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MITIGATING BEHAVIORAL OUTCOMES IN A MULTI-PROJECT ENVIRONMENT: A MODIFIED CCPM MODEL

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ABSTRACT

Organizations continue to struggle in managing projects that lead to successful conclusions. While tools such as PERT and CPM have helped the project management process, they have not produced the level of success as previously envisioned. In the last decade, a new tool, the Critical Chain, which incorporates Goldratt's Theory of Constraints has gained popularity among the project managers. This tool, which focuses on project buffer usage, provides a color coding scheme designed to alert project managers of potential projects at the risk of missing completion deadlines. Unfortunately, this tool can easily generate false alarms when a project is actually doing fine leading to unnecessary interventions by practitioners while managing multiple projects. Conversely, it may also not generate any alerts when a project is doing poorly. This paper proposes a modified prescriptive Critical Chain model that not only mitigates the false alerts but also the behavioral effects inherent in the current model. Additionally, our modification allows the project manager to incorporate a risk component. Data from an actual case is also used to test our model.

Keywords: Critical Chain, Multiple Project Management, Buffer Burn index, Project Risk

INTRODUCTION

Given today's highly competitive economy, on-time project completion is becoming increasingly important for a company to stay successful. Historically, being able to manage a single project by completing it on time and within budget has proven to be difficult. According to Steyn [2001], 90% of all projects are conducted under a multi-project environment. Managing multiple projects, then, becomes even more difficult knowing that each one of the individual projects has a high likelihood of failing. The manager must pay close attention to each project to ensure success. In a multi-project environment it becomes difficult and onerous for a manager to keep track of each project. According to Herroelen and Leus [2005], even though a plethora of project management software tools exist to assist the project manager, yet most projects fail to come to a successful completion. Fricke and Shenhar [2000] state that one of the primary reasons for these failures is project management's inability to effectively manage uncertainties associated with resource dependencies and its effective prioritization.

Project managers have been using tools such as PERT/CPM for many years, yet, projects still continue to consistently come in late, over budget or lack expected functionality. Rand [2000] posits that these tools have been ineffective because they fail to take into account resource availability and add a large amount of contingency reserve in to each activity to account for unexpected delays. According to Newbold [1988] this contingency reserve is lost or wasted in most instances due to workers either leaving the work to the last minute ("student syndrome") and/or taking all of the allotted time, including the reserve, to finish the activity ("Parkinson's syndrome"). Given these problems with the current project management tools, it becomes imperative that improved methods for managing projects, project activities and reserves be found.

In recent years, Goldratt's [1977] Critical Chain Project Management (CCPM) methodology, which has been codified in popular software applications, has emerged as a possible solution to the problems of managing projects. It has become increasingly popular with the project management professionals. A central concept of CCPM methodology is Goldratt's Theory of Constraints (TOC) which is applied to manage multi-project scheduling and control. As Hoel and Taylor [1999] point out, a control mechanism called Buffer Management lies at the heart of the Critical Chain methodology. A major difference between CCPM methodology and other methodologies is that instead of adding small buffers to each activity, it focuses on a project buffer. Typically this buffer is divided into three parallel zones that represent three different levels of buffer penetration. Typically, a green zone represents 0-33% penetration, a yellow zone represents 34%-66% penetration and a red zone represents 67%-100% penetration. Different managerial actions are tied to each zone. Generally speaking, Buffer penetration in the green zone warrants no managerial action, penetration in the yellow zone triggers mitigation planning and red zone penetration triggers corrective action.

Unfortunately the use of these color coded parallel zones often easily leads to false alarms on the actual progress of a project. A project that is nearly complete may very well have a buffer penetration well into the red zone, but, actually may not be in trouble. It may not need any corrective action. Conversely, a newly started project with a buffer penetration in the green zone may actually be in jeopardy needing proactive attention. An additional complication with using this color scheme is the psychological interpretation people make about the colors green, yellow and red. People often interpret green as "safe" or "good without concern", yellow as needing "caution" and red as "danger" or "emergency situation." Consequently, this may very well lead the project manager to take inappropriate actions concerning the project. For example using this scheme, a project that is 90% complete but has 80% buffer penetration will fall in the red zone. Given the above common interpretation of color, a project manager may initiate corrective actions when none are warranted. Stakeholders may become concerned about problems that do not actually exist. Conversely, a project that is 5% complete but has a buffer penetration of 25% is clearly in trouble but would be in the green zone. Given the normal interpretation of green, the project manager may take no action when corrective action is proactively warranted.

Presently, there is little in the literature that addresses the behavioral issues related to CCPM methodology. Most of the literature concerning Critical Chain follows three streams of research. The *first* stream focuses on discussing the philosophy, theoretical basis, key concepts, and the main assumptions underlying CCPM methodology [Newbold 1998; Cabanis-Brewin 1999; Globerson 2000; Leach 1999; Patrick 1999; Pinto 1999; Rand 2000; Umble & Umble [2000]. The

second stream focuses on the positive and negative aspects of the CCPM methodology. Authors such as Raz et. al [2003], Trietsch [2005], Herroelen et al. [2001] and Herroelen and Leus (2004), discuss the negative aspects of this methodology while authors such as Newbold [1998], Simpson and Lynch [1999], Homer [1998], and Leach [1999], Rand (2000), and Steyn [2001] and Lechler et al. [2005] discuss positive aspects of the CCPM methodology. The *third* stream focuses on the technical aspects of Critical Chain scheduling. Authors whose research focuses in this area include; Herroelen and Leus (2001), Cohen et al. [2004], Herroelen and Leus (2004), Trietsch (2005b), Herroelen and Leus (2005), and Trietsch (2006).

As discussed earlier, there exists significant behavioral implications while using the CCPM methodology, specifically, in the interpretation or misinterpretation of the buffer penetration zones. We see a need to help project managers improve their ability to manage projects effectively by concentrating their focus on the ones that actually need attention. Agarwal et al. [2010] attempted to address this by developing a 2-dimensional model (henceforth called the current model) that used the standard three parallel buffer penetration zones but, introduced an additional element being the slope of the progress line for each project. Conceptually, a factor (Buffer Burn Index) was developed that was calculated based on the slope of the project progress line in conjunction with the slope of the buffer penetration line. Essentially if the slope of the buffer usage line was equal to or less than the project progress line, this would be an indication that the project, at least during the time period being evaluated, was progressing well because the project buffer was being used at an equal or lesser rate than the project work being completed. If the slope of the buffer penetration line was greater than the slope of the project progress line it would mean the project is using the buffer at a faster rate than the project work being completed. Unfortunately, this model did not solve the issue of improper behavioral responses related to the projects appearing in the red zone that were actually not problematic and those appearing in the green zone that were in jeopardy.

This paper presents a modification to the current model to accurately reflect the relationship between project completion and buffer penetration. Instead of using three parallel horizontal lines to delineate the green, yellow and red zones, the new model proposes to introduce the use of diagonal lines representing the boundaries for the green, yellow and red zones. We believe that the use of these diagonal lines would more accurately reflect the relationship between the work completed and the buffer used by providing appropriate alert signals and encouraging only warranted behavioral responses. With the introduction of this concept, we also allow for a mechanism to reflect risk that a company is willing to undertake for each of its projects. The risk is quantified by the intercept of the diagonal lines along the Y-axis. As previously discussed, a limitation of the current model is its failure to mitigate false alarms and the associated improper behavioral interpretations concerning the green, yellow and red areas. However, our proposed new model actually takes advantage of this interpretation by eliminating false signals. Under this model, projects in the green area are seen to be running successfully without any need for intervention, whereas, projects in the red areas are seen to be out of control and in need of proactive corrective action. Risk is incorporated in the model by placing the initial positions of the diagonal lines either higher or lower on the Y-axis based on risk tolerance of the company. The degree of risk tolerance would in effect decrease or increase the areas of the green, yellow and red zones. For higher risk projects, the project manager may choose to make the red zone larger leading to a

quicker entry into the red zone and effectively allowing the project manager to address problems sooner and more proactively.

We feel that the proposed new model will provide a project manager with improved tools for managing projects. First, the Buffer Burn Index will provide an indication of whether or not the project is using up the project buffer and a rate consistent with project completion. Second, the model will provide a visual cue to more accurately alert project managers to projects in need of immediate attention. Third, companies can now manage multiple projects more effectively by eliminating behavioral outcomes arising out of a practitioner's color bias. As part of this paper, we will provide an application of the modified model using actual project data.

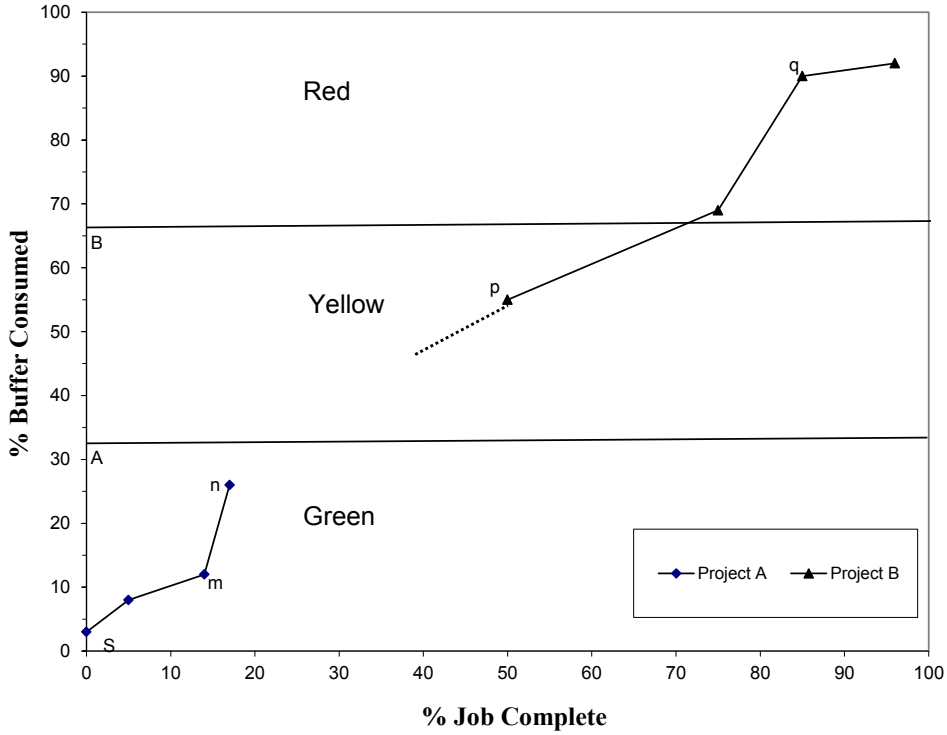
THE CURRENT MODEL LIMITATIONS

CCPM methodology uses buffer management control mechanism to manage project execution. It typically represents the process of managing uncertainty to improve throughput. A buffer is usually a unit of time considered safe that is placed strategically along the critical chain to protect the critical path. Under Critical Chain, a buffer that is placed at the end of the project to protect tasks along the critical chain from contingencies is called Critical Chain Project Buffer (CCPB). Buffer penetration simply implies its consumption due to variability when a critical chain task exceeds its given duration or when no work is done on that task. CCPM manages each project by monitoring the buffer to ensure that its consumption rate is appropriate.

Figure 1 shows the current model as proposed by Agarwal et al. (2010). It promised a more effective approach for project management by providing a 2-dimesioanl view of project progress based on % job complete and % buffer consumed. However, a serious limitation of the current model is its inability to mitigate improper behavioral responses by project managers due to false alarms generated while tracking project performance. For example, consider the weekly status of project B in yellow zone at point (p) in Figure 1.

A project manager's behavioral response to the yellow color association may be to become cautious and start formulating buffer recovery action plans. This is simply a false alarm with no need to worry as the project is progressing on track by being 50% complete with a buffer penetration rate of 50%. Similarly, now consider the weekly status of project B in red zone at another point (q). It can generate a false signal based on one's association with red color alone

Figure 1: Project Management Using 2-dimensional Current Model



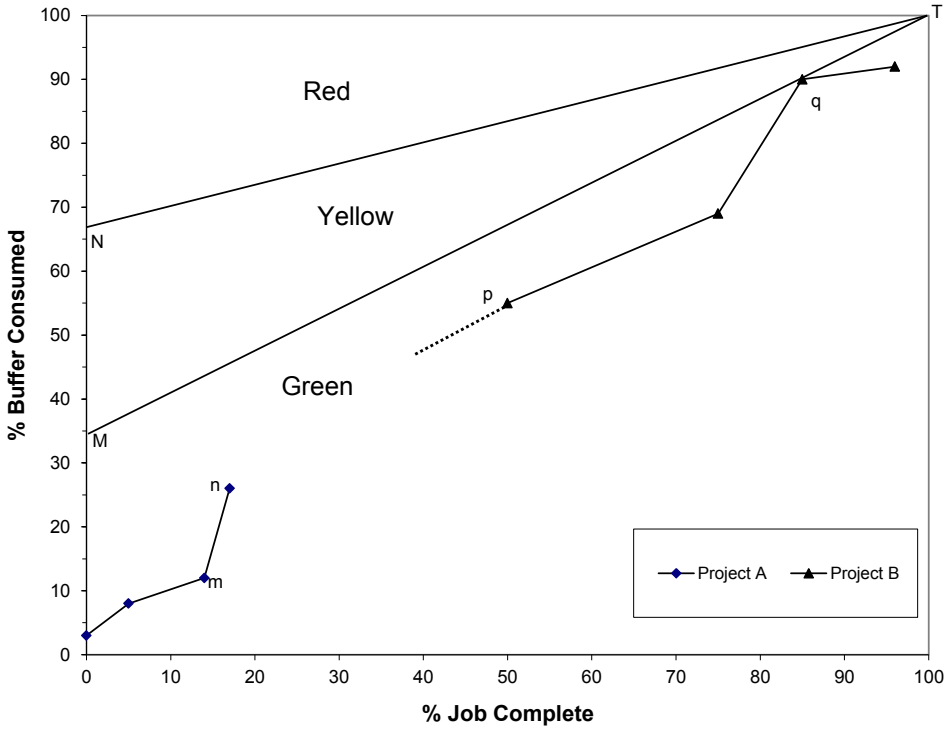
and trigger unnecessary behavioral response in the form of corrective action by a project manager. Note at this point the project's progression from previous week suggests no inappropriate rate of buffer consumption relative to that for job completion and availability of enough project buffer to protect the remaining critical chain.

THE MODIFIED MODEL

Figure 2 shows our proposed modified model for managing multiple projects more effectively. It considers the same 2-dimensions (% buffer consumed and % job completed) as in the current model by Agarwal et al. [2010]. However, the modified model differs from the current one on how the green/yellow/red bands are defined in the chart. Instead of creating three equal sized horizontal bands, the modified model positions the green/yellow/red bands based on the risk tolerance of each company for buffer consumption.

To begin developing the modified model, each company must answer the question: what are the maximum acceptable levels of buffer consumption at zero percent project completion that generates a sense of "no concern" and "high concern" respectively. Those points are represented

Figure 2: Project Management Using Modified Model



as M (33%) and N (67%) respectively in Figure 2. Note that point T in Figure 2 represents the project progress level where the project is 100% complete and buffer is also 100% consumed. Now the three bands are created by joining points M and N to point T. The region to the right of line MT represents the green band of "no concern" for project completion progress. The region between the lines MT and NT represents the yellow band of "moderate concern" requiring recovery plans to be formulated. The region to the left of line NT represents the red band of "high concern" recovery plan implementations to recover lost buffer.

It is to be noted that points M and N are merely parameter values representing a company's threshold cut-off between "no/some" concern levels and "some/high" concern levels for buffer consumption at 0% project completion level. Instead of these thresholds being 33% and 67%, another company may choose these levels to be 25% and 60% respectively. In that case, the relative positioning of the three bands would change.

In the proposed modified model, one can know the current status of a particular project by just looking at the latest coordinate points, (X, Y), representing percent job complete and percent buffer consumed respectively. Points (X, Y) are given by:

(X , Y) = (% job complete, % buffer consumed)

where
X = (Total Critical Chain duration – Remaining Critical Chain duration)/(Total Critical Chain duration) *100
and Y = (Buffer consumed/Original scheduled project buffer)* 100
Once X and Y values have been calculated, the relationship when paired gives more valuable information on project progress. The percent job complete data can be very useful to the upper management since it is usually not close to the individual projects. It may also serve as a quick scorecard.

Users can now not only view a project's weekly progress more effectively but also alleviate unnecessary behavioral responses associated with false signals generated due to one's association with green-yellow-red colors. For example, the weekly status of project B at points (p) and (q) now falls in the green zone implying that projects are moving smoothly and no managerial action is warranted based on one's psychological association with the green color. Thus, the proposed modified model eliminates false signals from being generated. It also embodies appropriate behavioral responses from users based on their psychological association with the green-yellow-red colors.

BUFFER BURN INDEX

During weekly meetings in a multi-project environment, ideally, a work team should review each project by analysis of its project tracking graph in the modified model. However, in a company that typically has over 50 projects implemented at any given time the weekly document can become too large. To see and compare multiple projects at a specific time we propose the use of a quantitative metric, Buffer Burn Index (BBI). To determine if a project is progressing smoothly, managers should compare weekly data points by calculating their slope. Thus, we define the metric, Buffer Burn Index (BBI), as:

$$Buffer\ \ Burn\ Index\ (BBI) = \left(\frac{change\ in\ \%\ buffer\ \ consumed}{change\ in\ \%\ \ job\ completed}\right) = \frac{(Y_{current} - \ Y_{previous})}{(X_{current} - \ X_{previous})} \qquad (1)$$

Ideally, BBI should be less than or equal to 1 implying job completion rate to be higher or equal to the buffer consumption rate. Any BBI value greater than 1 would imply inappropriate rate of buffer consumption relative to job completion rate. A negative BBI value would imply gain in buffer time during the course of job completion. An infinite BBI value would signal buffer consumption by an idle project. The progress on multiple projects can now be compared by plotting their latest (X, Y) coordinates along with their BBI values on the modified model.

THE CASE COMPANY

Company ABC is a full service provider of sheet metal stamping dies. ABC deals primarily with large transfer line dies for the automotive industry and commands a leading position in the design and manufacturing of progressive dies. At any given time, ABC has an average of 70 unique jobs with nearly 400 dies to produce. Currently, each die within each job has an average lead-time of 32-34 weeks. This multi-project environment constitutes a very complex system of planning, monitoring, documenting, and controlling projects. Lately, the company has been under pressure for on-time delivery from many of its customers.

ABC recognizes that given the complexity involved in each job and its current production methods, it is very difficult to monitor progress on all the jobs. It is not uncommon for the company to have a job run through the system and not have a true grasp of its potential lateness until the final 4-5 weeks. The company has identified three sub-problems - scheduling (kick-off) issues, prioritization conflicts, and basic resource contention – that it wishes to address to improve its on-time delivery performance.

Job scheduling or kick-off conflict has been a major issue at ABC for quite some time. Management commonly uses an ad hoc approach for job kick-off. For example, if a job is due on June 30 and it requires 20 weeks to complete, then as a general guideline engineering will not start it until February 11. However, this poses the problem of not knowing the degree to which lead times, and thus on-time delivery, may be affected if the company accepts the job late (such as on February 15) or uncertainty strikes the system. Job prioritization conflicts within individual departments tend to cause significant adverse effects on completing jobs within due dates. It is routine for departments to give higher priority to more profitable or partially completed jobs at the expense of the ones with earlier due dates. This causes rippling effect and confusion on lead times for rest of the system. Resource contention is another problem area where management does not allocate resources to projects based on their immediate need. Whenever a resource, worker or machine, becomes overloaded, it is common practice at ABC to either outsource jobs and/or put select workers or machines on overtime. This not only raises additional expense but also does not guarantee completion of project on time.

To prepare itself for newly emerging market realities and future success, company ABC decided to manage its projects and processes with greater efficiency and accuracy. The company felt the need for a system that not only could monitor job progress, but also handle multiple projects simultaneously and account for resource contention. After much deliberation, the company decided in favor of implementing Goldratt's Critical Chain model in its multi-project environment.

APPLICATION OF THE MODIFIED MODEL AT ABC

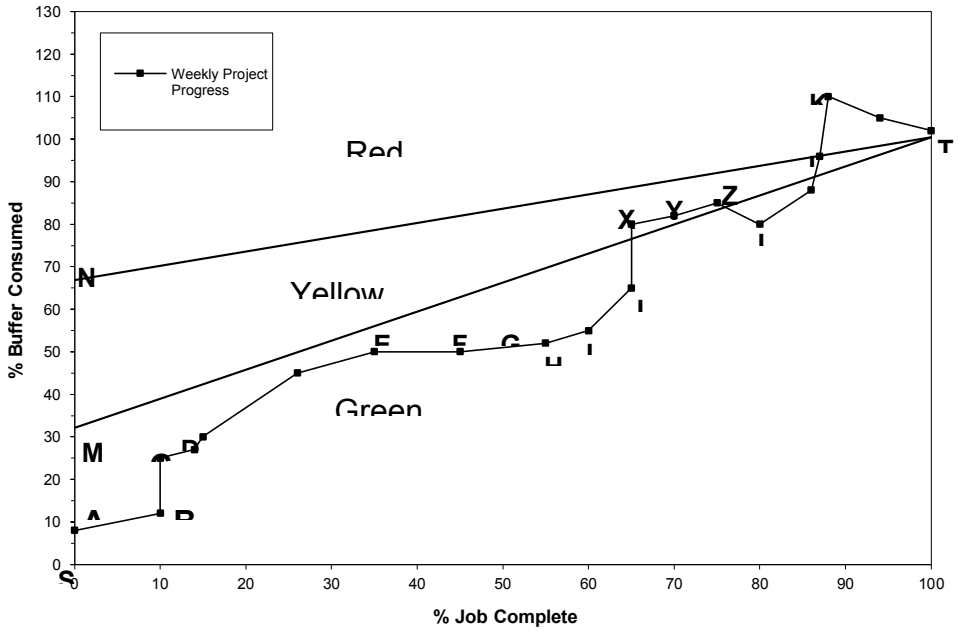
Table 1 shows actual weekly data for a typical project at ABC. Each data point (X, Y) reading was taken weekly for the duration of the project. Ideally, any project progress tracking

graph should show each point to the right of the diagonal line separating the green and yellow zones. In reality, however, a typical project's progress towards completion would show a mix of slopes and occurrences as shown in Figure 3.

