version and restricted the application to the case of two correlated variables. Montgomery and Klatt investigated the sensitivity of the model and concluded that both the magnitude of the shift and the sign of the correlation coefficient relating the two variables affect the optimum design parameters. They noted that negative correlation always leads to a more powerful test if the process shift is in the same direction for both variables.

3. Incremental Cost Function

The objective of this research is to assess the economic feasibility of utilizing Hotelling's T^2 control chart as an alternative to two traditional $\bar{x}$ charts. In doing so, the expected cost of using $\bar{x}$ charts are used to establish the baseline for economic assessment. By utilizing Equation (1), an incremental cost function was constructed to examine the cost and worth of switching from one alternative to the other. It is assumed that the user of the $\bar{x}$ charts have no knowledge of the correlation between the two variables and hence would use two separate charts to monitor their averages. The cost function consists of two terms as indicated in Equation (2). The first term represents the expected cost of using two separate $\bar{x}$ charts to monitor the average of two variables. Whereas, the second term represents the average cost of utilizing a T^2 chart to monitor the two averages simultaneously.

$$\Delta E(C) = 2E(C_U) - E(C_M) \quad (2)$$

Each term can be calculated using Equation 1. The difference, $\Delta E(C)$ represents the change in the expected cost per unit resulting from the selection of the T^2 chart alternative over that involving the use of two $\bar{x}$ charts. From the economic analysis stand point, the option of utilizing the $\bar{x}$ chars

represents the do nothing alternative. Positive changes in the estimated cost would support the decision to switch to an analog T^2 chart. Otherwise, continuing use of the $\bar{x}$ charts would be preferred economically. As such, the cost of utilizing the T^2 chart should be estimated using the same design parameters of the $\bar{x}$ charts.

In estimating the cost of utilizing a T^2 chart, the two quality characteristics are assumed to be jointly distributed according to a bi-normal distribution. Elements of the probability vector **q** associated with the T^2 chart are obtained assuming a non-central F distribution with υ_1=2 and υ_2=n-2 degrees of freedom. The non-centrality parameter is evaluated as a function of the sample size and shift magnitude given the covariance matrix of the two variables. A computer program was developed using MathCAD 11 to calculate each of the terms in Equation 2. This program was verified using values reported in Anderson (1958), Knappenberger and Grandage (1969) and Montgomery and Klatt's (1972). Program listing and details of the verification procedures used can be found in Khalidi (2007). The numerical results analyzed in the following section were obtained using this program.

4. Sensitivity Analysis

To investigate the effect of selected process and chart variables on the incremental cost function, an un-replicated two level factorial design was utilized. Six variables were selected as control factors; two chart variables and four process variables. The chart variables included the sample size (n) and the probability of type I error (α), whereas, the process variables included the level of correlation between the two variables (ρ), the shift magnitude in standard deviation units (δ), the number of units between successive samples (K), and the cost coefficients (a_i). In calculating both terms of Equation (2), it was assumed that, on the average, the process shifts out-of-control after every 1,000 units (i.e., λ`= 0.001), and that the average penalty cost $a_4$ is \$10. As such, the cost coefficients ($A_1$, $A_2$, $A_3$) were defined relative to the penalty cost $a_4$ and the average rate $\lambda$` as $A_i = (a_i.\lambda`)/a_4$. Levels of these cost coefficients were selected to include those considered by Montgomery and Klatt's (1972). Table 1 summarizes the actual levels and corresponding coded values of process and chart variables investigated.

Table 1: Process and chart variables

Factor	Actual Value	Coded Level
Cost coefficients (A_1, A_2, A_3)	(0.004, 0.0004, 0.004) (0.020, 0.0020, 0.020)	-1 1
Correlation (ρ)	0.0 0.9	-1 1
Sample size (n)	4 20	-1 1
Shift magnitude (δ)	1 3	-1 1
Type I error (α)	0.001 0.005	-1 1
Units between samples (K)	20 100	-1 1

Values of the response ΔE(C) were calculated using all combinations of the control variables as per Equation (2). It was noted, in all of the 64 cases considered, that the estimated values of ΔE(C) were positive indicating net savings in switching from the traditional $\bar{x}$ charts to a T^2 chart. Figure 1 represents a half normal probability plot of the absolute values of the estimated effects. This plot was constructed using Design-Expert 7.