Table 1: Weekly Progression for a Typical Project at ABC																				
Weeks	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
% Buffer Penetration	**8**	**12**	**25**	**27**	**30**	**45**	**50**	**50**	**52**	**55**	**65**	**80**	**82**	**85**	**80**	**88**	**96**	**110**	**105**	**102**
% Job Complete	**0**	**10**	**10**	**14**	**15**	**26**	**35**	**45**	**55**	**60**	**65**	**65**	**70**	**75**	**80**	**86**	**87**	**88**	**94**	**100**

Figure 3 shows the corresponding weekly project progress tracking graph.

Figure 3: Actual Project Tracking Using Modified Model at ABC



In Figure 3, Point A and segment BC show buffer penetration without any job progress during the previous week. Even though the current status of the project at these instances is in the green zone, a project manager should still try to find the associated bottlenecks and assignable causes. There is no need to trigger any alarm. Segment EF and GH represent very efficient task completion where job completion rate is higher than the buffer consumption rate with nothing to worry.

A cursory look at points X, Y, Z in the yellow zone should signal caution. There is no need for alarm but the project should now be monitored carefully to avoid its entry into the red zone in

future. The project team should begin to formulate buffer recovery plans which can be put into action if the project enters the red zone in future. Segment JK illustrates how uncertainty can hit towards the end of a project when it can be most devastating, thus calling for immediate corrective action. As shown, it results in the project shipping almost on time even though just 2 weeks prior it was at the risk of failing to meet its due date. Thus, unlike the current model, the modified model is in a better position to accurately reflect the project status and alert signals by considering a company's risk tolerance for buffer consumption. As a result, the model guarantees only the warranted behavioral outcomes based on a practitioner's psychological associations with the green-yellow-red color schemes.

To quickly compare the performance of multiple projects during weekly meetings at ABC, a 2-dimensional plot showing current status of all projects along with their BBI index values can be used efficiently. Table 2 shows the actual data on percent job complete and percent buffer consumed data for current and previous weeks for 18 projects at ABC.

Table 2: Managing Multiple Projects using Buffer Burn Index

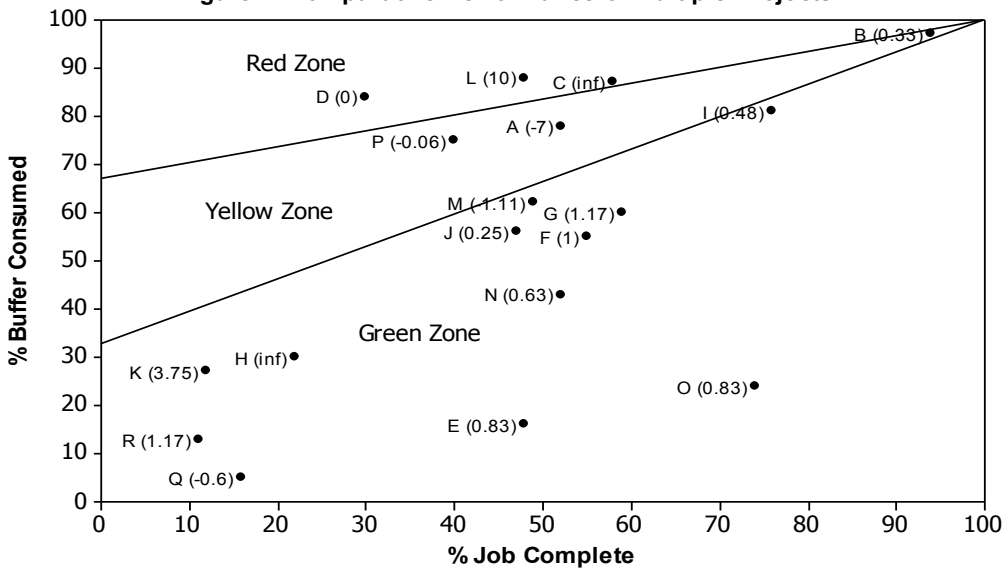
Project ID	A	B	C	D	E	F	G	H
	Project Number	% Job Completed 1/14/07	% Buffer Consumed 1/14/07	% Job Completed 1/21/07	% Buffer Consumed 1/21/07	Change in % Job Completed	Change in % Buffer Consumed	Buffer Burn Index (BBI)
A	1616	51	85	52	78	1	-7	-7.00
B	1935	88	95	94	97	6	2	0.33
C	1936	58	70	58	87	0	17	Infinite
D	1937	28	84	30	84	2	0	0.00
E	1938	42	11	48	16	6	5	0.83
F	1939	47	47	55	55	8	8	1.00
G	1940	53	53	59	60	6	7	1.17
H	1941	22	24	22	30	0	6	Infinite
I	1952	53	70	76	81	23	11	0.48
J	1953	43	55	47	56	4	1	0.25
K	1954	8	12	12	27	4	15	3.75
L	1955	47	78	48	88	1	10	10.00
M	1956	40	72	49	62	9	-10	-1.11
N	1957	44	38	52	43	8	5	0.63
O	1961	62	14	74	24	12	10	0.83
P	1962	22	76	40	75	18	-1	-0.06
Q	1995	11	8	16	5	5	-3	-0.60
R	1997	5	6	11	13	6	7	1.17

This data is used to calculate changes in percent job complete and percent buffer consumed in columns F and G respectively. The BBI metric for each project is then calculated using expression (1) as shown in column H. Finally, the modified model showing % job complete

(column D), % buffer consumed (column E), and BBI metric (column H) is used to compare the performance of multiple projects.

Figure 4 shows the current status and BBI metric (within parenthesis) for each of the 18 projects. The performance of projects C, D, and L in the red zone suggests buffer consumption rate at inappropriate levels when compared to their corresponding task completion rates. These projects should draw close management attention for corrective action. Even within this group projects can be prioritized for attention based on their BBI metric values. For example, the weekly progress represented by BBI values of "infinite" for project C and 10 for project L imply high levels of buffer consumption with zero and very little task completion respectively. Management should identify assignable causes for such performance deterioration on a priority basis. The current status of projects A, P, and B in the yellow zone call for some moderate concern on the part of the project management team. They should formulate buffer recovery plans.

Figure 4: Comparative Performance of Multiple Projects



Note that projects A and P show negative BBI values, implying a gain in buffer time during the previous week. It is good news but these projects should be monitored closely for next few weeks in case they run the risk of entering the red zone.

Figure 4 also shows significant deterioration in weekly performance of projects H and K with BBI values of "infinity" and 3.75 respectively. Even though both these projects are in the green zone, management attention should be focused (without any alarm) to identify the assignable causes for project H's idleness and project K's inappropriate rate of buffer consumption with very little task completion. For projects F, G, J, and M that are in the green zone, there is no need to worry. Based on BBI values, their weekly performance appears adequate. Thus, the proposed modified model can prove to be an effective tool in proactive management of multiple projects

since it focuses a manager's attention to projects that truly need corrective actions without generating unnecessary and misleading false signals.

CONCLUSION

This paper examined the behavioral outcomes associated with the implementation of critical chain and buffer management in a multi-project environment. We show how the use of our proposed modified model along with a quantitative metric, BBI, can be a useful tool to practitioners in managing multiple projects effectively. The modified model is a significant improvement over the current model since it eliminates the risks associated with false alarms and unwarranted behavioral responses which may prove costly and damaging to a project's progress to completion. We also presented a case example to test the practical dimensions of the proposed model. The proposed model is shown to aid managers in focusing their efforts on "proactive" management of projects that truly need attention and avoid unnecessary intervention.

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DESCRIBING ONLINE FILE SHARING BEHAVIOR AND PERCEPTIONS OF PAY CHANNELS FOR DIGITAL MEDIA

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ABSTRACT

Online file sharing has been a controversial phenomenon since compression technologies for digital media introduced the mp3 file format. Businesses are concerned about the misuse of the technology to share copyrighted digital works illegally. Individuals make justifications based on perceptions of the products, the environment, and the stakeholders. Extant research generally focuses in one of these areas but not all at once. This study proposes a framework for a holistic view of this phenomenon and finds that it is able to group individual perceptions into four dimensions of influence with online file sharing behaviors. These dimensions are a reinterpretation and extension of Lawrence Lessig's (Lessig, 1999b) 'Modalities of Regulation' which were originally proposed for understanding possible changes needed in law to support computer communication technologies. Using this framework provides businesses with a strategic view well suited for evaluating and reinventing business models for digital media sales. Additionally, the framework is applicable to further research in ethical use of information technology.

INTRODUCTION

Online file sharing is an activity which takes place between individuals using information technology to distribute electronic media files. The Internet provides the architectural backbone for the activity. Based on the data from this study, the most common type of media exchanged amongst file sharing networks is music files. Other files which were identified as popular were movies or TV shows, games, and eBooks. While the use of the Internet to share these types of files is not in itself an unexpected extension of technology, the fact that much of this file sharing is done with copyrighted materials has raised concern (Gopal et al., 2006; Liebowitz, 2008; Oberholzer-Gee & Strumpf, 2007).

In this study, online file sharing activity is described using four dimensions of influence. It is suggested that to fully understand, and where appropriate respond to, online file sharing activities, the activity and behaviors of those participating must be looked at with a holistic view. The four dimensions proposed here provide such a view. Given an encompassing perspective, better decisions may be made regarding behavioral interventions or altered business strategies in

response to file sharing activity. Some background is provided here to better understand how these dimensions of analysis fit into a research stream and potentially help describe it.

BACKGROUND

While work has been done toward an understanding of online file sharing behaviors, much of it focuses in specific areas (e.g. ethical decision making, moral influence, theory of planned behavior). This study seeks to enhance understanding by providing a broad scope of analysis encapsulated within a framework for analysis. The following is a discussion of the aforementioned specific areas covered in file sharing research.

Motivation to Share: This is a discussion of incentives for individuals to share files amongst each other (i.e. upload content to the network). A question has been broached as to whether or not any individual might have value to gain from such an online exchange (Xia et al., 2012). In one case this value was seen in direct and quantifiable ways. Participants of file sharing networks were rewarded with special privileges in return for sharing content into the network (Beekhuyzen et al., 2009). In other studies, motivations were less quantifiable but relevant. Factors ranged from altruism to peer approval (Golle et al., 2001; Ranganathan et al., 2003). Several other antecedents to sharing knowledge proposed were reputation, expertise, commitment, and reciprocity (Wasko & Faraj, 2006). These findings are relevant to understanding why individuals choose to contribute to a network that's primary value seems to come from downloads. Overall, there seems to be some understanding that without contributions, the networks would fail.

Responsive Business Strategy: There has been discussion on techniques or strategies for copyright owners responding to threats posed by online file sharing, in particular loss of profits. Work has been done to investigate the impact of using techniques for 'locking down' digital content with encryption or other forms of restrictions on use which is built into the digital media (Jaisingh, 2007; Van Wijk, 2002). In these cases the broader term is referred to as digital rights management (DRM) and has had its opponents. This type of technology may prevent legitimate owners from making copies of their own content for necessary reasons (e.g. backups, multiple device use). Others have investigated subscription type business strategies which circumvent concerns of individual file downloads altogether. One way to achieve this is to allow access to entire libraries of content for a monthly fee (Bhattacharjee et al., 2003; Bhattacharjee et al., 2006). Educating the participant community on updates in the law has also been discussed. Identifying and presenting examples of repercussions for file sharing behavior could be used as a deterrent for file sharing participation (Ingram & Hinduja, 2008). Strategies for response to the file sharing community were deemed possible and necessary if providers of digital content were to continue a line of profits.

Antecedents to File Sharing Behavior: Studies regarding the identification of antecedents to participation in file sharing behaviors can be grouped into two categories: those that propose influence comes from sources external to the individual participant (physical world), and those

that suggest the influence comes from within the individual (cognitive/affective). External forms of influence included the threat of prosecution from legal bodies (Chiou et al., 2005) or the physical architecture of the file sharing network (e.g. connection speeds, bandwidth issues) (Asvanund et al., 2004). External influences were found to have very direct influence where they were a factor, however, not everyone has bandwidth issues and law suits were more exemplary than ubiquitous.

Internal influences have been researched to a greater extent. Moral development was shown to have an influence, independent of age; individuals show varying stages of development along a continuum and correspondingly chose to participate in file sharing more when at a lesser stage of development (Hill, 2007). There was research built directly on work of Ajzen in the Theory of Planned Behavior (TPB)(Ajzen, 1991). Studies proposed additional antecedents, alongside attitude, subjective norms, and perceived behavioral controls, which lead to intention to participate in file sharing. Proposed antecedents included moral obligation, past behavior, and equitable relationships (Cronan & Al-Rafee, 2007; Kwong & Lee, 2002). Other research focused on influences directly tied to attitude toward file sharing or piracy in general. Moral judgment, affective beliefs, cognitive beliefs, and ethical ideology were found to influence attitude development (Al-Rafee & Cronan, 2006; Chan & Lai, 2011). There have been studies which suggested antecedents to intention to participate in piracy or file sharing. An ethical predisposition was identified as a complex construct based on individual beliefs (Gopal et al., 2004). Perceived value and degree of morality were discussed as having a direct impact on intention to download (Chen et al., 2008). Motivation/desire was proposed as an antecedent to behavioral intention. In this case motivation was a formative construct based on emotional and attitudinal components (Taylor et al., 2009). Hunt and Vitell's general model of ethics (Hunt & Vitell, 2006) was used as a basis for identifying antecedents to deontological evaluation (Shang et al., 2007).

Taken as a whole, the research suggests there is a mechanism internal to each individual by which a decision to participate in file sharing is made. It appears this mechanism may be complex or at the least include a significant amount of influential forces.

The Law: In a paper by Lawrence Lessig, the notion was put forth that upcoming law would most likely change due to the then new technologies provided by the Internet (Lessig, 1999b). Further, due to the complexity of this communication medium, specifics would have to be worked out by those beyond the roles of lawyers and judges. At a minimum changes would have to include 'technologists'. Forces beyond the law would influence the ethical behavior of individuals. Lessig went on to identify four regulatory forces that he felt represented the scope required to determine how regulation of activities on the internet might be determined.

The work presented here builds on Lessig's regulatory forces. The prior literature covered here, along with research data suggest there are dimensions of influence on file sharing which correspond to regulatory forces proposed by Lessig. Given the online file sharing context, dimensions are defined which help to describe forces of influence such that they affect the digital media industries (e.g. music, movies, books). With a better understanding of how these forces interact within the file sharing domain, businesses may be better prepared to develop business

models in response to or along side of online file sharing technology. Academics may find these dimensions useful in development of further research regarding this topic or other topics which deal with the ethical use of information technology. Finally, where there are issues identifying or enforcing laws relevant to online file sharing, this research may provide some helpful understanding as to how or why difficulties arise.

THEORY

In 1999, growth of the internet and its use was blossoming. Of growing concern was how humanity might respond to activities and behaviors that internet based technologies might bring about (Lessig, 1999a). Further, since some of these activities and behaviors might be new or at least displayed in a new context. How might laws be adapted in response? Lawrence Lessig is a law professor who addressed this topic with a paper suggesting that regulatory forces in the domain of a computer communications network would extend beyond that of the law (Lessig, 1999b).

These forces were labeled as four 'Modalities of Regulation'. This paper seeks to build on the work originally proposed by Lessig's modalities by discussing how these might be used to better understand the full scope of behaviors/activities associated within the specific technological context of online file sharing.

To lay groundwork for this study, a brief discussion of Lessig's modalities is given here. This is followed by a description of how this study specifically applies the conceptual approach of modalities toward gaining understanding of online file sharing behaviors.

LESSIG'S MODALITIES OF REGULATION

The four modalities were proposed to describe regulatory forces which would guide the behaviors of individuals when exchanging information over the Internet. At the time of Lessig's key paper the Internet was still relatively young in terms of business proliferation and personal/social use. The main topic of Lessig's paper was to deal with a concern that United States law would have to respond to new types/forms of behavior as a result of internet technology, however, the law could not be talked about in isolation from other forces of influence. Lessig proposed four modalities of regulation as: law, social norms, markets, and architecture.

The law would regulate primarily as it had, through the threat of punishment. If individuals were to not obey its boundaries, there would be a penalty. The law would state the expected behaviors of individuals (e.g. it is unlawful to download copyrighted material without consent/agreement from the rightful owners) and upon violation (e.g. downloading copyrighted music files without paying) prosecution would ensue. By this method, the law would be a regulatory force.

Social norms are dictated by other parties than a governing body. Family, friends, coworkers, church, hobbyists, etc.., all contribute to community based influence which can impact

the internal decision making processes that an individual employs. Norms are not written, and violation of a norm does not necessarily result in a direct or tangible punishment. Yet, there is a penalty for violating norms (e.g. negative social response) and thus this can be seen as a regulating force.

Markets regulate by price. The cost of a music CD can be seen as exorbitantly high when judged against the quality of the songs it contains. As such, a high price might dictate few sales of the CD once information about the quality of the music gets out. In this way, the market itself may be influenced by social norm, but is still seen as a regulating force whereby price may drive behavior.

Finally, architecture is proffered by Lessig as given by the physical world "as we find it". As we find it in internet technology means routers, switches, servers, clients, software, and people. It might be the case that if there were no grocery stores, one might find the purchase of dinner somewhat more of a challenge. The physical entity of 'a grocery store' dictates a quick stop on the way home would achieve the goal. Were this architectural element (or a substitute) missing, there would instead be a need for a well planned and time consuming hunt and gather. The Internet has no shortage of architectural elements which can easily be seen to be regulate (e.g. bandwidth, protocol usage, firewalls, etc...).

Lessig's modalities were proposed to identify regulatory forces which might guide the behaviors of individual's with regard to their interactions using computer communication technologies. These regularities were proposed in response to a need to evolve the structure of law. This study proposes an interpretation of these modalities that might be used as a framework to explain behaviors associated with ethical use of information technology, specifically online file sharing. Further, it is proposed that this framework might guide future research seeking explanations encompassing a systems approach to ethical use of information technology. The proposed framework is shown in table 1 and will be further explained in the discussion section of this paper.

Table 1 – Dimensions of Influence Translation

Dimensions of Influence on Online File Sharing Behaviors	Lessig's Modalities
Law	Law
Digital Content Availability	The Market
Technological Infrastructure	Architecture
Social Norms	Social Norms

METHOD

Data for this study were collected from two group sessions and 19 individual interviews. The groups consisted of 8 and 10 participants. In both the group sessions and the individual interviews, semi-open ended questions were used (questions can be found in appendix A). Group

sessions were conducted with volunteers from MIS courses at a southern university. Individual interviews were conducted with random participants solicited from an on campus coffee house. Participants were given a $5 gift card for participating in the survey. All survey respondents had participated in online file sharing. Respondents were not required to have had experience with file sharing. All those that decided to participate had experience and all but 2 were actively participating in online file sharing at the time of the study.

Respondents were reassured that the information they were sharing would remain anonymous. They were informed that any data or analysis included in publication would be in aggregate form. Further, they were reassured that the researcher had no affiliation with governing bodies or agencies concerned about copyright infringement that might be interested in prosecution.

Data gathered from the groups sessions were used to formulate more specific questions for the individual interviews. The data matrix supplied here does not include all questions/responses. Only those that were relevant to this particular study are represented.

Responses to the questions were aggregated in a spreadsheet. The answers were judged for similarity of meaning and grouped together. Where more than one response aligned, they were grouped together and a comprehensive title for the response was created. For example, several respondents gave a brief statement about their perception of a difference in quality between digital media purchased in the store versus what they would download online. The descriptions of this difference in quality varied from a few words to several sentences; however, the essence of the category for this response was captured with the term 'lower quality' identifying the shortcoming of digital downloads over store bought products.

Some respondents did not have a response for every question. In other cases, it appeared the respondents did not understand the question and responses were not relevant. In these cases the responses were not included in the data analysis.

RESULTS/DISCUSSION

The data analysis matrix presented here (Table 2) was the result of consolidation, generalization, and specificity. Not all questions on the surveys were incorporated for analysis, only those relevant to this particular study. The result was a matrix with six relevant questions conforming to four categories of behavioral explanation. These were identified as dimensions of influence for determining online file sharing behavior. These categories align with those initially proposed by Lessig (Lessig, 1999b). (See Table 1)

Table 2 – Response Analysis Matrix					
(combination)	*(law/DCA)*	*(law)*	*(social norm)*	*(Technological Infrastructure)*	*(combination)*
Question A	**Question B**	**Question C**	**Question D**	**Question E**	**Question F**
What do you think of the p2p file sharing phenomenon?	**How do you feel about information copyright protection?**	**Are you worried about legal recourse?**	**Do you think there is something to be done about online file sharing?**	**Do you think of online content as different from goods bought in a store?**	**Is content free because it is online?**
convenience (10)	owners should be paid (10)	probability seems low (15)	law suits (8)	lower quality (11)	no (9)
concerns about data corruption / viruses (9)	owners abuse this to make more money than what is fair (5)	yes, significant potential (7)	allow sharing (4)	physical good has more to it (5)	yes (3)
response to overpriced products (5)	understand it but it doesn't stop me (4)	doesn't apply - nature of content (3)	can't win the war (3)	no difference (3)	response to overpriced products (5)
promotes media diversity (4)	doesn't stop the activity (3)	don't download enough (2)	change business model (3)	better variety (2)	promotes media diversity (4)
free content (4)	It is okay to violate if I can't find the content in pay channels (3)	don't think it is technically illegal	lock down connections (2)	free content (4)	It is okay to violate if I can't find the content in pay channels (3)
sampling (3)	it only applies if I want to support an artist (2)		take files away or corrupt them if found - no legal prosecution	sampling (3)	it only applies if I want to support an artist (2)
it's a part of life (3)	I feel guilty about violating (2)		limit the number of times a file can be shared/copied	it's a part of life (3)	I feel guilty about violating (2)
cause for a new business model (2)	will create a downward spiral in art		intentional viruses	cause for a new business model (2)	will create a downward spiral in art
form of borrowing (2)	don't think file sharing violates it		educate participants	form of borrowing (2)	don't think file sharing violates it
negative impact on media industries (2)					
cool technology (2)					
guilt for not supporting artists					
should be legal					
a lot of abuse					
starting artists benefit from exposure					
seems there are not a lot of legal options					

The matrix identifies the dimensions of influence to which each question adheres with the exception of question A. This question was designed as a 'catch all' question in attempt to identify any areas that were not covered in the remaining questions. For each question the number of responses that were grouped into each response category is specified in parenthesis. Where there is no parenthesis the response was considered unique. The following discussion focuses on response categories (items with numbers in parenthesis). Single person responses are included in the matrix for completeness and possibility of future study

LAW

Where Lessig identified the law as a force of regulation, this study echoes the law as a dimension of influence on online file sharing behaviors. Questions B and C each provided responses which aligned with the influential force of the law.

A majority of the respondents felt the owners of digital copyrighted material should be paid for their work and the law was there to support that fact. Note that all participants did participate in online file sharing at the time of this study. This suggests that even though participants felt laws were in place to justly protect artists, authors, and developers, awareness of the law did not prevent participation in online file sharing. The top response to question C further explains this behavior. Participants didn't feel there was a very high probability of prosecution for their actions. Therefore, awareness of the law does not necessarily lead to observance of it in light of a low probability of being caught.

While the majority felt the probability of being caught was low, there were a significant number of responses which suggested some were concerned about the potential of prosecution for their actions. Yet again, this did not stop the behaviors (with the exception of possibly 2 respondents). Therefore, regardless of whether or not respondents felt there was potential to be caught and prosecuted for their actions, file sharing behavior continued in spite of an understanding that laws were in place defining the behavior as illegal.

There were justifications given for violating the law. Some pointed to the lack of availability of content in the open market. Where some files simply could not be found in pay channels, file sharing provided the only possible resource. Several perceived their actions as being 'under the radar' since the type of content they were downloading was not popular and thus would not draw much attention. Others believed the frequency of their actions was so small that once again, it simply would not draw attention.

The data suggests there is a general awareness of laws designed to protect the owners of digital content from illegal sharing of copyrighted material. Further, the general belief is that these laws are just. However, while there is awareness of the laws, behaviors continue either because of or despite probabilities of being caught.

DIGITAL CONTENT AVAILABILITY

Lessig's modality of the market suggests price is the main regulator. Indeed, this is the mechanism behind supply and demand (Lessig, 1999). In the context of online file sharing, the market ends up with multiple suppliers. A legitimate set of suppliers is represented by stores supplying physical media, online stores shipping physical media, and online sales of electronic media. A secondary set of suppliers are the individuals participating in online file sharing. Since there are competing suppliers, price plays a role, but it is not the only regulator in this category. The data suggests there is a force similar to that of the market but with a broader scope, termed here as 'Digital Content Availability'.

Support for this force was found in responses to questions A and B. Responses to both A and B suggest there is a perception that the media industry is 'overpriced'; that the file sharing phenomenon in general may be a response to a perception of years of abuse by producers of content. Respondents described a market in which interests of the artists were not necessarily supported by the producers of the content (e.g. the recording labels) and this coupled with unreasonable prices justifies the circumvention of pay channels. It is the file sharing technology coupled with internet technologies that make possible a secondary set of suppliers. This second set of suppliers augments the market in a way in which legitimate suppliers have to compete with free.

There were responses which suggested the diversity of content was much greater in the file sharing domain than through pay channels. Especially where new, upcoming, or geographically disparate artists were concerned, the file sharing domain may be the only place to find such products. Some identified the domain as a resource for 'sampling' content. Trying out products to determine whether or not they were worthy of a purchase. There were those that would follow up sampling with a purchase based on quality or desire to support a given artist.

One last argument was in favor of an altered market in which the artists/content owners would make money through other means than the digital files themselves, but those means would be supported by content provided through the file sharing domain. This would leave digital content available for free. Respondents would suggest concerts, merchandising, and other events were the perceived market domain for profit. Getting the digital files out the public could be thought of as marketing material rather than the end product.

It was clear that the data was supporting a set of market forces impacting file sharing behaviors. In this context however, the market takes on a less traditional structure. The introduction of free suppliers creates an imbalance in the law of supply and demand. Justifications were given for circumventing pay channels for the sake of a broader and what was perceived as a more accurately valued alternative.

TECHNOLOGICAL INFRASTRUCTURE

In the modality of 'Architecture' Lessig suggested the physical world 'as we find it' regulates behaviors. This has been demonstrated in key theories commonly used in IS stemming from a perceived behavioral control (Ajzen, 1991; Davis, 1989; Venkatesh et al., 2003). Within the online file sharing context, the architecture is specifically the technological infrastructure. This infrastructure is primarily enabled by the Internet and is comprised of internet service providers (ISPs), internet protocols, file sharing software clients, file sharing protocols, and of course, the digital media files. Some responses from question A directly address the impact of this architecture on file sharing behaviors. Additional support was found in responses from questions E and F.

A majority of respondents perceived the file sharing domain as providing a 'convenience' that could not be obtained otherwise. Some of this convenience is reiterated from prior discussion where the file sharing networks give access to rare, unreachable, or generally difficult to find content. Others simply felt the ease of use of file sharing technology made it a straight forward choice.

Although convenient, many respondents also felt the technology came with risk. Experiences included multiple attempts to achieve a download that did not have corrupted data. Where corrupt data was not a concern, viruses were. Viruses were, in some cases, intentional on the part of copyright owners/protectors (e.g. Recording Industry Association of America (RIAA)), and in other cases, simply attached unknowingly by those uploading content to the community. Either way, respondents mentioned cases where entire hard drives were lost due to the download of a virus using file sharing technology.

When discussing the morality of file sharing overall, some respondents felt the activity was akin to loaning someone a book. It was simply the technology that enabled the loaning process to happen across a wider population and geographic spread. This was given as both a justification for its use and an advantage of the technology.

When asked if the file sharing technology produced an equivalent product to that found in pay channels, the majority of respondents claimed a lack of quality in file sharing downloads by comparison. Indeed, the sampling rate (measure of quality) at which many uploads are created generally falls short of that which may be obtained from the purchase of physical media. The lower sampling rates provide smaller files which speed up downloads. Additionally, respondents observed additional materials (e.g. photos, lyrics, t-shirts) were included with purchases of physical media which were not included with file sharing downloads. Again, variety or diversity of available content was cited as a difference in the product obtained, in this case being in favor of the file sharing content. While some felt there was no difference in the product obtained, it appears there is a general perception that file sharing downloads are not the same product as that obtained through pay channels.

Respondents were asked if they understood the content they were obtaining through file sharing networks to be free simply because it was 'online'. The majority of those answering this

question felt this was not the case. This echoes the perplexing situation observed under the 'Law' dimension. Here again, respondents were saying they understood that this content is not free, yet they paid nothing to obtain it. In this context, the technological infrastructure was observed as an enabler of an activity that would not have been otherwise undertaken. Some respondents had comments about the technology making the process 'so easy' it was difficult for them to resist.

The physical world 'as we find it' in this context becomes technological infrastructure which enables file sharing activity. The activity could not take place without the infrastructure. Therefore, the infrastructure is a dimension along which behaviors must be evaluated. The data represented here suggests the infrastructure provides for opportunities not gained elsewhere, while susceptible to risks and lesser quality products. Further, as an enabler, the infrastructure provides a temptation that mitigates any concerns to the negative.

SOCIAL NORMS

Social norms, like laws, are enforced primarily upon violation. Whereas laws are enforced by government, norms are enforced by social communities. Sometimes this means the community at large, but in more cases than not, it is a local community of influence (Brown & Venkatesh, 2005). The normative acceptable behavior must be somehow communicated through interaction. Online file sharing participants find their community through the technological infrastructure previously mentioned (e.g. blogs, chats, social networks), through peer groups, and in many of the same areas they would otherwise find normative influence (e.g. school, work, church, etc.).

Support for a dimension of social norms was primarily found in responses to question D in this study. Respondents were asked if they felt there was something to be done about file sharing activity. It was anticipated that responses to this question would mirror the factors that went into the individual's determination process. They would need to decide whether or not something should be done about the phenomenon. This would require a moral evaluation based on the individual's internal sense of right and wrong. Such a determination, by its nature, incorporates normative influences.

Responses did reflect a sense of whether or not something should be done about file sharing and if so, what that was. There were responses which indicated it should be stopped. The most frequent answer for how this could be done was for the pursuit of law suits and prosecution of violators. Once again, considering 100% participation in file sharing activities, this is an interesting response. Some felt responsibility was with the infrastructure; specifically ISPs should lock down internet connections when they sensed file sharing activity.

Several responses suggested the behavior should not, or in fact could not, be stopped. Respondents felt that the activity should simply be made legal and acceptable. Several responses stated that this was a 'war that could not be won'. There was little sense in trying to stop file sharing behaviors, they were here to stay. Several respondents said that file sharing was 'a part of

life', clearly labeling it as a social norm. Others suggested that content owners/representatives should change their business models to shift profit making into other areas.

Social norms, as a dimension of influence on file sharing behaviors, are important. The data presented here suggest file sharing as an activity had become an accepted behavior among peer groups. There were those that went so far as to suggest that businesses and even government should change their practices to incorporate the activity. The momentum seemed to be changing the focus of moral judgment from the law to the community.

CONCLUSIONS

Four dimensions of influence were presented here as a framework for analyzing individual behavior using online file sharing technology to download copyrighted media files. The dimensions are suggested as a systems approach to analysis. Building on the work of Lawrence Lessig and interpreting his intentions into the information technology research domain, this approach to analysis can provide a holistic view of behaviors which industry and academia may find important and useful. Research to date suggests there has been an ongoing conflict between the file sharing community and key stakeholders behind ownership of copyrighted digital works (e.g. artists, producers, labels).

Thus far, research in this domain has focused on specific aspects of file sharing behaviors, but not the phenomenon as a whole. The holistic approach suggests there are perceptions about media production industries which influence individuals toward unethical behaviors. These perceptions are used as justification for actions that might otherwise present enough cognitive dissonance to dissuade action. In this study, respondents agreed that file sharing behaviors were not considered appropriate behavior along two dimensions, social norms and the law, yet file sharing continued. The bigger picture provides further explanation showing how the technological infrastructure of the Internet and file sharing software clients enable this activity. Where walking into a store and taking a music CD off the shelf without paying would not be considered, perceptions of downloading music through a file sharing network have less impact on moral reckoning.

The community approach to the behavior seems to further manage impressions. Respondents feel they are part of a mechanism that cannot be stopped and is becoming common place in society. The community as a whole can provide better variety/availability of content than traditional distribution methods. Perception of the possibility of legal retribution is considered to be low, lost in the masses or considered not suspect at the individual level. Further impressions are voiced as suggestions for modified business models which eliminate consumer charges for media files altogether, to the perceived benefit of both the community and the content owners.

This data suggests the media business should focus efforts on impression management and/or give credence to some of the suggested business models provided here. At least there is support for further solicitation of suggested business models for sales and distribution of digital

media. Taken at its extreme, the data suggests profits may lie in areas other than the sale of digital copyrighted works and that free distribution of media could be used as support of other products (e.g. concerts, merchandise, supplemental materials).

Further research can use this framework to structure a holistic approach to understanding online file sharing behaviors. When viewed as a system, file sharing incorporates many stakeholders. The approach described here takes all of these stakeholders into account simultaneously. Such an approach can serve well when pursuing strategy which involves said stakeholders.

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APPENDIX

Questions used in group sessions and individual interviews	
Q1	What do you think of the whole p2p file sharing phenomenon?
Q2	Which client/technology do you use for file sharing?
Q3	About how many files per week do you think you share?
Q4	What type of file do you share?
Q5	What motivates you to upload content to the network?
Q6	Are you aware of file sharing etiquette associated with your particular client? Do you follow it?
Q7	Are there specific factors you look for when deciding to share/download? What are they?
Q8	Do you feel like you are part of a community when filesharing?
Q9	How much effort is required to participate in a filesharing network?
Q10	How do you feel about information copyright protection?
Q11	Are you worried about legal recourse?
Q12	Do you think there is anything to be done?
Q13	Do you think of online content as different?
Q14	Is it (content) free because it is online?

COORDINATING PRICING AND INVENTORY PURCHASING DECISIONS OF A SUPPLY CHAIN FOR AN E-TAILER IN FACE OF QUANTITY DISCOUNTS

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ABSTRACT

Traditional models have assumed that when a product's demand curve is known and stationary, a retailer of a product would find it optimal to replenish the inventory with a fixed quantity, and to sell the product at a fixed price. Current studies have shown that an E-tailer is better off if he/she would increase the price during an inventory replenishment cycle when price and demand elasticity is present. This research shows how this strategy can be adopted for E-tailers in face of quantity discounts offered by the manufacturer of a supply chain to encourage sales, and how retailers can be misled to adopt a suboptimal policy by using the cost-based model alone. We further illustrate that a continuously increasing price policy can lead to significant increase in profits over a fixed pricing policy.

Key words: inventory model, supply chain, E-tailers, EOQ, continuously increasing price, profit maximization

INTRODUCTION

Ford Harris's (1913) study on batch sizing started the studies on inventory policy a century ago. The Harris Model has then been forgotten until the idea was later published by Wilson (1934) in Harvard Business Review. Following the Review, the Harris's batching rule is now known as the Wilson Economic Order Quantity (EOQ) as it applies to inventory control.

This classic model assumes that a retailer buys a product at a constant unit cost, incurs a fixed cost per order, stores the product at a constant inventory carrying cost per unit per year, and faces a deterministic and constant demand rate over an infinite horizon, the retailer's optimal strategy is to buy a fixed quantity every time he or she replenishes the inventory. Ignoring inventory related costs, classical price theory tells us that when a product's demand is price sensitive but the demand curve is known and stationary, the retailer's optimal strategy is to charge a single price throughout the year. Although Whitin (1955) was the first one to integrate the concepts of inventory theory with the concepts of price theory, however, he did not formally investigate the simultaneous determination of price and order quantity decisions of a retailer.

Kunreuther and Richard (1971), perhaps the predecessors of supply chain management, then showed that when demand is price elastic, centralized/coordinated decision-making (using

simultaneous determination of optimal price and order quantity) was superior to the common practice of decentralized decision-making whereby the pricing decisions were made by the marketing department while the order quantity decisions were made by the purchasing department independently. Although Kunreuther and Richard (1971) were perhaps unaware of Whitin's (1955) paper, their model was very similar to Whitin's (1955) model. Assuming a known and stationary demand curve along with the conditions of the EOQ model, Arcelus and Srinivasan (1987, page 173) asserted: "given constant marginal costs of holding and purchasing the goods, the firm will want to maintain the same price throughout the year". Again, they assumed a fixed single selling price throughout each inventory cycle. What they did not realize is that, even though marginal holding costs are constant per unit, a firm's holding costs at any particular time within an inventory cycle are a function of inventory on hand, which itself is a function of the time from the beginning of the inventory cycle.

Since Whitin's (1955) work, numerous authors (Tersine and Price, 1981; Arcelus and Srinivasan, 1987; Ardalan, 1997; Hall, 1992; Martin, 1994; Arcelus and Srinivasan, 1998; Abad, 2003) have used Whitin's (1955) and Kunreuther and Richard's (1971) models as foundations to their own models. But none of these authors have ever questioned Whitin's (1955) and Kunreuther and Richard's (1971) assumption that the retailer's optimal strategy would be to sell the product at a fixed price throughout the inventory cycle. The fact that Whitin's (1955) and Kunreuther and Richard's (1971) assumption of a single price throughout an inventory cycle leads to suboptimal profits for the retailer is due to declining carrying costs as a function of time. It seems that any optimization model allowing a retailer with a price-insensitive demand to set the selling price arbitrarily would push the price to infinity. In other words, in that situation, price is not seen as a decision variable for any mathematical model. Given an arbitrary price (and corresponding demand), the retailer's only strategy is to minimize his inventory ordering and holding costs by using the EOQ model.

Considering a situation of price sensitive demand, Abad (1997; 2003) found that, in the case of a temporary sale with a forward buying opportunity, a retailer's optimal strategy is to charge two different prices during the last inventory cycle of the quantity bought on sale—a low price at the beginning of the inventory cycle and a higher price starting somewhere in the middle of the cycle. Yet, Abad (1997; 2003) did not consider a similar strategy in every regular inventory cycle of a product with price sensitive demand. Inspired by Abad's (1997; 2003), Joglekar, Lee and Farahani (2008), showed that a continuously increasing price strategy: charging a relatively low selling price at the beginning of an inventory cycle when the on-hand inventory is large, would lead to higher profit, abide the gain is relatively small. Subsequent study by Lee and Joglekar (2012) for gradual inventory production/replenishment cycle showed that significant gains on profit can be acheived by taking advantage of the demand elasticity.

With the widespread use of revenue management or yield management techniques (Feng and Xiao, 2000; McGill and Ryzin,1999; Smith and Leimkuhler, 1992; Talluri and Ryzin, 2000; Weatherford and Bodily, 1992) in the airline, car rental, and hotel industries today, a time-

dependent (or dynamic) pricing strategy has become commonly adopted. Revenue management techniques are typically applied in situations of fixed, perishable capacity and a possibility of market segmentation (Talluri and Ryzin, 2000). In recent years, retail and other industries have begun to use dynamic pricing policies in view of their inventory considerations. The recent recession has brought forth dynamic pricing to a new light.

As retail sales dropped, retailers were facing unusual built-ups of inventory that would lead to order cancellations affecting all parties of the supply chain. To counter such demand issues, wholesalers started to offer quantity discounts to retailers to boost sales. Hence, the E-tailers are presented with an opportunity to review their inventory policy, and pricing.

In addition, supply chain literature has shown that coordination of supply chain activities such as pricing (marketing) and inventory policies (production/distribution) would yield greater rent than acting as individuals. The case of bullwhip effect is well-known when supply chain partners that are hedging against risks and variations of demands, independently adjust the ordering quantities wildly to prevent stock-outs leading to magnification of inventory orders up the supply chain. The results, of course, would lead to huge inventory costs of retailers, and wholesalers, and production scheduling problems for manufacturers, and suppliers.

In the situation when manufacturers use a quantity discount to encourage larger sales, literature shows that the optimal ordering quantity to minimize inventory costs is derived from balancing setup cost, holding cost, and costs of inventory at various discount levels. However, with the supply chain approach of coordinating sales demands, and inventory, an E-tailer would benefit more if he/she would focus on profit optimization.

Joglekar, Lee and Farahani (2008) proved that by using profit maximization, one would enjoy higher profits by simply switching to price optimization in the EOQ (Economic Order Quantity) context. Furthermore, they showed that E-tailers who can easily change price via computing systems can obtain higher profits by changing price continuously. Although, the profit increase in an original EOQ inventory models is relatively small, they do provide a tool on price increasing schemes that can lead to higher profits.

This research would continue the investigation of profit maximization approach on quantity discounts when manufacturers would offer their supply chain retailers to achieve larger sales. In the next section, we shall review the cost model with quantity discounts (or bumpy breaks). Following that, we shall recapitulate the fixed price model, and extend the model for quantity breaks. The fourth section will show how the continuously pricing model can be implemented in face of quantity discounts. Finally, we would illustrate with numerical examples how all three models would perform under the same set of data, and offer some concluding remarks on cost models versus profit based models, and possible future research directions.

Cost Based Quantity Discount Model

The traditional EOQ models with quantity discount can be easily found in any operation or inventory management text. The general formulation is to find the optimal ordering quantity within each break, and when that quantity does not happen within the (price) breaks, we would bring the corresponding optimal ordering quantity up or down to the break point. The total inventory cost per period would then equal to the sum of inventory cost plus the cost of the goods sold per period. The following notations are based on fixed quantity review policy:

C_i = retailer's known and constant unit cost of buying the product within the quantity discount break, B_{i-1} and B_i,
Q_i= ordering quantity, when unit price is C_i, per cycle,
S = retailer's known and constant ordering cost per order,
I = retailer's carrying costs per dollar of inventory per year,
D = retailer's annual demand per period, and
B_i = quantity discount break, i, when ordering quantity $B_i > Q_i \geq B_{i-1}$, with corresponding unit cost of C_i.

To obtain the optimal ordering quantity with discount, one would find the optimal, Q_i, by minimizing, TC, the total cost per period, i.e., we minimize

$$TC = (D/Q_i)S + \tfrac{1}{2}(Q_iIC) + DC_i \text{ for all } i. \quad (1)$$

Notice that with constant demand/consumption, the fixed quantity review policy is the same as fixed periodic review policy with B_i being given as ordering cycle time, T_i where $T_i = B_i/D$.

Thus, the periodic review model would be to minimize, TC with respect to T, such that:

$$TC = S/T + \tfrac{1}{2}(DTIC_i) + DC_i, \text{ where } T = (2S/DIC_i)^{1/2} \text{ for all i.} \quad (2)$$

Note that if we simply switch the cost minimization model to maximization of profits via optimal price, such as maximizing ($P^*D - TC$) where P is the price for selling each product, the solution would set P to be infinite, rendering the solution impractical.