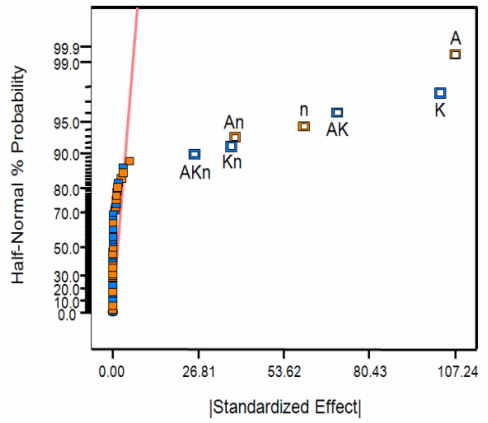

Figure 1: Half normal probability plot of |effects|

As can be seen, the plot indicates significant contributions of three factors and their interactions. These include the cost coefficients (A_i), subgroup size (n) and the number of units produced between samples (K). The analysis of variance of the fitted model confirmed these results.

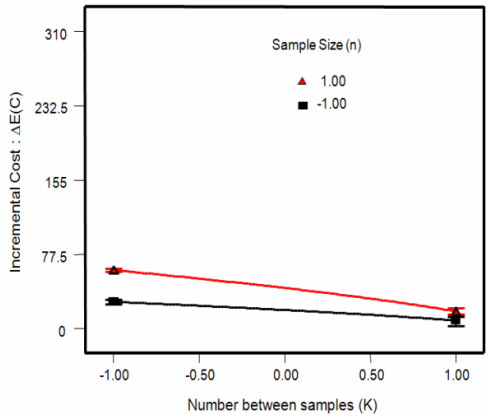

Figure 2: K.n interaction plot (low levels of A_i)

Figure 2 represents a plot of the interaction involving the subgroup size (n) and the number of units produced between samples (K) at the low levels of the cost coefficients. As shown, changes in the subgroup size appear to have much higher effect on the average net savings when samples are drawn more frequently (i.e., a sample every 20 units). However, the average net savings tend to diminish as samples are drawn less frequently (every 100 units). This is the scenario typically used in practice to justify the selection of traditional $\bar{x}$ charts.

On the other hand, as shown in Figure 3, at the high levels of the cost coefficients, significant average cost savings can be attained especially when large samples are drawn more frequently.

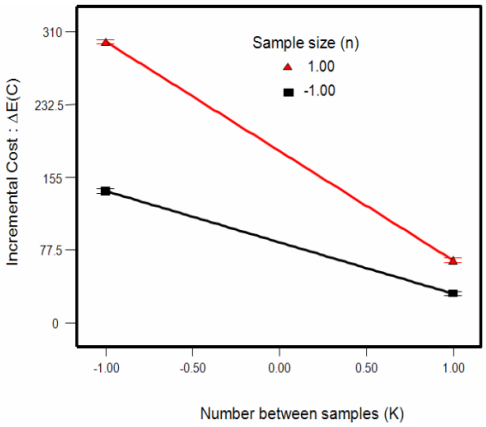

Figure 3: K.n interaction plot (high levels of A_i)

These are scenarios where tight control of the process over time is required coupled with high levels of the cost coefficients, regardless of the level of correlation between the variables and the shift magnitude. To this end, the average cost savings are more likely to offset the added costs of training operators on the construction and interpretation of the T^2 charts.

5. Summary and Conclusions

The objective of this research was to assess the economic feasibility of utilizing the T^2 chart as an analog to $\bar{x}$ charts. The investigation was conducted for the case of two normally distributed quality characteristics, by utilizing the economic design model developed by Knappenberger and Grandage's (1969),

and modified by Montgomery and Klatt's (1972). An incremental cost model was constructed to examine the benefits of using a T^2 chart instead of two $\bar{x}$ charts under specified levels of process and chart variables. The effect of four process variables and two chart variables on the average incremental cost were investigated. The results indicated that using a T^2 chart for monitoring two characteristics, regardless of the level of correlation and shift magnitude, would result in positive net savings. The average net savings tends to increase as the sample size and frequency of sampling increase at high levels of the cost coefficients. It is hopeful that this research will encourage practitioners to consider multivariate control techniques as viable alternatives to traditional techniques.

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