Fixed Price Quantity Discount Model

Both papers of Whitin "(1955), Kunreuther and Richard (1971) consider a situation where all the other assumptions of the EOQ model are valid but demand is price sensitive, with a known and stationary demand curve. Whitin's (1955) notation is different from Kunreuther and Richard's (1971) notation. Although the model is applicable to any form of the demand function, for simplicity, we use a linear demand function.

Let the notations of the previous section hold. In addition, we assume,

$D_1 = a - b\,P_1$, where a and $b > 0$, and a is the maximum demand per period,
P_1 = retailer's selling price per unit in this model,
t = time elapsed from the beginning of an inventory cycle,
T_1 = duration of an inventory cycle,
Q_{1i} = retailer's order quantity per order in this model when unit cost is C_i, and
Z_1 = retailer's profit per period.

It is assumed that,

$P_1 > C_i$, (for all i), and D_1 = retailer's annual demand as a function of the selling price, P_1, hence, $D_1 = a - b\,P_1$, where a and b are nonnegative constants, a representing the theoretical maximum annual demand (at the hypothetical price of \$0 per unit) and b representing the demand elasticity (i.e., the reduction in annual demand per dollar increase in price). Although P_1 would remain constant throughout a cycle, we choose to express it in an affine function form to be consistent with the price increasing model in the next section.

Note that since D_1 must be positive for the conceivable range of values of P_1, $a > bP_1$ for that range of values of P_1, and since $P_1 > C_i$, it follows that $a > bC_i$.

The fixed pricing model of Joglekar, et al (2008) for the constant cost, C, inventory model; with Q being the ordering quantity per order, then $Q = D_1/T_1$, the profit per period is given by,

$$Z_1 = (P_1 - C - ICT_1/2)(a - b\,P_1) - S/T_1 \tag{3}$$

Differentiating Z_1 with respect to P_1 and T_1, the first order conditions for the maximization of this function are:

$$P_1 = (1/2)(a/b + C) + (ICT_1/4), \tag{4}$$

where T_1 is a positive root of the following equation:

$$T^3 - 2[(a - bC)/(bIC)]T^2 + 8S/(I^2C^2b) = 0. \tag{5}$$

Substituting T_1 into (3), we obtain the profit per period as

$$Z_1 = (b/4)[(a/b) - C - (ICT_1/2)]^2 - S/T_1 \tag{6}$$

By using Excel's Solver®, one would be able to find the optimal T_1, and hence, the optimal price from equation (4), and the corresponding demand $D_1 = a - bP_1$, per period, and the optimal ordering quantity Q.

To adopt this model for ordering quantity with discount, we substitute C by C_i, for equation (6) above. From the resulting optimal T_1, we can compute the corresponding D_1, and the optimal ordering quantity, Q_{1i}. When C_i is not eligible for discount under the above conditions due to the breaks, we then, will proceed like the cost based model to utilize the optimal ordering quantity at the breaks, either B_{i-1}, or B_i, accordingly.

We derive the optimal pricing, P_1, at price breaks in the following for B_i, in general. With ordering quantity of B_i, the inventory cycle time, T_i, is given by

$$B_i = D_1T_1$$

or, $T_1 = B_i/(a - bP_1)$, after substitution of $D_1 = a - b\,P_1$. (7)

By substituting (7) into (3), the profit per period,

$Z_1 = (aP_1 - bP_1^2 - C_ia + bC_iP_1) - IC_iB_i/2 - Sa/B_i + SbP_1/B_i$

Differentiating Z_1 and setting the first order condition to zero for optimal P_1, we obtain,

$P_1^* = (a + bC_i + Sb/B_i)/(2b)$ (8)

Continuously Increasing Price Model With Quantity Discounts

Joglekar, et al (2008) developed the model of continuously increasing price within an inventory cycle. We recapitulate their model below for E-tailers. We retain all the notations of the previous section for the fixed pricing model. We also add the following notation:

t = time elapsed from the beginning of an inventory cycle,
$P_2(t)$ = the retailer's selling price at time t,
$= f + gt$, where f and g are nonnegative decision variables,
T_2 = duration of an inventory cycle,
Q_{2i} = retailer's order quantity per order in this model when unit cost is C_i, an
Z_2 = retailer's profit per period.

Thus, the retailer's annual profit under this model is given by maximizing Z_2, with respect to f, g, and T_2.

$Z_2 = (a - bf)(f - C_i - IC_iT_2/2) + (a - 2bf + bC_i)gT_2/2 + bg(IC_i - g)T_2^2/3 - S/T_2$ (9)

Notice that the model is a periodic review model similar to the fixed price model while the cost based model is a quantity review model. However, since the cost based model is shown to be easily transformed to a periodic based model, this would make our comparisons easier later.

As suggested by Joglekar, et al (2008), we can utilize Excel Solver® to find f, g, and T_2 simultaneously. The optimal ordering quantity per order Q_{2i}^* is given by,

$Q_{2i}^* = (a - bf)T_2 - (bg/2)T_2^2$ (10)

For using this model with quantity discount breaks, we, again, have to consider the scenario when Q_{2i}^* is not in the range of corresponding price breaks. Under such circumstances, we would have to adjust the ordering quantity to the break point, B_i, as in the previous two models. That is, we would maximize (9) with respect to f, g, and T_2, subject to the constraint,

$B_i = (a - bf)T_2 - (bg/2)T_2^2$ (11)

Numerical Examples

Consider the following situation with price breaks, when the retailer's cost of a product is C_1 = \$7 per unit when ordering quantity is below B_1 = 2000 units/order, C_2 = \$6.50 per unit when ordering quantity is between B_1 = 2000 and B_2 = 6000, and C_3 = \$6.00 per unit when ordering quantity is greater than or equal to B_2 = 6000 units. We further assume that the ordering cost, S, is \$400/order, the inventory carrying cost rate, I, is 0.4 per unit per year, and for price and demand elasticity parameters, a and b, are 50,000 and 5,000, respectively. Notice that for the cost based model, demand D is given and constant over time, while for the price-based models, D_1 and D_2 are dynamic depending on C_i. In order to be able to make comparisons, we arbitrarily pick D_1* when unit price is \$7 as annual demand D of the cost-based model.

Table 1. Comparisons of Optimal Policies of Cost-Based Model, Fixed Price Model, and Continuously Increasing Price Model

Assumptions: S = \$400/order, I = 0.4/per unit per year, a = 50000, b = 5000.
Discount breaks are: \$7 per unit for Q < 2000, \$6.5 per unit for $Q \leq 2000 < 6000$, and \$6.00 per unit for $6000 \leq Q$.

	Cost-Based Model			Fixed Pricing Model					Continuously Increasing Price Model						
C_i	D	Q	TC	D_1	Q_1	T_1	P_1	Z_1	D_2	Q_2	T_2	f	g	$P_2 = f + g*T_2$	Z_2
\$7.00	6781.597	1391.977	51368.71	6781.597	1391.977	0.205258	8.643681	7249.245	6035.031	1416.315	0.209281	8.5	1.4	8.792994	7284.319
\$6.50	6781.597	2000	48036.7	8250	2000	0.242424	8.35	11012.5	7434.434	2000	0.243169	8.196997	1.299986	8.513113	11054.01
\$6.00	6781.597	6000	48341.69	9833.35	6000	0.610168	8.0333	12138.89	9833.333	6000	0.617566	7.686344	1.200011	8.427429	15364.95

Table 1 shows the optimal solution for each of the models presented in this paper. Note that for the optimal ordering quantities Q, Q_1 and Q_2, the actual solution when C_i is \$6.50 or \$6.00 per unit are in fact smaller than the required discount breaks. Hence, the optimal solutions for those ordering quantities are set at break points, B_i. The shaded cells represent the best option for each model, respectively.

For the cost-based model, we minimize TC, the total inventory cost plus the cost of products per year. The optimal policy is to purchase 2000 units per order for a total annual cost of \$48,036.70. For both the fixed price model and the continuously increasing price model, we elect to order 6,000 units per order instead, contributing to \$12,138.89, and \$15,364.95 in profits/year, respectively. Thus, the continuously increasing price model garners an increase of \$3226.06 in annual profit, or 26.58 % over the fixed price model.

Although EOQ models based on costs are generally insensitive to changes of parameters, such as ordering cost, holding cost, and so on. Table 1's cost-based model shows that the difference in total cost between ordering 2000 and 6000 units per order is a mere 0.635 % difference. Unfortunately, the same logic does not apply to the profit maximization models. Should we have adopted the 2000 units per order as our inventory policy, based on fixed pricing model, the retailer would lose 9.272 % profit, while compared with using the continuously increasing profit model, a retailer would lose a drastic 28.057 % of profit instead.

The Joglekar, et al (2008) study shows that the continuously increasing price models are superior to the fixed price models. In the basic EOQ models, the profit increase of the continuously

increasing price models deliver higher profit/per period over the fixed price models by about 1 to 2 %. However, Lee and Joglekar's (2012) study discovers that when some of the EOQ restrictions are changed, including the current models of quantity discounts, the profit increase could be drastic: over 25 % increase in profit, while total demand per year, or the number of units sold per year actually decreases.

Although we are not going to repeat the sensitivity analysis here performed by Joglekar, et al (2008), and Lee, et al (2012), we did perform some informal tests on the profit maximization models, and found that the results are consistent with the previous reports. In particular, the continuously increasing price models are consistently much more profitable than the fixed price models by selling less per period.

On a separate analysis, the cost-based model arrives at the same optimal policies as the profit maximization models when the annual demand D increases. That is, when D increases from 6781, the optimal policy of ordering 2000 units/per order also shifts to 6000, in agreement with the other models. Obviously, the results are very much dependent on the parameters such as the price and demand elasticity, a and b being used, or the cost factors employed in the models. Based on these findings, a retailer should proceed with caution when relying on the traditional cost-based models alone for determining the optimal inventory policies with discount breaks since they might be misled as in our numerical example.

CONCLUSIONS

Since Harris's (1913) pioneer work on lot sizing and inventory, it is customary to set inventory policies according to the cost structure of the company. Since Abad (1997, 2003), and Joglekar, et al (2003, 2008), and Lee, et al (2012), it has been shown that price driven inventory policy (or with supply chains: a coordinated pricing and stocking policy) actually would increase the profit drastically. Although the continuously increasing price model does not offer much profit increase for the traditional EOQ situation, it, however, turns out to be most effective in dealing with other members of the EOQ family. In fact, Lee, et al (2012) and the previous section provide solid evidence that coordinating price and inventory in a supply chain would help both E-tailers and traditional retailers with gradual production, and price discounts.

Admittedly, the continuously increasing price models can be seen as more complex and more difficult to implement, but given today's technology, especially for E-tailers, the continuously increasing price scheme can be easily adopted via web servers. In fact, E-tailers can coordinate their inventory, replenishment, and pricing with their suppliers and customers with today's internet technology. Given the ease of implementation and in the event of quantity discounts with suppliers, E-tailers should seriously consider adopting the profit maximization policies instead of the traditional cost-based replenishment policies for achieving better profits.

This study together with the research by Joglekar, et al (2008) and Lee, et al (2012) have shown that continuous increasing price models with deterministic demands have consistently

reigned in significant profits over the fixed pricing models. We would extend our study and report our findings for probabilistic demands of a supply chain and how coordinating price and inventory would impact the overall profit versus the traditional inventory models in the future.

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MODELING A DEPARTMENT COURSE SCHEDULING PROBLEM USING INTEGER PROGRAMMING: A SPREADSHEET-BASED APPROACH

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ABSTRACT

This research studies a department course scheduling problem, considering the scheduling of courses (and sections of courses) at specific times, and the assignment of faculty to the different sections. The general problem has been addressed in the management science literature, and due to the complexity of the problem (because it typically involves a large number of variables and constraints), solution approaches have been largely based on heuristic techniques. The overall research goal is to come up with a realistic model and solution procedure that captures the main features of the scheduling problem while being computationally tractable. The problem is modeled using integer linear programming, and a simplified version of the problem solved using the Premium Solver Platform in Microsoft Excel. The model was used on actual data for four academic quarters, and in each case, Solver found a solution that closely replicated the current manual solution, with a significant time saving.

INTRODUCTION

The university course scheduling or timetabling problem typically involves the scheduling of multiple courses to be taught by multiple faculty members over multiple timeslots across multiple classrooms. The complexity of the problem makes it difficult to solve to optimality, and applications generally involve simplifications to make the problem tractable. Most of the studies in this field focus on applications pertaining to course scheduling at a single or at most few departments of a university (Sarin et al, 2010). The research presented in this paper is a pilot study to model the scheduling issues faced by one of the departments in the College of Business at a CSU (California State University) campus. There are scheduling challenges faced in trying to ensure that students are able to get the classes they need at the times that are convenient for them (for example, many of the students are not full-time students, and therefore have work-related constraints; further, students do not typically move through courses in cohort groups), while also considering faculty teaching preferences and availability. The department currently does the scheduling manually.

In general, effective scheduling can be instrumental in ensuring a smooth flow of students through the university system, and reducing the time to graduate. This is particularly important

under the tight budget environment that many universities face. The overall research goal is to develop a realistic model and solution procedure that captures the main features of the scheduling problem while being computationally tractable. Our focus is on the scheduling of courses (and sections of courses) during specific timeslots, and the assignment of faculty to the different sections. We do not consider classroom allocations in this research.

The remainder of the paper is organized as follows. Section II presents a review of the literature. In Section III we provide the specific context for our problem and outline the current manual scheduling procedure. We modeled the problem using integer linear programming, and the model details are described in Section IV. Section V discusses our use of a spreadsheet approach to pilot test the model, along with the results. We conclude in Section VI with limitations and suggestions for future enhancements.

LITERATURE REVIEW

Scheduling classes at universities is a challenging problem. The timetabling problem is generally large, highly constrained, and solution by exact optimization methods is difficult (Mirrazavi et al, 2003). Therefore, solution approaches typically rely on heuristics. There are several examples in the literature on the use of heuristics in university scheduling. For example, a major curriculum review in the School of Hotel Administration at Cornell University revealed that course scheduling was a major problem (Hinkin and Thompson, 2002). The authors developed a computer program to automate the scheduling process, considering conflicts among core required courses, and among electives within areas. The program was used by an administrator in the student services office. The College of Business Administration at Texas A&M University used a network-based model considering the dimensions of faculty, subject, time, and room (Dinkel et al, 1989). Derigs and Jenal (2005) described a Genetic Algorithm – based system for professional course scheduling using strategies such as pre-assigning subsets of courses. Another heuristic procedure based on genetic algorithms is described in Adewumi et al (2009). This procedure addresses lecturer timetabling at a Nigerian University, and uses an iterative process to generate schedules based on the degree of violation of hard constraints. Other articles describing heuristic approaches to course scheduling in university environments include Ferland et al (1994), Boronico (2000), Daskalaki et al (2004), and Dimopoulou and Miliotis (2004).

Several researchers have adopted the approach of developing subproblems for the overall problem. For example, the Anderson School of Management at UCLA implemented a course timetabling system by dividing the overall problem into two subproblems, and using integer programming and heuristics as solution approaches (Stallaert, 1997). The United Arab Emirates University developed a two-stage procedure, first seeking to maximize faculty course preferences in assigning faculty members to courses, and then maximizing faculty time preferences in allocating courses to time blocks (Badri, 1996; Badri et al 1998). Mirrazavi et al (2003) described a timetabling problem for a university department where an integer goal programming formulation

was implemented in two phases – the first phase allocated lectures to rooms and the second allocated start times to lectures. Daskalaki and Birbas (2005) developed a two-stage procedure for a department providing structured curricula for well-defined groups of students. The procedure includes a relaxation approach for computationally heavy constraints, and subproblems to obtain timetables for each day of the week.

The past few years have continued to see strong interest in the problem, and several studies address applications using integer programming. For example, Schimmelpfeng and Helber (2007) considered several hard and soft constraints and modeled the problem as an assignment problem using the context of Hannover University, Germany. They used a commercial CPLEX solver and found that it was able to generate solutions that satisfied teacher preferences to a high extent. Another example of an integer programming approach with a CPLEX implementation is described by Sarin et al (2010). They applied Bender's partitioning to solve the problem at Virginia Tech. The quality of the schedule was evaluated by the distance that faculty members would need to travel from their offices to the classrooms. The authors demonstrated that their approach could generate higher quality schedules than the current scheduling practice. Gunawan et al (2012) considered integrated teacher assignment and course scheduling at a university in Indonesia, and used a heuristic based on Lagrangian relaxation. The models were solved in phases using CPLEX. The proposed method was compared with the manual allocation done by the university for two problem instances, and found to provide better solutions. Rudova et al (2011) described a system for course scheduling at Purdue University that used constraint satisfaction as the basis of the solution procedure. The procedure initially focused on hard constraints and then used a perturbation approach and addressed soft constraints.

A survey of metaheuristic-based techniques (Lewis, 2008) reinforced the concept that meeting the needs of all concerned may not always be possible. According to the survey, most metaheuristic algorithms fall into one of three categories – one-stage optimization simultaneously attempting the satisfaction of both hard and soft constraints, two-stage optimization attempting the satisfaction of soft constraints only after the hard constraints, and algorithms that allow relaxations. Another recent survey paper (MirHassani and Habibi, 2013) focused on the various solution approaches to university course timetabling. According to the study, the most frequently used heuristic methods are Mixed Integer Programming, Genetic and Memetic Algorithm, Tabu Search, Graph Coloring Algorithm, and Simulated Annealing. The authors also reiterated the point that the problem is computationally challenging, that manual techniques are very time-consuming, and that decomposing large problems into smaller ones and using heuristic methods are effective approaches.

A couple of papers have addressed department level course scheduling in the College of Business at a California State University (CSU) campus, which is the context of our research. For example, Chong (2004) described generating a department schedule at CSU Long Beach, considering AACSB accreditation requirements, budget, and teaching preferences. This was a manual procedure and did not consider other student-oriented issues. Saltzman (2009) described

developing an optimization model for scheduling classes in the Decision Sciences department at San Francisco State University. His impetus for this came about when he became department chair and thought about ways to make the current manual scheduling process more efficient. His model was based on maximizing faculty preferences for courses and teaching times. It used integer programming and was solved with ILOG OPL Studio interfaced with Microsoft Excel. The procedure provided a reduction in the time needed to generate schedules.

The goal of our research was to develop an approach that would enhance scheduling effectiveness by capturing the main elements of the problem while being relatively simple and easy to use. With that in mind, a spreadsheet-based procedure was a logical choice as spreadsheets are widely available, easy to use, and enable what-if analysis.

PROBLEM CONTEXT

This study focuses on the scheduling issues faced by one of the departments in the College of Business Administration at a California State University campus. The Department offers courses that are classified as either College of Business Core Courses, or Department Courses. College of Business Core Courses are required of all students majoring in business, while Department Courses are courses required by the department for its majors, as well as elective courses. All courses are four unit courses taught in a Quarter system (an academic year is comprised of three quarters).

College of Business Core Courses: Three core courses are offered by the department. These are general and are typically taught by several faculty members. Multiple sections of each core course are offered each quarter across different timeslots. The total number of sections of Business Core Courses is about twenty five per quarter.

Department Courses: There are twenty courses in this category. They represent courses in Technology and Operations Management (TOM prefix) as well as e-Business (EBZ prefix). These are specialized, with each course typically taught by a very small subset of the faculty. The courses are offered in a rotation schedule in order to provide access to students with other time constraints (e.g., work requirements). A two-year plan of course rotation is established in advance so that students may plan their coursework effectively. Most courses are offered three to four times in a two-year cycle. The total number of Department Courses is about ten each quarter. Table 1 shows an example of a two-year plan for TOM courses. A similar plan is established for EBZ courses.

Faculty: The Department has eleven tenure-track faculty members. Standard teaching load is twelve units each quarter (three courses); however, this differs for some faculty members, for example, due to reassigned time. In addition, the department hires part-time lecturers to fill in as needed.

Timeslots: There are twelve standard timeslots for meeting days/times. These are MWF at 8 a.m., 9:15 a.m., 10:30 a.m., and 11:45 a.m.; MW at 2 p.m., 4 p.m., and 6 p.m.; and TTh at 8 a.m., 10 a.m., 1 p.m., 3 p.m., and 6 p.m.

Table 1: Two-Year Plan for TOM Courses						
Class	**Fall 2012**	**Winter 2013**	**Spring 2013**	**Fall 2013**	**Winter 2014**	**Spring 2014**
	Day& Time	**Day & Time**	**Day & Time**	**Day& Time**	**Day& Time**	**Day & Time**
TOM 309		Tu/Th 3:00-4:50 PM		Tu/Th 10:00-11:50 AM		MW 6:00-7:50 PM
TOM 315		MW 6:00-7:50 PM	Tu/Th 10:00-11:50 AM		MW 2:00-3:50 PM	Tu/Th 3:00-4:50 PM
TOM 319	Tu/Th 6:00-7:50 PM		Tu/Th 1:00-2:50 PM		MW 6:00-7:50 PM	
TOM 320		Tu/Th 10:00-11:50 AM		MW 6:00-7:50 PM		Tu/Th 1:00-2:50 PM
TOM 332	Tu/Th 10:00-11:50 AM		Tu/Th 6:00-7:50 PM		Tu/Th 1:00-2:50 PM	Tu/Th 10:00-11:50AM
TOM 350		MW 4:00-5:50 PM		Tu/Th 3:00-4:50 PM		MW 2:00-3:50 PM
TOM 401	MWF 11:45AM-12:50 PM	MW 2:00-3:50 PM		MW 2:00-3:50 PM	MWF 11:45AM-12:50 PM	
TOM 419	MW 2:00-3:50 PM			Tu/Th 6:00-7:50 PM		
TOM 420	MW 4:00-5:50 PM		MW 6:00-7:50 PM		Tu/Th 3:00-4:50 PM	
TOM 425	.	Tu/Th 6:00-7:50 PM		Tu/Th 1:00-2:50 PM		MW 4:00-5:50 PM
TOM 432	MW 6:00-7:50 PM		MW 4:00-5:50 PM		Tu/Th 10:00-11:50 AM	
TOM 434	Tu/Th 3:00-4:50 PM		Tu/Th 3:00-4:50 PM		MW 4:00-5:50 PM	
TOM 436		Tu/Th 1:00-2:50 PM		MW 4:00-5:50 PM		Tu/Th 6:00-7:50 PM
TOM 453			MW 2:00-3:50 PM		Tu/Th 6:00-7:50 PM	

Current Scheduling Procedure

Currently, the Department Chair generates the schedules using a manual procedure. This is done as a two-stage process. Step 1 involves scheduling the department courses. For this, the assignment of courses to timeslots is based on the two-year plan published in advance. The assignment of faculty to courses is based on the specializations of individual faculty members. Step 2 involves scheduling the business core courses, which consists of assigning faculty to

sections of business core courses, and timeslots. The output of Step 1 is an input to Step 2, with the schedule in Step 2 being built around the assignments from Step 1. The objective is to create compact schedules for faculty (reducing the time between the first class of the day and the last class of the day), while considering course and timeslot preferences.

INTEGER PROGRAMMING MODEL

We used integer linear programming to model the department scheduling problem. The model details are given below.

Model:

- **Decision Variables**
  - X_{ijt} = 1 if course i is assigned to faculty j in timeslot t
    = 0 otherwise
    (These variables represent the department schedule – incorporating the assignments of faculty to courses and timeslots)

- **Parameters**
  - Faculty time availability matrix
    - F_{jt} = 1 if faculty j is available in timeslot t
      = 0 otherwise
    (The faculty time availability matrix takes into account times when a faculty member is not available to teach, for example, due to ongoing committee meetings, or personal constraints)

  - Faculty – Course matrix
    - C_{ij} = 1 if course i can be taught by faculty j
      = 0 otherwise
    (The faculty-course matrix considers faculty teaching areas)

  - Course – Timeslot matrix (for department courses)
    - M_{it} = 1 if course i is assigned to timeslot t
      = 0 otherwise
    (The course-timeslot matrix is based on the two-year plan of course offerings)

  - Faculty time preference matrix
    - W_{jt} = weight (preference) of faculty j for timeslot t
    (This matrix represents faculty preferences for timeslots)

- **Objective function**

$$\text{Max} \quad \sum_j \sum_t W_{jt} Y_{jt} \quad \text{Weighted faculty preferences}$$

Where Y_{jt} = 1 if faculty j is assigned in timeslot t

= 0 otherwise

$$(Y_{jt} = \sum_i X_{ijt})$$

(The objective function maximizes the total weighted faculty preferences based on the assigned timeslots for each faculty member. The current scheduling procedure has an objective of creating compact schedules for faculty i.e., minimizing the time from the first class of the day to the last class. However, this creates a nonlinear model which is more difficult to solve to optimality. To overcome this, we used a weighted preference objective and manipulated the weights to facilitate the creation of compact schedules by the solver. This preserved the linearity of the model making it easier to solve.)

Constraints

1. Assign all department courses:

For each department course,

$\sum_j \sum_t X_{ijt} = 1 \quad \forall\ i \in$ department

(This set of constraints ensures that all department courses are assigned to a faculty and timeslot)

2. Observe cap on the number of core course sections:

For each core course,

$\sum_j \sum_t X_{ijt} \leq S_i \quad \forall\ i \in$ core

Where S_i = # of sections of course i

(These constraints establish that the number of sections of each core course assigned to a faculty and timeslot is within the total number of sections budgeted for that course. Core courses remaining unassigned after the scheduling process would typically be staffed by part-time lecturers. The department has a pool of part-time lecturers.)

3. Faculty teach only courses from their choice list

$\sum_t X_{ijt} \leq S_i C_{ij} \qquad \forall\ i \qquad \forall\ j$

(This set of constraints ensures that a faculty member will only be assigned to teach courses that they are eligible to teach per the Faculty-Course matrix)

4. Faculty teach only during their available times

$\sum_i X_{ijt} \leq F_{jt} \qquad \forall\ j \qquad \forall\ t$

(These constraints make sure that the schedules are compatible with the Faculty time availability matrix. They also establish that a faculty member can teach a maximum of one course in each timeslot.)

5. Faculty should be assigned the required # of courses (teaching load)

$$\sum_i \sum_t X_{ijt} = N_j \quad \forall\, j$$

Where N_j = # of courses to be assigned to faculty j

(This set of constraints is to make sure that the number of courses assigned to each faculty member corresponds to their teaching load. Standard teaching load is three courses per quarter, but this number can be different for different faculty members, for example, due to reassigned time. Typically, the three courses include one department course and two sections of a business core course.)

6. Course should be scheduled in its designated timeslot (department courses)

$$\sum_j X_{ijt} \le M_{it} \quad \forall\, i \qquad \forall\, t$$

(These constraints enforce compatibility with the Course-Timeslot matrix based on the two-year plan of course offerings)

7. No more than s sections of a core course in a timeslot (the limit s can be adjusted)

$$\sum_j X_{ijt} \le s \qquad \forall\, t \qquad \forall\, i \in \text{core}$$

(To ensure that sections of business core courses are offered across a variety of timeslots, thereby making it easier for students to find a section that would work with their time commitments, there is a limit on the number of sections that can be offered at the same time. This limit is typically set to 1 for most timeslots, and 2 for the more popular timeslots.)

8. Faculty teach either MW/MWF or TTh but not both (2 or 3 day teaching schedule)

$$\sum_i X_{ijt'} + \sum_i X_{ijt''} \le 1 \quad \forall\, j \quad \forall\, t' \in \{\text{MW/MWF}\}\ ,\ t'' \in \{\text{TTh}\}$$

(These constraints establish that if a faculty member is assigned to teach a course during a MW or MWF timeslot, they will not be assigned to teach during a TTh timeslot, and vice versa)

9. Faculty should not be scheduled to teach both 8 am and 6 pm TTh

$$\sum_i X_{ijt8} + \sum_i X_{ijt12} \le 1 \quad \forall\, j$$

(These constraints ensure that a faculty member does not get scheduled for an excessively long workday)

10. Faculty should not be scheduled to teach both 8 am MWF and 6 pm MW

$$\sum_i X_{ijt1} + \sum_i X_{ijt7} \le 1 \quad \forall\, j$$

(These are similar to constraints 9 above)

This model captures the scheduling considerations facing the department. As outlined in the literature review, modeling using integer programming, as well as adopting a two-stage solution procedure, are common approaches to the problem. Of course, the specifics of the model depend on the particular department/university. Also, as summarized in the literature review, there are different ways to implement a solution approach, with CPLEX being one of the popular ones. However, as mentioned earlier, the goal of our research was to develop an approach that would enhance scheduling effectiveness by capturing the main elements of the problem while being relatively simple and easy to use. Hence, a spreadsheet-based procedure was a logical choice as spreadsheets are widely available, easy to use, and enable what-if analysis. Accordingly, we implemented the key elements of the model using a linear programming solver add-in to Microsoft Excel.

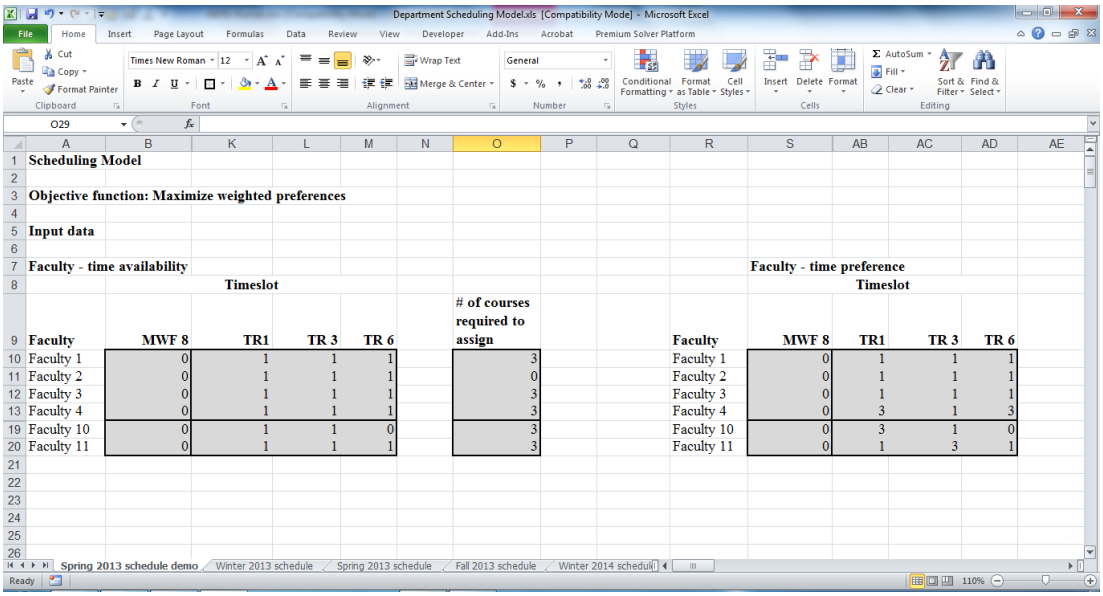
SPREADSHEET SOLUTION APPROACH

We used the Premium Solver Platform V12.5 (advanced optimization) add-in to Microsoft Excel to pilot test our integer programming model. The advantage of using Premium Solver is that it provides an interface that matches the standard Excel Solver, so that the model details can be entered using the standard Excel Solver dialog boxes. Models created using the standard Solver can be directly run using Premium Solver. Premium Solver can handle larger problem sizes than the standard Solver, and has faster engines, which is particularly helpful for integer programming models.

For a typical quarter, our integer programming model has a problem size of approximately 1700 variables and 1000 constraints. We incorporated all the model details in the spreadsheet. However, since our goal for the pilot testing was to replicate the current manual process, we were able to reduce the problem complexity. In the current process, Step 1 involves scheduling the department courses. Since the timeslots for these courses are fixed based on the published two-year schedules, and the faculty members are fixed based on their specialization, these assignments can be fixed in the spreadsheet. Accordingly, we fixed these, and used these as the starting point for Step 2, which involves scheduling the business core courses. Solver was then used to optimize the process for Step 2.

The current process has an objective to create compact schedules for faculty, while satisfying all constraints. In the integer programming model, this would have resulted in a nonlinear formulation. To preserve the linearity of the model, a weighted preference objective function was used. For this, the weights in the faculty time preference matrix were adjusted after the assignments from Step 1 were complete. During Step 1, if a faculty member was assigned to teach a department course during a particular timeslot, then the weights for the adjacent timeslots were increased. This facilitated the creation of feasible compact schedules during Step 2, which was the Solver optimization step.

Figure 1: Input Data (Faculty Time Availability and Preferences)



Scheduling Model

Objective function: Maximize weighted preferences

Input data

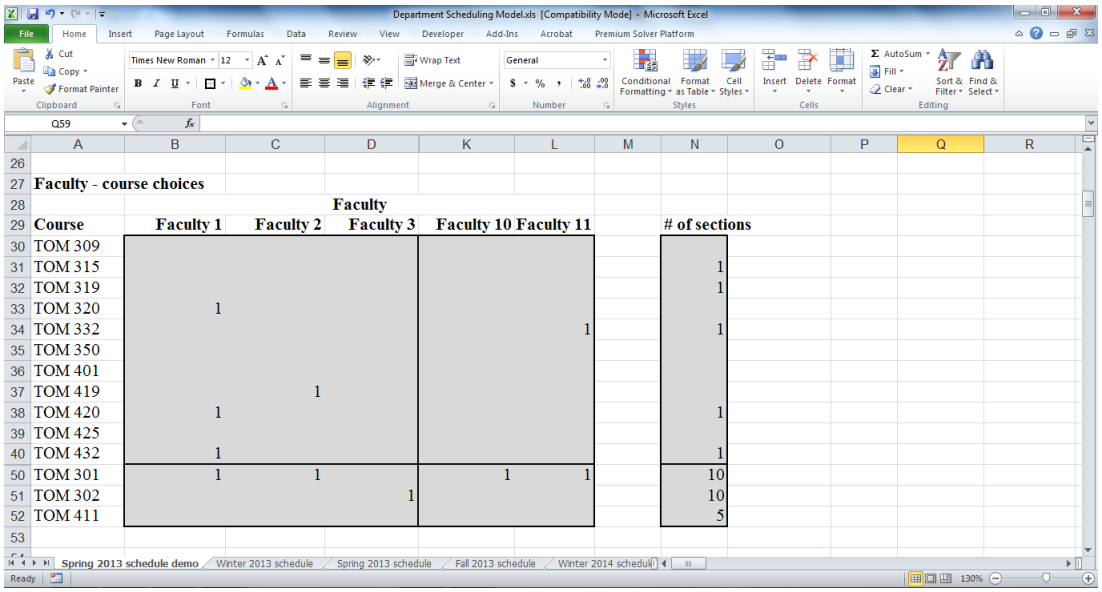
Faculty - time availability

Faculty	Timeslot MWF 8	TR1	TR 3	TR 6	# of courses required to assign
Faculty 1	0	1	1	1	3
Faculty 2	0	1	1	1	0
Faculty 3	0	1	1	1	3
Faculty 4	0	1	1	1	3
Faculty 10	0	1	1	0	3
Faculty 11	0	1	1	1	3

Faculty - time preference

Faculty	Timeslot MWF 8	TR1	TR 3	TR 6
Faculty 1	0	1	1	1
Faculty 2	0	1	1	1
Faculty 3	0	1	1	1
Faculty 4	0	3	1	3
Faculty 10	0	3	1	0
Faculty 11	0	1	3	1

Figure 2: Input Data (Faculty-Course Choices)



Faculty - course choices

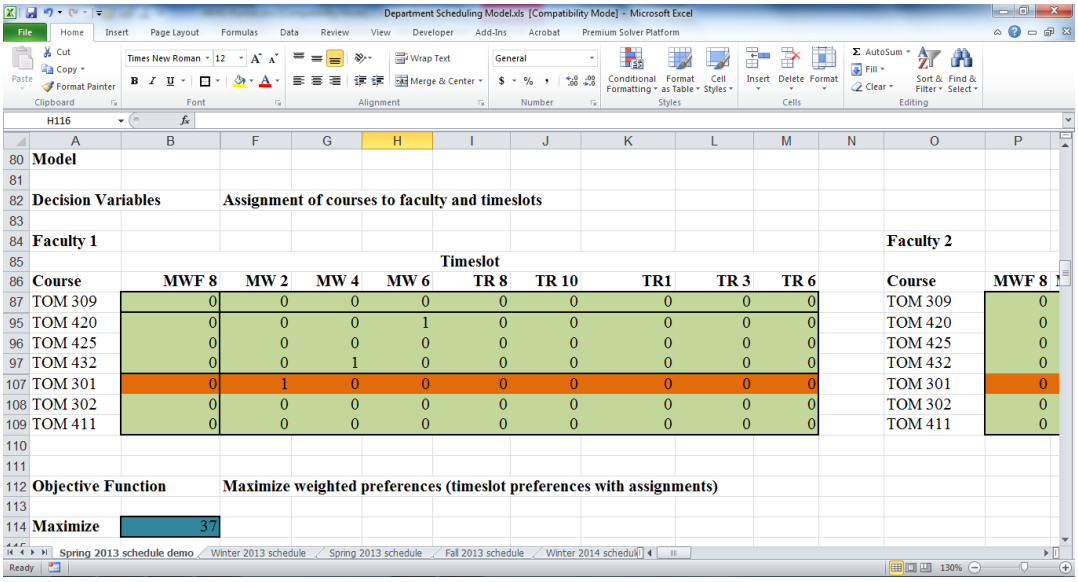
Course	Faculty 1	Faculty 2	Faculty 3	Faculty 10	Faculty 11	# of sections
TOM 309						
TOM 315						1
TOM 319						1
TOM 320	1					
TOM 332					1	1
TOM 350						
TOM 401						
TOM 419		1				
TOM 420	1					1
TOM 425						
TOM 432	1					1
TOM 301	1	1		1	1	10
TOM 302			1			10
TOM 411						5

Figures 1 and 2 show partial screen shots of some of the parameters to the Solver model. Figure 1 shows the Faculty time availability and Faculty time preference matrices, as well as the array representing faculty teaching loads. Figure 2 shows the Faculty-Course matrix along with the number of sections of each course. Since the purpose of the figures is to illustrate the structure

of the spreadsheet and not meant to be exhaustive, several rows and columns are hidden (for example, rows for faculty 5 through 9, and columns for timeslots 2 through 9). The data in these and the subsequent figures is from Spring 2013.

Figure 3 shows a partial screen shot of the decision variables and objective function. The department courses are at the top and the three core courses at the bottom of the list. Again, several rows and columns are hidden in this as well as subsequent figures.

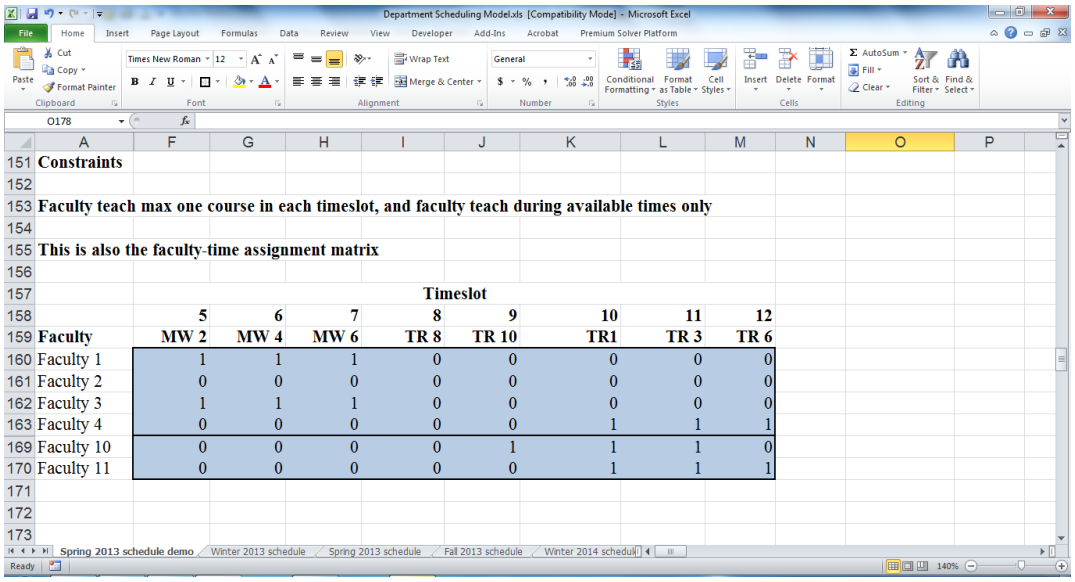
Figure 3: Decision Variables and Objective Function



	A	B	F	G	H	I	J	K	L	M	N	O	P
80	**Model**												
81													
82	**Decision Variables**		**Assignment of courses to faculty and timeslots**										
83													
84	**Faculty 1**											**Faculty 2**	
85						**Timeslot**							
86	**Course**	**MWF 8**	**MW 2**	**MW 4**	**MW 6**	**TR 8**	**TR 10**	**TR1**	**TR 3**	**TR 6**		**Course**	**MWF 8**
87	TOM 309	0	0	0	0	0	0	0	0	0		TOM 309	0
95	TOM 420	0	0	0	1	0	0	0	0	0		TOM 420	0
96	TOM 425	0	0	0	0	0	0	0	0	0		TOM 425	0
97	TOM 432	0	0	1	0	0	0	0	0	0		TOM 432	0
107	TOM 301	0	1	0	0	0	0	0	0	0		TOM 301	0
108	TOM 302	0	0	0	0	0	0	0	0	0		TOM 302	0
109	TOM 411	0	0	0	0	0	0	0	0	0		TOM 411	0
110													
111													
112	**Objective Function**		**Maximize weighted preferences (timeslot preferences with assignments)**										
113													
114	**Maximize**	37											

Figures 4 and 5 represent some of the constraints. Figure 4 shows the matrix corresponding to the left hand side of constraint set 4 from the integer linear programming model (faculty teach only during their available times). Each cell represents $\sum_i X_{ijt}$ for the respective faculty member and timeslot. The corresponding constraints in Solver are that this matrix is ≤ the faculty time availability matrix (which was excerpted in Figure 1). From Figure 4, we can see the optimal assignments by faculty and timeslot. Compact schedules are ones with assignments in adjacent timeslots.

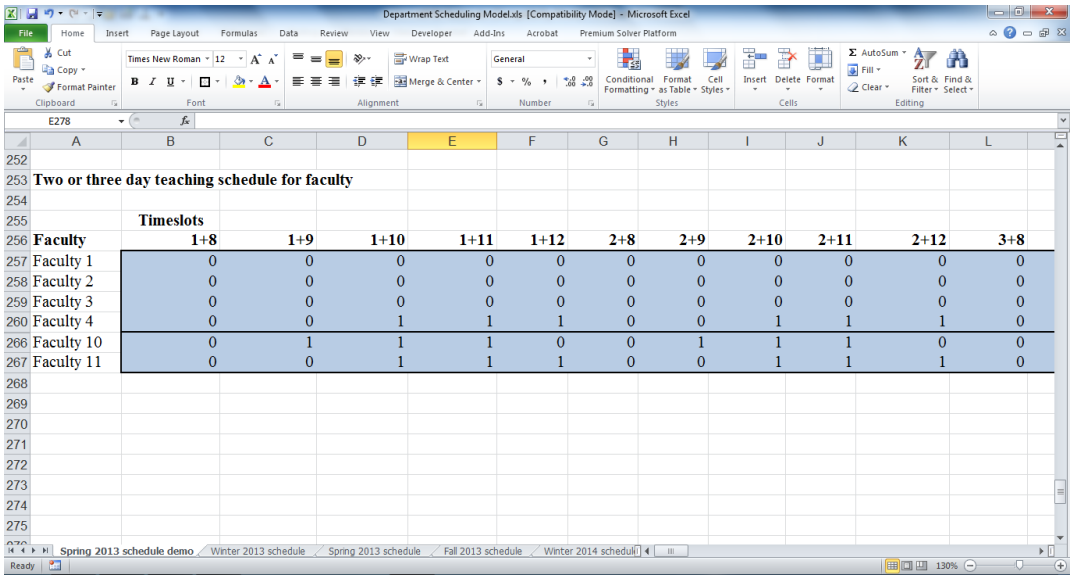
Figure 4: Constraints (Faculty Time Availability)



	A	F	G	H	I	J	K	L	M	N	O	P
151	**Constraints**											
152												
153	**Faculty teach max one course in each timeslot, and faculty teach during available times only**											
154												
155	**This is also the faculty-time assignment matrix**											
156												
157						**Timeslot**						
158		**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**			
159	**Faculty**	**MW 2**	**MW 4**	**MW 6**	**TR 8**	**TR 10**	**TR1**	**TR 3**	**TR 6**			
160	Faculty 1	1	1	1	0	0	0	0	0			
161	Faculty 2	0	0	0	0	0	0	0	0			
162	Faculty 3	1	1	1	0	0	0	0	0			
163	Faculty 4	0	0	0	0	0	1	1	1			
169	Faculty 10	0	0	0	0	1	1	1	0			
170	Faculty 11	0	0	0	0	0	1	1	1			
171												
172												
173												

Figure 5 corresponds to constraint set 8 from the integer programming model (faculty teach either MW/MWF or TTh but not both). Each cell represents $\sum_i X_{ijt'} + \sum_i X_{ijt''}$. Timeslots 1 through 7 are for MWF and MW, while 8 through 12 are for TTh schedules. The corresponding constraints in Solver are that each cell in this matrix ≤ 1.

Figure 5: Constraints (Two or Three Day Teaching Schedule)



	A	B	C	D	E	F	G	H	I	J	K	L
252												
253	**Two or three day teaching schedule for faculty**											
254												
255		**Timeslots**										
256	**Faculty**	**1+8**	**1+9**	**1+10**	**1+11**	**1+12**	**2+8**	**2+9**	**2+10**	**2+11**	**2+12**	**3+8**
257	Faculty 1	0	0	0	0	0	0	0	0	0	0	0
258	Faculty 2	0	0	0	0	0	0	0	0	0	0	0
259	Faculty 3	0	0	0	0	0	0	0	0	0	0	0
260	Faculty 4	0	0	1	1	1	0	0	1	1	1	0
266	Faculty 10	0	1	1	1	0	0	1	1	1	0	0
267	Faculty 11	0	0	1	1	1	0	0	1	1	1	0
268												
269												
270												
271												
272												
273												
274												
275												

RESULTS

The spreadsheet incorporated all the model details from the integer linear program, however, for the purposes of testing, we fixed the values of the variables from Step 1 (department courses), and ran the optimization solver for Step 2 (business core courses). This reduced the number of decision variables as well as eliminated the need for some constraints (for example, constraints set 1 and 6, pertaining to department courses, which were fixed during Step 1). The resulting Solver model contained approximately 130 binary variables and 600 constraints. The model was tested on actual data from four academic quarters (Winter 2013, Spring 2013, Fall 2013, and Spring 2014). In each case, Solver found a solution that closely replicated the Department Chair's manual solution, with a significant time saving. Further, the use of spreadsheets makes it easier to incorporate what-if analysis, by changing the values of the parameters as needed, and re-running the solver. Examples of what-if analysis could include changes in faculty teaching loads or availability, and changes in the number of sections of core courses.

CONCLUSIONS

This paper describes a spreadsheet approach to a department course scheduling problem. The problem was modeled using integer linear programming. A two-step solution process, mirroring the current manual process, was replicated using spreadsheets. As outlined in the literature review, integer programming as well as breaking the overall problem into sub-problems and solving, are widely adopted approaches to university course scheduling problems. With respect to the use of spreadsheets with the Solver optimization add-in for scheduling, some examples are available in the literature. For instance, Birge (2005) discusses an example of scheduling a professional sports league. Ovchinnikov and Milner (2008) describe a spreadsheet model to assign medical residents to on-call and emergency rotations. However, the use of spreadsheets with Solver for optimization does not appear to be common for university course scheduling. This may be due to the limitations of Solver when it comes to very complex problems. The contribution of our research is in showing that a spreadsheet with Solver add-in can be an effective tool for solving simplified versions of the problem.

Our scheduling context was a relatively small department. This effectively reduced the complexity of the problem, lending it more amenable to a spreadsheet solution. While the approach would work for a slightly larger department, it may not translate to significantly larger departments, or entire colleges or universities operating under a centralized scheduling framework.

This paper has presented a simple, practical approach to a complex problem. Future enhancements to the model could include incorporating additional elements. For example, increasing the range of courses taught by a faculty member would increase problem complexity. If the range is increased for department courses, multiple scenarios for Step 1 assignments could

be tried out, and the Step 2 optimization could be run for each scenario. If the range is increased for core courses, additional constraints could be added to limit the number of preps each quarter. Another enhancement would be to increase the user-friendliness of the spreadsheet, making it easier for someone unfamiliar with the model to be able to use it. Finding effective ways to address university/department course scheduling will continue to be an important issue for researchers in the field.

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THE ROLES OF POSITIVE AND NEGATIVE EXEMPLARS IN INFORMATION SECURITY STRATEGY

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ABSTRACT

The strategic approach used to manage organizational security is strongly influenced by management's perception of risk. These perceptions often lead executives to focus on the use of technology based solutions. Such solutions, aimed primarily at keeping data safe from outsiders, overlook the potential that more severe security breaches may be perpetrated by trusted insiders. Behavioral concepts such as ethnocentrism, group membership and intergroup bias, form the basis of an investigation that is aimed at developing our understanding of information security as a social issue. This paper considers the influence of in-group trust and out-group distrust, and the potential impact that positive and negative exemplars have on information security strategies.

Keywords: Information security, ethnocentrism, intergroup bias, exemplars

INTRODUCTION

On September 11, 2001 two planes crashed into the World Trade Center in New York City. Most of us can recall where we were on that morning. For many of us, hearing the date, or remembering 9/11 evokes strong emotions, causing us to automatically feel fear, sadness, hate…or an overwhelming sense of patriotism. However, by contrast, another date, August 2, 1988 probably doesn't have the same effect.

What thoughts come to mind when you think of the name Barack Obama? Again, does the name evoke strong emotions, both positive and negative, depending on your political views? For many African-Americans his name evokes a sense of accomplishment and a belief that anything is possible.

Each of these can be considered exemplary; a representative example of what typifies a person, group, event or instance (Zhou, 2008). Exemplary people and events have such an impact that when encountered, they trigger or activate an automatic affective response. This paper will examine how such exemplars, both positive and negative, play a role in an important organizational context: information security strategy.

Evidence gathered since the 1980s suggests that organizations continue to be victims of serious incidents that put their information at risk (Hoffer & Straub 1989; Taylor, 2006; Taylor & Brice, 2012). Occurrences of information security breaches continue to be an issue even though

there are continually highly publicized events that amplify the risk potential to organizations (Kasperson et al., 1988). These breaches should serve as wake-up calls for managers.

Security breaches by some specific individuals (i.e. Edward Snowden) are well-known by company executives, and understandably, cause them to reflect on the level of information security of within their organizations. These executives become concerned that their organization could be vulnerable to the same type of attacks.

However, many of security breaches are perpetrated by individuals who still remain unknown, such as the 2013 event that exposed Target customer information Even though the names of the perpetrators are not known; the representative nature of such events, as exemplars (Zhou, 2008) leads executives to question their vulnerability.

These recent high profile incidents support the contention that information security is currently not being adequately addressed, leaving many organizations critically exposed. Clearly, security remains a top concern for IS managers, who acknowledge escalating risks to organizational information resulting in financial losses for their organizations.

To address the issue of vulnerability to information security threats, organizations must change their current perspective on information security and adopt a new view. The current view of information security is very technology oriented (Taylor, 2008). As a result organizations spend heavily on technology-based solutions to protect organizational information. These technology solutions include firewalls for perimeter security, anti-virus software to prevent viruses and worms, and intrusion detection systems to discover potential abusers (Cavusoglu, et al., 2005). Properly installed and maintained these hardware and software solutions do create a solid foundation for effective information security.

However, these technology-based solutions are primarily intended to prevent outsiders from gaining access to organizational information and are thus inadequate to prevent all security breaches. This can ultimately create a false sense of security for an organization (Frolick 2003, Taylor 2006, Taylor & Brice, 2010). The authors' position is that along with these technology-based solutions, organizations must also adopt a human-based approach to address the information security risks introduced by the social and cultural aspects of the human element (Frolick 2003, Taylor, 2008).

Understanding information security as a social issue calls for an investigation of organizational behavior issues that may affect information security. While several such issues may merit consideration this paper will consider the influence exemplars, both negative and positive, associated with group membership.

CLASSIC ETHNOCENTRISM & GROUP MEMBERSHIP

Ethnocentrism is part of a "family of constructs" (Raden 2003, p.803) in the general area of prejudice. Classic ethnocentrism is a special and distinctive form of bias. According to Hewston, Rubin, and Willis, (2002), intergroup bias refers to the tendency to evaluate members of one's own group (designated the in-group) more favorably than non-members (designated the out-group). This group-serving tendency involves favoring the in-group--"us" and/or derogating

"them"-- the out-group. The term "bias" implies that this favoring and/or derogation involves an interpretive judgment that may be unfair and unjustifiable (Brewer & Brown 1998).

Throughout history societies have formed group relationships for the purpose of survival, thus creating in-groups. Those not associated with one's in-group were considered the out-group. Sumner (1906) coined the term 'ethnocentrism' to refer to positive sentiments toward one's in-group—pride, loyalty, and perceived superiority.

Being attached to an in-group does not necessarily mean there is hostility toward the out-group (Allport, 1954); it may simply represent a preference for one's in-group. Raden (2003, p.805) characterizes this absence of hostility as forms of ethnocentrism involving "simple in-group bias" and "mere in-group preference".

However, hostility toward the out-group is not uncommon. If out-group members are perceived as posing a threat, strong intergroup bias will exist (Stephen & Stephen 2000). Threats can involve the in-group's social identity, values, or goals, and may or may not be realistic (Esses, Jackson, & Armstrong 1998). Derogation of an out-group is often associated with fear of the out-group members (Stephan & Stephan 2000).

In its classic formulation, (Sumner, 1906) the connection of favorable evaluations of one's own group with negative evaluations of other groups as when an in-group rates itself favorably and an out-group unfavorably on the ***same*** traits is central, even essential. According to Raden (2003, p.803-804), "the distinguishing feature of the ethnocentrism construct continues to be that it jointly involves ***attitudes*** (emphasis added) of the in-group toward both the in-group and the out-group".

Research in the area of intergroup bias has also established the concepts of in-group trust and out-group distrust (Allport 1954; Brewer 1979; Brewer 1999). Favoring takes the form of trust in and among in-group members; derogation occurs because there is distrust of out-group members.

The psychological expectations of in-group members result in a high level of interpersonal trust in and among "us" in-group members.

> *"... in-groups can be defined as bounded communities of mutual trust and obligation that delimit mutual interdependence and cooperation. An important aspect of this mutual trust is that it is depersonalized, extended to any member of the in-group whether personally related or not. Psychologically, expectations of cooperation and security promote positive attraction toward other in-group members and motivate adherence to in-group norms of appearance and behavior that assure that one will be recognized as a good or legitimate in-group member"* (Brewer 1999, p. 431).

In-group-trust and out-group-distrust can also be attributed to the "homogenous effect" (Judd & Park 1988). Members of an in-group are seen as homogeneous with behavioral expectations based on positive exemplars, while members of the out-group are also seen as homogeneous, however behavioral expectations are highly influenced by negative exemplars.

EXEMPLARS & EXEMPLIFICATION OF GROUP MEMBERSHIP

The concept of exemplars has been used extensively in psychology, communications studies, organizational behavior, and strategic management research (Brauer, 2000; Thomas, Schermerhorn and Dienhart, 2004; Lockwood, et.al. 2005; and Zhou, 2008). An exemplar is a representative example of a type of object or thing; a model that is typical of a person, group, event or instance. An exemplar can be an individual, that person's situation, or an event happening to and/or around the individual if it models shared group attributes (Zhou, 2008). Exemplars offer concrete information about typical individuals and representative experiences that raise issues in a given setting (Zhou, 2008). Exemplars are activated during attitude assessment (Sia et al., 1997), and they offer heuristics to simplify and expedite information intake and utilization (Brosius, 2003). This process is especially pertinent in organizational contexts where evaluation and judgments are often made and responsive behavior and actions are the result.

Conceptually, exemplars represent an idea or mental image that allows for items that share common properties to be grouped together or categorized as either person or event based. Exemplar representation "may be constructed on the basis of actually perceiving the stimulus object, imagining it, being told about it second-hand, etc" (Smith, 1998, p. 411). As Reisberg (2006) notes, the more frequently an item is encountered, the more stored representations of it will be held in memory.

Research on the characteristics of exemplars often focuses on their vividness and salient nature to explain effects (Zillman & Brosius, 2000). Vividness can come from the power of the language used to describe the exemplar, the imagery it evokes or the emotional value attached to the instance when it occurs. Salience refers to those aspects of the exemplar that draw more attention since they stand out because of their unusual character. The use of emotion-evoking imagery has been found to create perceptions and dispositions that actually gain strength over time. The presence of exemplars automatically activates affective responses. This exemplar activation is unintentional (Macrae, et.al, 1998).

POSITIVE EXEMPLARS

A positive exemplar, as an individual, is one whose conduct should be emulated. A positive exemplar can also be an instance or event that is worthy of being repeated. As the representation of an ideal, an exemplar is worthy of imitation, serves as a pattern or archetype and deserves to copied (Merriam-Webster, 2014). An example of a positive exemplar is Dale Beatty, a 2013 CNN Hero of the Year, who founded an organization that built or modified homes for disabled veterans.

A single exposure to a positive exemplary act is a sufficient condition for the influence process to occur; a series of such events can help build mindful behavior in areas such as ethics (Thomas, Schermerhorn & Dienhart, 2004), workplace safety (Gyekey & Salminen, 2005) or any area of strategic emphasis (Zillman, 1999). Thomas, Schermerhorn & Dienhart (2004, p. 57) showed that leaders who are viewed as positive exemplars can influence a substantial majority of an organization's membership. However, it should be noted that individuals may consider *themselves* to be the positive exemplar. In such instances, therefore, that individual's judgments

about fellow in-group members are based on their own self-perceived positive behavior (Brauer, 2000; Judd & Park, 1998; Park & Rothbart, 1982).

NEGATIVE EXEMPLARS

In contrast, negative exemplars represent behavior or situations that are undesirable (Reisberg, 2006). In the case of a negative exemplar, recipients can give disproportional attention to an errant actor or a concrete, often vividly displayed event that engages the emotions. Negative exemplars can motivate others to avoid a specific behavior or an event that may result in an unpleasant fate (Lockwood et al., 2005). For example, the recent death of actor Paul Walker, who died in a car accident attributed to excessive speed, may motivate others to avoid fast driving, especially when he (Paul Walker), or the actual event, is recalled. Lockwood et al. (2005: p. 1) describe an advertising campaign featuring an overweight teen named Eddy, who "has a passion for burgers, butts and his sofa", that is aimed at encouraging teens to eat healthy. The purpose was to depict Eddy as a negative exemplar whose behavior, if emulated, would result in becoming overweight.

The strategic use of exemplification in addressing issues is effectively the starting point in that the world of exemplars, examples, or representations influences perceptions of and judgments about phenomena and issues encountered in the organizational context. Their vividness, salience and affective characteristics explain how groups of people will blindly trust members of their in-group, while out-group members are shrouded by suspicion, distrust, and hate, even when little is known about the actual members of the out-group (Insko, Schopler, Hoyle, Dardis & Graetz, 1990).

Exemplars, both positive and negative, and exemplification theory form the basis of this investigation of the influence of group membership on managers' perceptions of information security risks in their organizations. The discussion in the next section raises and addresses the connections between managers' biased perceptions and information security behavior.

GROUP MEMBERSHIP AND INFORMATION SECURITY RISK

Past research on intergroup bias was primarily focused on societal level biases; however, these same principles can be applied to business organizations and the philosophies they use to create their information security strategies. We expand the concept of ethnocentrism to include not only beliefs or attitudes, but expectations about practices, actions and behaviors that members of a group are likely to perform.

This research investigates what happens when biases based on group membership leads to in-group trust (favoritism) and out-group distrust (derogation). In the information security context on which this paper is based, the in-group is composed of persons who are employed by the organization while the out-group members consist of everyone else.

Members of an in-group are expected to act one way, generally in compliance with security measures and accepted industry standards of practice. Members of the out-group, however, are subject to suspicion based on the perception that they are likely to engage in behaviors that are

detrimental to the maintenance of information security. Such suspicion is grounded in the forms of bias (e.g. in-group trust and out-group derogation or distrust) that are described in the preceding paragraph.

Perceived threats from outsiders seem to be the driving factor for an organization's information security strategy (Taylor, 2008). Hence, out-group distrust is evident in most aspects of an organization's security strategy.

Management utilizes physical security measures to keep the organization protected from outsiders through the use of door locks, electronic entry systems, video cameras, and security guards. Information security management is approached in the same manner. Technological solutions such as firewalls and intrusion detection systems are put in place for the primary purpose of keeping an organization's information protected from outsiders—the out-group.

Internal Information security measures directed toward in-group members are generally less stringent. Managers may require employees (members of the in-group) to change passwords, attend security awareness training, and review policies and procedures on an annual basis. These practices reflect managers' overall beliefs about the willing compliant behavior of subordinates, who represent in-group members.

Both in-group and out-group members can be the source of information security threats. However, group membership influences management's perception of both the source and severity of the threat posed to information security.

Perceptions about the existence or severity of threats which underlie organizational information security management are based largely on group membership. According to Park and Rothbart (1982) in-group judgment can be group level or based on a particular member of the group, including *the self*. This notion can be applied to perceptions about security behavior of in-group members. Positive security behavior can be influenced by positive exemplars**.** Often the manager(s) who are ultimately responsible for security management (*the self*) represent positive exemplars. Managers trust that employees are reading information security policies and adhering to established norms to protect the organization's information. These expectations exist because the manager him/herself follows policies and norms and therefore blindly trusts that other employees (in-group members) will do the same. In organizations, as well as society, such in-group trust (as well as out-group distrust) can also be attributed to the "homogenous effect" (Judd & Park 1988). Members of an organizational in-group (the employees) are seen as homogeneous whose behavioral expectations are "similar to" and based on a positive exemplar (e.g. the manager).

In-group trust is a significant contributor to information security risks. For example, research (Dhillon 2001. Taylor, 2006; Taylor & Brice 2012) confirms that in-group trust is grossly overlooked as a factor in information security management. Ingroup-trust can result in fewer information security countermeasures and lower levels of employee monitoring (Dhillon 2001), both of which have been identified as factors in increased information security risks (Straub & Welke 1998). In this research, IT Managers are considered positive exemplars and in-group members are expected to follow their behavior example (e.g. security practices). As a result, managers perceive fewer risks associated with information security breaches by in-group members.

We posit that such trust increases the potential for internal threats due to the gap between the expectations held by a positive exemplar and employees' actual behaviors and actions. Managers whose trust in employees' information security behavior is based on their confidence in fellow in-group members are the focus of our first hypothesis.

H1: Management perceptions of themselves as positive exemplars increase Information Security risks.

As with in-group members, members of the out-group are also viewed as being homogeneous, that is sharing common within-group attributes and attitudes. Perceptions about security breaches by out-group members are influenced by the presence of negative exemplars**.** Although security breaches are carried out by individuals, for the most part it's the threat of external security events that represents the negative exemplar, as these are what guide management's information security decisions. Accounts of high-profile security breaches, such as those mentioned earlier in this paper, identify events as the outside factors that can be characterized as negative exemplars. In other words, perceptions of threats posed by out-group members are based largely on the characteristics of the events with which these outsiders become identified, *after* those events take place. The perceived likelihood is that negative exemplars (events) will be perpetrated by outsiders. Therefore, managerial expectations regarding behaviors for out-group members are highly influenced by persons such as Snowden or the anonymous hackers in the Target Stores case whose actions trigger major events. This is supported by Linville et al. (1987), whose research showed that information about an individual member of an out-group or a specific event associated with an out-group is stored in memory and subsequent group judgment can be made when these memories are recalled. It can be expected that when managers recall Snowden (the actual individual) or the Target Store incident (the event) they will likely consider the potential risk to their operation and thus evaluate their organization's information security protection against the specifically triggered event. The second hypothesis addresses the impact of management's assessment of negative exemplars and perceptions of the associated risks.

H2: Management perceptions of negative exemplars decrease Information Security risks.

METHODOLOGY

As a research tool, the case study method is both appropriate and effective for investigating a complex subject such as information security, especially when the study offers a unique opportunity to observe what is becoming an increasingly important focus of organizational and management studies. Yin (1993) presents the domain of management information systems as an application for employing the case study method as a research strategy. He reports that management scholars have successfully extended the use of case studies beyond their traditional use as teaching tools (1993, p 64). The growing interest in case studies as research tools serves a useful purpose for a phenomenon that (a) is broad and complex, (b) needs a holistic, in-depth investigation, and (c) cannot be adequately studied outside the context in which it occurs (Benbasat et at. 1987; Bonoma 1985; Feagin et al. 1991; Yin 2003).

The case study makes it possible to "retain the holistic and meaningful characteristics of real-life events such as [the] organizational and managerial processes..."(Yin, 1984 p14) that accompany the continued expansion of management information systems. A holistic, in-depth investigation which follows a naturalistic approach to generating a qualitative understanding of information security concerns, certainly offers advantages. Lincoln & Guba (1985) outline a method that takes into account time, context and human social interaction, factors that foster a holistic view of the problem domain, especially within the scope of the networked organizational forms, instead of the simplistic, one-dimensional, explanation, more suitable for hierarchically structured organizations (Dhillon & Backhouse 2001). The case research strategy allows for a great deal of flexibility and individual variation (Cavaye 1996). This makes the case study an ideal methodology for investigating the concerns of information security.

Management information systems security is difficult to study outside the context in which it occurs (Benbasat, Goldstein, and Mead 1987). It may be difficult to get honest answers to questions regarding information security. Therefore the case study method allows the researcher to conduct probing interviews as well as engage in ethnographic observations of information security practices within the organizational context. For this case study, access was granted to a financial institution.

THE ORGANIZATION

Financial One (not the organization's real name) is a financial institution located in a major metropolitan area in the southern United States. There are seven Financial One branches throughout the metropolitan area, consisting of approximately 200 full and part-time employees. Of the seven branches, one branch is housed at the Financial One headquarters. At this location are the executive offices, the information technology (IT) department, accounting, credit card services, wire transfers, and other back-office and support services. This organization was chosen for several important reasons.

First, financial institutions are at greater risk because of the potential gain for perpetrators who steal or corrupt organizations' information assets (Yeh & Chang, 2007). For example, information systems in the financial services industry can provide access to customer credit card and account information.

Second, the presence of both federal and state information security regulations put pressure on affected organizations to ensure proper security measures are being taken. For these reasons financial institutions would be more likely to emphasize information security than organizations in other industries (e.g., a restaurant chain). Finally, one of the authors served as an executive in this industry for over 10 years before entering the academic community, therefore providing additional insight into the organizational environment and the issues facing the industry. Being considered an industry insider provided a high level of legitimacy with the Financial One staff, resulting in employees' willingness to divulge information and permit greater access to organizational resources (Malone, 2003).

Case study research requires a high degree of ethical consideration (Roth, 2005), especially when the research involves a sensitive subject such as information security. The CEO and CIO of the Financial One served as "gate-keepers" who allowed access to the organization and its

employees (Miller and Bell, 2002). It was important to keep these two individuals updated on a constant basis. Each staff interview was conducted where only the primary researcher and the subject employee were present. Document review was conducted by the researcher alone after the documents were provided by the CIO. All other events were conducted with the CIO present.

After each phase of the investigation, the CEO was briefed on the findings, and additional consent was sought (and granted) before moving ahead to the next phase of the research. Schwandt (1997) defines such briefings as member or respondent validation. These member checks were initially made to establish the current level of information security. Their baseline perception formed a risk assessment of information security systems that were in place. As the investigation progressed, these briefings were used to share and corroborate findings.

These research activities establish what Lincoln and Guba (1985) refer to as the credibility of the process and help ensure the trustworthiness of findings. These authors developed four criteria that serve as case study research equivalents for internal and external validity, reliability and objectivity (Schwandt, 1997). Careful steps were taken to assure that interviewee observations that are used to support results match the respondents' views of the organization. Finally, the results reported herein are linked directly to the interview data in order to establish that findings are not simply products of the researchers' imaginations.

In accordance with the suggestion of Yin (2003) the authors concluded that conducting the case study within Financial One would be an effective method to obtain in-depth data and generate rich analysis needed to apply existing theory to a phenomenon in a different context, which is what we are doing. We seek support for hypotheses that address the influence of positive and negative exemplars as the source of intergroup bias as applied to information security risks within organizations.

RESULTS

Table 1. Managers as Positive Exemplars

Positive Exemplar Analysis						
Employee	**Will Give Out Password (exemplars/managers)**	**Others Will Give Password**	**Would Fall For Social Engineering (exemplars/managers)**	**Others Would Fall For Social Engineering**	**Reviews IS Policies (exemplars/managers)**	**Others Review IS Policies**
Exec 1	NO	NO	NO	NO	YES	YES
Exec 2	NO	NO	NO	NO	YES	YES
Exec 3	NO	NO	NO	YES	YES	YES
Exec 4	NO	NO	NO	NO	YES	YES
Exec 5	NO	NO	NO	YES	YES	YES
Exec 6	NO	NO	NO	NO	YES	YES
Exec 7	NO	NO	NO	NO	YES	YES
Exec 8	NO	NO	NO	NO	YES	YES

H1 Management perceptions of themselves as positive exemplars increase Information Security risks.

Executives at Financial One were in unanimous agreement that their organization operated with a high level of information security. This belief was expressed in their personal observations, documented in reports from outside audit firms, and even based on "intuition". According to the CFO:

> *"I believe our information security is solid. My opinion is not based on our IT department, but based on what the so-called experts have told me. That's where my decision is coming. Not that I have any concerns with our IT department, but if I hear it from an expert what else am I to believe?"*

The executives at Financial One considered themselves positive exemplars (Table 1). Because they believe that "our employees are well trained" in information security issues (CEO of Financial One), these executives believed their information security behavior was emulated by the other employees, who are considered members of the in-group. They expressed confidence that their employees read Information security policies, would not share their password with anyone, and were not vulnerable to social engineering involving the gathering of confidential information through lying or other types of deception.

Evidence in support of this hypothesis comes from the application of exemplar theory to in-group and out-group trust in Financial One. The positive exemplar analysis of eight executives in this setting demonstrates that these managers (1) acted in accordance with (1) their beliefs in their strength as positive exemplars and (2) an illusion of control that produced an optimistic bias that employees, as in-group members, would act accordingly.

To verify the accuracy of management's perceptions, employees throughout the organization were interviewed. Employees have been shown to be the best source for understanding the behavior and actions of other peers (Murphy & Cleveland, 1991). Behavior that is observed by employees is different than that observed by management, because employees have opportunities to see a wider range of behaviors of which managers may not be aware.

Policies

Organization security models have stressed the importance of the establishment and implementation of security policies (Segev et al., 1998). Security policies at Financial One were posted on the company's intranet and updated continually as needed. All employees were encouraged to read the security policies. Every year employees were required to sign a document verifying that they had done so. Because of the existence of policies that had been established to protect organizational information, management perceived that these policies were being followed by the staff. It was also perceived that department supervisors were effective in the enforcement of these policies.

The executives who were interviewed were aware of organizational information security policies and procedures. As positive exemplars, they believed that others would be also. Furthermore, these executives regularly reviewed and followed information system policies and assumed that the employee in-group members did so also.

Statements made by employees, didn't, however, confirm the executives' belief regarding reading policies. One employee admitted receiving the handbook, and was aware that it was online, but stated:

> *"I haven't read the handbook to be honest with you. I guess I might have pulled it up to find the answers to thing that I have questions to…but it's going to be on something that interest me like wage compensation, raises…merit raises…stuff like that…but not security stuff."*

This sentiment was confirmed by other employees within the organization. When one was asked about reading security policies she replied:

> *"For someone that has been here for five or six years then they know it…they know what they are supposed to do."*

Yet, when the same employee was asked if she was aware that it was against company policy to give out her password, she replied, "*…our company has a policy like that?....no [I was not aware of it]".*

Interviews with other employees at Financial One provided additional support for the hypothesis. Interview data also supports previous findings that managers may feel overly optimistic regarding their employees' awareness of organization security policies (Taylor & Brice, 2012).

When interviewed, the executives also pointed to the existence of a policy that stressed the importance of shredding sensitive information.

> *"Anything dealing with customers' accounts goes to that shred bin and it's kept locked up in a back room with the door shut and the cleaning people don't go into. We are pretty good about putting things in shredder bins. Could I 100% say there is nothing in there [the trash], but all in all the chances of it happening are very slim."*

To emphasize the importance of this policy, each employee workstation was equipped with a trash can (black) and a shred can (blue). According to the security policy, each employee was responsible for emptying their blue shred can each night into a larger shred bin that was located in a secured area. However, after personal observation by the first author of this paper, who was allowed to remain on the premises afterhours while the CIO was present elsewhere in the building, it was noted that employees did not empty their shred cans into the dedicated shred bin. It was also further noted that the evening cleaning crew stopped at each desk, where both the black trash can and the blue shred can were emptied into a single trash receptacle. Contents of that receptacle were then bagged and thrown into the outside dumpster. Employees expressed surprise when asked about this the next day. They assumed that their blue shred cans were being picked up each night and taken to the dedicated shred receptacle.

Passwords

Notably, there is another security policy at Financial One that requires employees not to share or reveal their system passwords to anyone. When asked if they thought employees would give out or share their system password, management unanimously declared that employees would not. Managers felt that employees were well aware of existing policies and that they fully understood the importance of protecting their system passwords.

> *"I wouldn't sit here and tell you that it would be 100%, depending on who was asking, some people would probably offer it up, but overall most would not."*

Based upon interviews with Financial One employees it was noted that although most employees were aware of the policy, it was not an uncommon practice to share passwords if deemed necessary. An employee confirmed that she would give her password to anyone in the IT department, to the VP of Branch Operations, and to her Branch Manager. She stated that she had shared her password on several occasions. Employees of the IT department also admitted to sharing passwords among themselves when it was necessary for one of them to access a system they did not generally have access to.

To further test whether employees would give out their password, the IT department was asked to call 60 employees (in-group members) from all levels of the organization, and simply ask them for their password. Of the 60 calls that were made they obtained 10 voicemails and 50 passwords. Employees who surrendered their passwords had their passwords automatically reset, forcing them to change it immediately.

Two of the passwords were received from executives who stated they would not give out their password (as shown in Table 1). When informed of this, the CEO expressed both surprise and concern:

> *"It's like IT was saying here's a lollipop give me your password…but they weren't even giving them a lollipop….they just asked for it."*

Social Engineering

Infamous hacker, Kevin Mitnik stated that he rarely relied on hacking to access a company's computer system because technology controls were getting better to prevent outside access, and even though he could still get through most of the controls it took a lot of effort. However, with social engineering, he said it was like taking candy away from a baby (Mitnik & Simon, 2002).

Executives at Financial One were asked if they would fall for social engineering attacks. They each gave assurances that they would not. Again, relying on themselves as positive exemplars, they believed their employees were also too well trained and would not fall for the deceptive tactics. Notable exceptions were the two executives mentioned in the preceding section, who didn't have the same level of confidence in their employees, presumably because they had violated the password policy (Table 1).

Financial One employees were told about a scenario used by infamous hacker Kevin Mitnik in which he would randomly place CD-ROMs throughout an organization in areas, such as restrooms, where he was allowed and that employees would typically go. The CDs would be

labeled "Employee Salaries". Any employee, who was tempted to look at this CD, would have keystroke capture software installed on that. The results were then emailed to Kevin, which would automatically give him access to the organizations computer system. In response to hearing the scenario, one employee offered this observation, *"I think you have people that would be nosey enough to stick it in their CD ROM and try to look at it."*

A second social engineering scenario was presented to the employees: Someone claiming to be an employee of their primary information system vendor called and described a fictitious problem that required the employee's password to correct. The vendor thus tricked the employee to revealing their password to them. In response, a different Financial One employee observed, *"Wow…that's pretty good…I bet at least half of the people would fall for that."*

When given the two social engineering scenarios, most of the employees admitted that that would fall for one or both of them, again providing support for the hypothesis.

Further additional support for this hypothesis comes from the fact that researchers consistently found evidence of blind trust for the in-group employees. The fact that these executives were dealing with employees who were known to them personally as individuals compounded the risks of insider threats to information security.

> *"Most of the guys have been here for almost as long as I have or a lot longer…so I would tend to trust them more than someone brand new walking in the door."*

The CEO believed that the ingroup members were displaying good security behavior based on his perception that employees followed his own exemplary behavior:

> *"We have a lot of in house expertise and I think we have devoted a lot of resources trying to provide good security. I think that we have had pretty good performance down the line. It's more intuitive than data based".*

As seen in the previous quote, the CEO's expressed optimism that employees were performing well when it came to information security was based totally based on his intuition. This lack of concern about security risks was rooted in the confident optimistic perception that employees would follow his exemplary security behavior example. These findings demonstrate that management was clearly unconcerned with negative employee behavior insofar as information security.

Due both to the executives perceptions of their influence as exemplars, and their beliefs that their employees' (in-group members) behavior was not a threat, the issue of information security was not adequately addressed. Management put too much trust in their employees, resulting in a lack of monitoring and supervision which ultimately increased information security risks within their organization, thus providing support for Hypothesis 1.

H2 Management perception of negative exemplars decreases Information Security risks

In this case the negative exemplars are actually events that trigger the affective response. Findings in this study indicate that negative exemplars affect managers' perceptions of threats to

information security posed by out-group members. Thus, threats posed by out-group members increased awareness of the probability of their occurrence which ultimately leads to increased security measures.

Consider these observations by both the CEO and COO of Financial One:

> *"When you're working out front, seeing people come in with long coats and ski-masks on is typically a bad sign. With online stuff, you can't distinguish who will try to get into your system. Could be some kid, an ex-employee, or some professional hacker. There's no way to know."*

The impact of the media can also have "lasting effects on impressions, beliefs, and associated disposition" (Zillman, 1996, p. 70) which heighten the executives' awareness of security threats.

> *"I hear stories on the news or read about them in the paper…they really concern me. I remember one night on the news where people's cancelled checks showed up in gift baskets. They were shredded….but they could easily be put back together."*

When information security incidents occur in a manner that the executive is more closely associated with, a personal connection is made which further strengthens the impact of the negative exemplar (Aust & Zillmann, 1996). In this instance, the CEO has an increased affective reaction because the incident occurs in the same industry, and even more so because it is in close proximity to him.

"We always think it won't happen to us, but it still hits home when I read in the newspaper or see on TV that a bank has had a security incident…especially if it's local. If it can happen to them it can surely happen to us."

In each of these instances, the negative exemplar was an event (e.g. shredded cancelled checks showing up in gift baskets, security incidents). Only after a security breach occurs (Snowden) or when an event compromises or threatens information security (Target Department stores), identifying the perpetrator and characteristics of the individual and outgroup becomes an important consideration as part of the effort to minimize the potential for a similar incident to occur at their organization.

The possibility of such negative exemplars affects management's perceptions of the threats and influences their decisions related to avoiding breaches and maintaining information security. When managers' perceptions and expectations of the likelihood and severity of negative exemplars increase so does distrust of persons associated with such events.

The lack of information in decision making is a psychological reality and can weigh heavily on the decisions that have to be made by the Financial One executives (Gigerenzer, 2001). When

making decision, the executives will use information and experiences that are readily available. According to Selten (2001, p.212),

> *"It is useful to distinguish between familiar and unfamiliar problems of this kind. A problem is familiar if the decision maker knows the optimal way to attack it, i.e., knows what to do through prior training or mathematical investigation, or perhaps the problem is so simple that a suitable method immediately suggests itself. In the case of an unfamiliar problem, the decision maker must devise a method for finding the alternative to be chosen before it can be applied.*
> *...risky decisions are rarely based on explicit probability judgments."*

Managers are required to make nonprogrammed decisions under suboptimal conditions of environmental uncertainty such as lack of information (Simon, 1957). When making these information security decisions, the Financial One executives did not always have sufficient knowledge regarding threats to their organizational information. Managers will use all information and experiences that are readily available and will often turn to trusted advisors whose opinions they value (Siegrist & Cvetkovich, 2000). For example, when information security advice is sought, Financial One management typically turns to the Information Security Officer (ISO) or the Information Technology (IT) manager. According to the CEO of Financial One, when he becomes aware of a negative exemplars he seeks out someone more qualified to assess the organization's risk**.**

> *"I usually call [CIO] just to make sure we are protected from something like that happening to us" (CEO).*

Applied in this context, the social amplification of risk (Kasperson et al., 1988) suggests that high profile security breaches (negative exemplars such as the security information leaks that were traced to NSA contractor Edward Snowden and the theft of Target Stores' customer credit information that is believed to have been perpetrated by hackers) serve as a wake-up call, the result of which is an information security risk analysis of the threats posed by out-group members which ultimately decreases the information security risks for that organization, thus supporting hypothesis 2.

DISCUSSION

This case provides support for the two hypotheses presented in this study. Financial One executives were in agreement that their level of information security was "solid" and "above average". They relied on several different perceived factors to reach their conclusion: they had a strong information technology department with experienced IT employees, outside firms provided confirmation to them regarding their level of security, they had never experienced an information security breach, and they trusted their employees to "do the right thing".

In most cases, people want to do the right thing (Pelletier and Vallerand, 1996). Policies have been shown to be an effective in getting this result. Security policies have been identified by researchers as an

effective deterrence to security threats (Whitman, 2003; Siponen and Iivari, 2006). However policies must be followed for them to be effective. Financial One had policies regarding password security, and research has shown that the existence of password policies do decrease security risks (Zvirian, 1999; Ives et al., 2004). Financial One also had a policy regarding shredding confidential information; however even though policies exist against throwing confidential in the trash, it still happens on a regular basis (Jones, 2005).

The existence of formal security policies did not appear to be associated with security-related behavior because the policies were often unread therefore employees were unaware of their expected behavior (Frank et al., 1991). Even though the information security policies were readily available to all employees on Financial One's intranet, there was no method in place to ensure that employees were actually reading the policies, even though employees were required to sign a document claiming that they had indeed read the policies and agreed to abide by them. Effective monitoring to ensure policies are being followed is an important part of an organization's information security strategy (Straub & Welke, 1998). Financial One did not have effective monitoring in place.

If often takes a security incident to open management's eyes to threats within their organization (Dhillon & Moores, 2001). People only respond to threats they perceive (Slovic et al., 1980). Therefore Financial One executives had no reason to take additional information security precautions against insider threats since they believed their employees were following their positive exemplar behavior. They perceived that employees were acting in a manner that would not put the organization at risk. In all the instances observed in this study, employees were not intending to put the organization at risk; however their behavior was unintentionally putting the organization at risk (Taylor, 2006).

Information security is about risk assessment, so focus is placed where the threat is perceived to be the greatest (Slovic et al., 1980). The amount of resources an organization invests in information security is a factor of the risk they are willing to accept and the management's perceived probability of their exposure to security threats (Gordon & Loeb, 2002). Resources are limited and must be allocated in a manner that sufficiently addresses information security within a limited budget (Farahmand, et al., 2005); therefore Financial One executives believed they should focus their information security strategy on protecting their information from untrusted outsiders. This ethnocentric approach to their information security strategy was not based on the probabilities of information security threats at Financial One. Their strategy was developed as a result of the federal examinations and technology-based third party audits. Because of their lack of personal security experience, the executives relied on the knowledge of more trusted individuals (Siegrist & Cvetkovich, 2000), such as the auditors, examiners, and the CIO, to make security recommendations or to validate their existing information security risks. The recommendations of these individuals resulted in technology-based approach to keep out-group members from accessing their information systems.

Because of this approach, the executives failed to consider the human-based behavioral element of organization security; "…we often overlook the human solution and instead opt for technology solutions, when in fact the human factor must be addressed first, with technology assisting in the enforcement of desired human behaviors" (Whitman, 2003, p.92). The executives trusted their employees, the in-group members, would follow their exemplary behavior. However their in-group trust lead to their own security blindness resulting in increased risks to the organization's information. Therefore, Hypothesis 1 was supported.

The executives at Financial One were familiar with some negative security events (i.e. shredded checks showing up in gift baskets), primarily those reported in the media. These events served as negative exemplars that made them question the adequacy of their information security (Aust & Zillmann, 1996). The concerns were amplified when the exemplar were local or in their industry. Their concerns led them to reevaluate their current security countermeasures that were in place to prevent such attack from happening to them. This provides support for Hypothesis 2.

CONCLUSION AND IMPLICATIONS FOR FUTURE RESEARCH

Present day managers face increasingly complex, dynamic and changing conditions. The landscape has expanded from the traditional view of MIS as a company subfunction to a newer conceptualization of systems with the potential to restructure an entire organization. The broader scope, accompanied by increased complexity, explains our call for a new view of information security that considers both behavioral and technical factors.

This paper focuses on understanding how the managerial actions undertaken by organizational actors are influenced by their perceptions of risk. Specifically, we address how assessments of the threat to information security are based on attitudes about group membership. Several important areas of organization and management theory are necessary to understand and to generate conclusions about the roles of positive and negative exemplars. Managers' perceptions about threats and group membership as a factor in decisions about how to address information security needs must be considered.

Organizational behavior (group characteristics) and interpersonal processes form the backdrop for this examination of interpersonal factors that influence information security decisions within a specific context. As management information systems continue to expand, theoretical underpinnings of this investigation include models of decision-making, organizational change processes, and organizational design considerations.

This paper takes a new look at information security risks, by applying theoretical perspectives that have, in the past, been reserved for sociological studies of bias and discrimination. We have made the case that these theories can provide a new lens through which to view the level of trust that develops among members of an organizational in-group and how that relationship affects management decisions about information security.

For the academic community, this research introduces another method to study questions about managerial perceptions regarding their information security strategies. In this case, management's perceptions were filtered through a lens of simplified cognitive heuristics which resulted in inaccurate conclusions about the actual level of potential threats to organizational security. These perceptions came from an optimistic view of themselves as positive exemplars. Yeh and Chang (2007) found that a gap existed between management's perception of their information security threats and the perception of the proper countermeasures they have in place to prevents threats. Their findings show that management tends to be overoptimistic about their information security risks. Our results support their findings.

This research can be valuable to the practitioner community by increasing awareness of the inaccuracies of managerial perceptions. Ultimately, the goal of this study is to point out to management that there are factors that affect their perception of their organization's information

security risks. By understanding the problem, managers may seek better understanding of the limits of their cognitive biases and devise methods and controls to prevent the projection of their own behaviors onto their employees. Managers should continue to be positive security exemplars but they must also enforce ways to monitor their employees' behaviors to ensure they are following the managers' exemplary behavior. When employees perceive that security is a concern to management, they tend to increase the awareness of their security related behavior to be in line with that of the managers (Hoffman & Morgenson, 1999).

This research can also help organizations better understand attitudinal and behavioral issues that contribute to information security risks. The results of this investigation offer strong support for our hypotheses and make a case for a human-based approach to information security, viewing it as a social issue. As long as managers continue to focus primarily on the outside threats, organizations will remain vulnerable to threats from insiders.

Organizations should realize that technology-based actions such as monitoring of employee behavior and the implementing security countermeasures are not necessarily signs of distrust (Dhillon & Backhouse, 2000). It is the fiduciary responsibility of organizations to insure that their information is adequately protected. They surely have to take adequate measures to protect their information from out-group members who may attempt to gain unauthorized access. But they cannot stop there. They must also insure that members of their in-group are not abusing the trust relation within the organization, thus putting the organization's information at risk. This research is not suggesting that trust within organizations be decreased, because research has shown that organizations that create trusting environments are able to accomplish more than a comparable group without that trust (Coleman 2002). However, organizations can benefit from understanding how these high levels of trust can also have negative ramifications.

Das (2003) complained that managerial perception research occurs without "even a modicum of appreciation of the real-world managerial environment." This study analyzed the perceptions of real-world managers who work in a real-world organization, which may face the real-world consequences of (in)activity based on those perceptions.

Future research should continue to investigate the effect of optimism bias on exemplars. Early research has shown that managers are overly optimistic about their adequacy of their information security (Goodhue & Straub, 1991); however even though this has been understood for a long time, the problem still exists. Because of this optimism bias, knowledge about negative exemplars may not always result in reduced information security risk, especially if an optimism bias is present. For example, the recent hacking attacks on the Target Stores should have served as an eye-opener for other organizations, especially since shortly thereafter both Nordstrom's and Neiman Marcus stores were the victims of similar attacks. Where Nordstrom's and Neiman Marcus management overly optimistic about their security countermeasures that were in place to prevent the same type of attack? Gal & Chose (2005) found that there is value for everyone when security information regarding threats, systems vulnerabilities, and fixes for such system vulnerabilities are shared. Overly optimistic managers may not feel the necessity to acknowledge or act on the shared information.

Developing an information security strategy is filled with uncertainty for managers making it difficult for them to fully understand the risks involved, including their level of exposure to specific threats, and the consequences that a security breach could have on their organization

(Vonsolms, et al., 1994; March and. Shapira, 1987). This study, supported by statistics and other research (Dhillon 2001; Taylor & Brice 2012), confirms that in-group trust and out-group distrust are significant factors in information security management that should not be overlooked. Executives' perceptions of both positive and negative exemplars play a role in their information security strategy. Negative exemplars increase their awareness of potential threats, therefore resulting in precautionary actions to protect the organization's information. By seeing themselves as positive exemplars, executives develop unwarranted faith that employees will mimic their exemplary behavior. Such blind trust of insiders can potentially pose the greatest risks to the organization. By understanding these issues, organizations can learn to counteract behaviors that increase information security risks.

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MARKET AND BUREAUCRACY COSTS: THE MODERATING EFFECT OF INFORMATION TECHNOLOGY

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ABSTRACT

Transaction Cost Economics is used to explore the uses of information technology (IT) as a moderating variable in the TCE model. An assertion is made that the same dimensions of information technology affect bureaucracy and market costs differently, thus affecting the efficiency of a given strategic choice. An argument is presented for the use of IT systems, rather than individual components, to be used as a construct to study the impact of IT on strategic choice.

Key Words: Typology, Transaction Cost Economics, Efficiency

INTRODUCTION

Gathering information has been a function of managers since the days of Barnard (1938) because, as suggested by Porter (1979), the information about the environment that is available to an organization affects the efficiency of the strategy it chooses to employ. For this reason, one structural variable that is receiving a great deal of attention is information technology(IT) (Davis, 1991; Fiedler, Grover, & Teng, 1996; Radhakrishnan, Zu, & Grover, 2008; Soh, Markus, & Goh, 2006), especially as IT has become affordable for even the smallest of firms (Unknown, 2003).
One problem in the strategy-IT literature, however, is that, in most instances, only specific components of information technology are examined. For example, a review of the last few years' strategy-IT literature has shown investigations into reverse auctions(Mithas, Jones, & Mitchell, 2008), supply chain management (Jean & Sinkovics, 2008), outsourcing (Rustagi, King, & Kirsch, 2008), use of the World Wide Web (Bemslimane, Plaisent, & Bernard, 2005), knowledge management (McGill, 2007) and interorganizational systems (Han, Kauffman, & Nault, 2008). Very few (e.g., Radhakrishnan, Zu, & Grover, 2008) deal with complete IT systems and their uses.

Strategy researchers disagree which is the most appropriate theoretical paradigm to use to explain business performance (e.g. Kristensen & Lojacono, 2002; Williamson, 2008; Doty, Glick, & Huber, 1993; Tiwana & Bush, 2007), thus another problem that arises in the literature is that many different theories are proposed to explain the impact of IT systems on strategy and vice-versa. These include such varied themes as Miles and Snow's (1978) organizational taxonomy (Karimi, Gupta, & Somers, The Congruence between a Firm's Competitive Strategy and

Information Technology Leader's Rank and Role, 1996), Hambrick and Mason's (1984) upper echelon theory (Leonard & Dooley, 2007), social embeddedness (Chatfield & Yetton, 2000), transaction cost economics (Brynjolfsson, Malone, Gurbaxani, & Kambil, 1994; Jean & Sinkovics, 2008), trust (Rustagi, King, & Kirsch, 2008), resource based view (Radhakrishnan, Zu, & Grover, 2008), and punctuated equilibrium (Lassila & Brancheau, 1999) to name but a few.

However, there does appear to be a common theme in much of the IT literature: efficiency. Efficiency is either directly discussed or implied in much of the IT material, regardless of the theoretical approach taken. Considering that transaction cost economics has efficiency as its underlying foundation (Williamson, Markets and Hierarchies: Analysis and Antitrust Implications, 1975), it would make sense that TCE could be used to explain and predict the relationship between information technology and strategic choice.

THEORY & PROPOSITIONS

The strategy a firm adopts, according to transaction cost economics, depends upon the costs associated with that strategy. In cases where the chosen strategy of the firm does not provide the optimum available reduction of transaction costs (i.e., efficiency), performance suffers. Thus, when the costs of transacting in the market are high or the market fails, transactions will be brought "in-house" and a hierarchical governance mechanism will be used. Conversely, when the costs of transacting in the market are low, a market system will be chosen. However, the strategy of the firm leads to high performance only when the structure that the firm adopts optimizes the transaction costs associated with the chosen strategy (Williamson, Markets and Hierarchies: Analysis and Antitrust Implications, 1975). TCE, therefore, follows the accepted model of strategy – structure – performance (e.g., Williamson, 1975; Porter, 1980; Miles & Snow, 1978; Abernethy & Lillis, 2001; Jones & Hill, 1988).

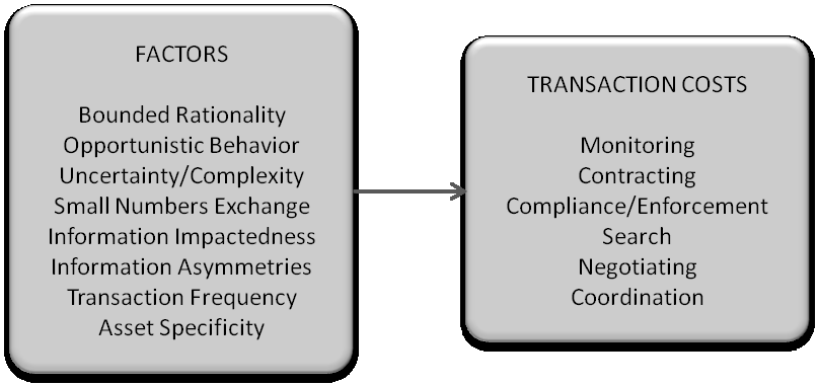
Gurbaxani and Whang (1991) have suggested that all transaction costs result in one way or another from lack of information. Thus, information technology, with its ability to increase communication within or between firms (Davis, 1991; Jean & Sinkovics, 2008; Rustagi, King, & Kirsch, 2008), information availability with respect to internal operations, competitors, buyers or suppliers (Clemens, Reddi, & Row, 1993; Bemslimane, Plaisent, & Bernard, 2005; McGill, 2007), and coordination and monitoring capabilities (Gurbaxani & Whang, 1991; Bemslimane, Plaisent, & Bernard, 2005) becomes an important factor with respect to reducing transaction costs.

TRANSACTION COST ECONOMICS

Transaction cost economics posits there are costs associated with any transaction that takes place. Costs are created through the interaction of bounded rationality or opportunistic behavior and uncertainty/complexity or small numbers exchange (Williamson, Markets and Hierarchies:

Analysis and Antitrust Implications, 1975). The resulting monitoring, contracting, compliance and enforcement, negotiating, coordinating, and search costs may be exacerbated by the presence of information impactedness, transaction frequency, and asset specificity (Jones & Hill, Transaction Cost Analysis of Strategy-Structure Choice, 1988; Williamson, Markets and Hierarchies: Analysis and Antitrust Implications, 1975) as shown in the figure below.

Figure 1: Sources of Transaction Costs

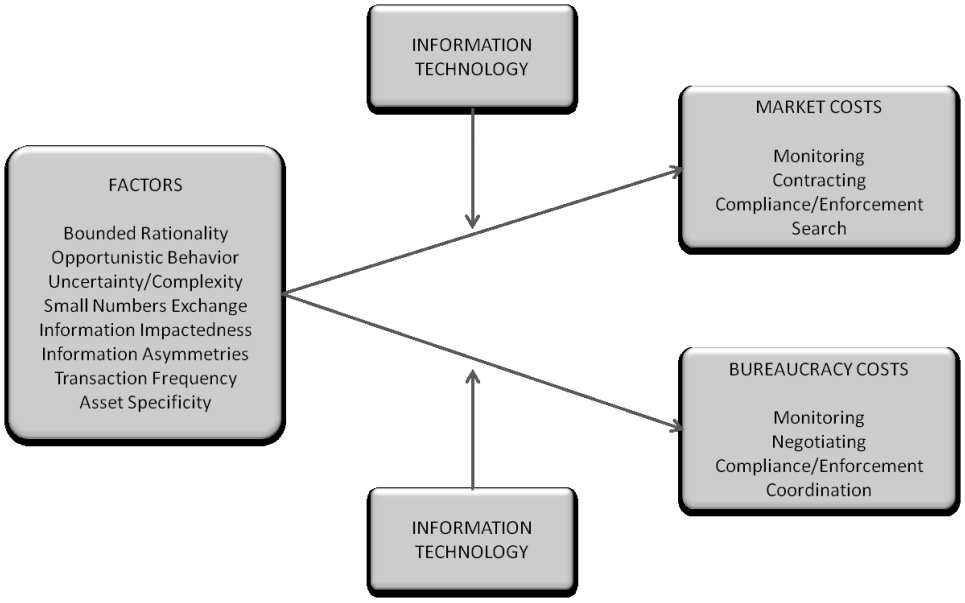


Information technology can mitigate the factors that cause transaction costs by providing strategic support (Leonard & Dooley, 2007), communication (Chan & Davis, 2000; Dennis & Tyran, 1997), and decision support and knowledge management (Chen, 1995; Hackbarth & Grover, 1999). These three broad areas encompass the major uses of IT systems, although each has sub-levels. For example, strategic support includes such matters as environmental monitoring (Leonard & Dooley, 2007) and business-to-business integration (Iacovou & Benbasat, 1995; Radding, 2000); communication encompasses group communication (Dennis, Pootheri, & Natarajan, 1998; Nunamaker & Briggs, 1996), person-to-person or person-to-group communication (Barua, Ravindran, & Whinston, 1997), or business-to-business communication (Townsend, DeMarie, & Hendrickson, 1998), while knowledge management and decision support subsumes the sphere of expert systems (Jenks & Wilson, 1999), artificial intelligence (Quereshi, Shim, & Siegel, 1998), executive information systems (Lam & Ching, 1998), and group decision support systems (Townsend, DeMarie, & Hendrickson, 1998).

While organizations may use an IT system to decrease transaction costs in general (through communication, thereby reducing information impactedness or business-to-business integration to reduce complexity and the risk of opportunistic behavior), transaction costs may be separated into two distinct types: market costs (i.e., costs associated with doing business with trading partners outside the firm) or bureaucracy costs (i.e., costs associated with the use of a hierarchical form of governance – transacting within the firm) (D'Aveni & Ravenscraft, 1994; Hill & Hoskisson, 1987; Jones & Hill, Transaction Cost Analysis of Strategy-Structure Choice, 1988). Information systems, like transaction costs, focus on either the internal aspects of the firm or the external market forces (Dennis, Pootheri, & Natarajan, 1998; Fiedler, Grover, & Teng, 1996; Keen, 1991; Senn, 2000).

Thus, it becomes advantageous to examine the relationships at the internal (bureaucracy) or external (market) efficiency level as indicated in the figure below.

Figure 2: Moderating Effects of IT on Specific Transaction Costs



MARKET COSTS. In essence, market costs are created by the need to search for trading partners and contracting, monitoring, and enforcing compliance with contracts that take place outside of the firm's boundaries. Transaction costs are created when opportunistic behavior exists or bounded rationality is evident in association with complexity or small numbers exchange (Williamson, 1975; 1991). Information impactedness, transaction frequency, asymmetries, and asset specificity increase the costs already present under such conditions (Jones & Hill, Transaction Cost Analysis of Strategy-Structure Choice, 1988; Williamson, 1975; Williamson, 1991).

Transaction cost economics assumes that information impactedness exists: that information is not equally available to both parties in a transaction because it is not shared (or sharable) or that the costs of obtaining needed information is prohibitively costly (Williamson, 1975). Thus, in situations where information impactedness is combined with complexity or opportunistic behavior, transaction costs increase as the need for monitoring and contracting escalate. As complexity or opportunistic behavior intensifies and the disparity between partners' information increases, the need for the deficient partner to monitor the behavior of the partner with more complete information in order to protect its own interests also increases (Williamson, 1991). Additionally, contracts must be more complex in order to counteract the effects of the information asymmetry in such situations (Williamson, 1975). Sherry and Teece (2004), in their case study of

a petroleum industry contract, supported the relationship between decreased information impactedness and reduced transaction costs.

An increase in contracting, search, and monitoring costs may also be brought about when transaction frequency is present in conjunction with complexity and bounded rationality (D'Aveni & Ravenscraft, 1994; Reeves, 2008; Williamson, 1975; Williamson & Ouchi, 1981). The less often firms interact, the more the partners must rely on contractual safeguards and extensive monitoring to protect their interests. On the other hand, repeated transactions may lead to trust and commitment, which can be used as a reputational safeguard, and, thus, the need for complex contracts and monitoring is reduced. Search costs may also be reduced through trust as firms that have had previous interactions become confident in the trading partner's ability to provide the goods or services needed, thereby reducing the search for other suitable partners (Chiles & McMackin, 1996; Mithas, Jones, & Mitchell, 2008). Dyer's (1997) automobile manufacturer study supported the hypothesis that when repeated transactions are present transaction costs are lowered, as did Gulati's (1995) investigation of 2,400 American, European, and Japanese alliances.

When found in combination with small numbers exchange, bounded rationality may cause one partner in the exchange to feel it is held hostage by the other due to its inability to find other trading partners (Bensaou & Venkatraman, 1995), which, in turn, may lead to problems with contracting and compliance enforcement. The addition of asset specificity may cause bilateral dependency, thus increasing the costs of contracting, monitoring, and enforcement (Kogut, 1988; Menard, 1986).

A few of the numerous ways that information technology may assist in reducing search, compliance/enforcement, monitoring, and contracting costs are communication and data sharing (Clemens, Reddi, & Row, 1993), providing information that was otherwise unavailable (Hackbarth & Grover, 1999), making available advanced analysis tools (Chen, 1995), and offering new possible trading partners (Mithas, Jones, & Mitchell, 2008).

An IT system may increase information flows between contracting parties, through communication, data, and application sharing (Clemens, Reddi, & Row, 1993; Fiedler, Grover, & Teng, 1996). The use of such technology as decision rooms, distribution lists, bulletin boards, chat sites, computer-conferencing, project rooms, video conferencing, email, and voice mail (Barua, Ravindran, & Whinston, 1997; Raisinghani, Ramarupa, & Simkin, 1998) makes communications between and among group members nearly as simple and cost effective as communicating with only one person or in face-to-face settings (Raisinghani, Ramarupa, & Simkin, 1998). Faster processing speeds and communication links reduce the amount of time between the event and the time information is available (Keen, 1991). The resulting increase in communication and information sharing decreases uncertainty and information impactedness between the organization and its trading partners.

Interfirm communication may be used to increase the transaction frequency between the contracting parties, thereby reducing market costs. Transaction frequency, in conjunction with uncertainty, bounded rationality or information impactedness, can increase the amount of

monitoring that may be required (D'Aveni & Ravenscraft, 1994; Williamson, 1975; Williamson & Ouchi, 1981; Truman, 2000) as infrequent transactions keep a firm from acquiring information about subsequent transaction performance (Jones, 1987). Keen (1991) has suggested that the biggest gains to be made from IT are through managing documents electronically and fast, clear, and natural communications.

Planning and decision-making based market costs are associated with monitoring, enforcement, negotiation, and search costs (Williamson, 1975), which are caused by bounded rationality, information impactedness, and uncertainty in combination with small numbers exchange, transaction frequency, the possibility of opportunistic behavior, and asset specificity (Baysinger & Hoskisson, 1989; D'Aveni & Ravenscraft, 1994; Jones, 1987; Vanderbosch & Huff, 1997).

Decision support and knowledge management include the ability to capture information from sources external to the organization as well as the ability to create new knowledge from novel interpretations of both existing knowledge and new data (Hackbarth & Grover, 1999). By providing increased access to information, sophisticated analysis tools, the ability to draw on multiple experts, and interaction that allows for communication and decision support that is not required to take place in a face-to-face setting (Chen, 1995; Gurbaxani & Whang, 1991), an IT system reduces uncertainty, bounded rationality, and information impactedness (Bakos & Treacy, Information Technology and Corporate Strategy: A Research Perspective, 1986; Hackbarth & Grover, 1999). The ability to use external information that may not have been previously available also reduces bounded rationality (Gurbaxani & Whang, 1991). Furthermore, interorganizationally integrated information allows for better decision-making, as information impactedness is reduced (Goodhue, Wybo, & Kirsch, 1992).

Executive decision support systems, which include communication, organization, access, and analysis tool components (Chen, 1995), offer timely and convenient access to data from all levels of the organization as well as information from trading partners and other external sources (van den Hoven, 1995). However, because information is readily and cheaply available, managers may quickly suffer from information overload, therefore access to information is not enough; analysis tools play a large part in efficient IT information systems (Chen, 1995; Lam & Ching, 1998). Access to and ability to process external information quickly through a user-friendly interface allow managers to reduce uncertainty in a volatile environment (Bakos & Treacy, Information Technology and Corporate Strategy: A Research Perspective, 1986; Chen, 1995).

The use of IT has allowed for the employment of new and specialized interorganizational group support systems (Dennis, Pootheri, & Natarajan, 1998) that boast sophisticated decision support applications (Turrof & Hiltz, 1993). Group support systems allow for a larger number of participants than do traditional face-to-face meetings (Raisinghani, Ramarupa, & Simkin, 1998), resulting in a wider range of expertise and knowledge bases (Hambrick & Mason, 1984; Nunamaker & Briggs, 1996) and interorganizational information sharing (Gurbaxani & Whang, 1991). Anonymity is often built into group support systems, thus permitting participants to provide

information that might not otherwise be made available to the group due to politics, position, or personality (Dennis & Tyran, 1997; Nunamaker & Briggs, 1996). Increases in participants and participation also allows for wider diversity in the expertise upon which the group has to draw (Hambrick & Mason, 1984; Nunamaker & Briggs, 1996). The use of a group support system, then, reduces bounded rationality and information impactedness.

Another advantage provided by the use of information technology is that decisions and communications are maintained in computer memory, thus aiding in future decisions or continued deliberation of current decisions (Raisinghani, Ramarupa, & Simkin, 1998). Additionally, as managers are traditionally very busy, this memory allows a manager to continue a task after interruption with a minimum of restart time (Dennis & Tyran, 1997). Together these features provide for reduced uncertainty and information impactedness.

Knowledge management systems permit cost-effect access and analysis of internal and external information thereby reducing market costs related to contracting, since they reduce uncertainty and information impactedness through data and application sharing and mutual monitoring (Gurbaxani & Whang, 1991). Archived information, maintained by knowledge management systems, is readily accessible, and may provide insight into prior decisions, thereby making contract negotiations more efficient (Hackbarth & Grover, 1999) than they may otherwise have been.

Additionally, knowledge management systems that are interorganizational in nature allow for the firms involved to take advantage of synergies between the organizations and may allow a firm to either gain bargaining power over trading partners, or at a minimum, reduce the threat that trading partners may gain power over the firm (Bakos & Treacy, Information Technology and Corporate Strategy: A Research Perspective, 1986). Knowledge management, through data mining, allows managers' access to information that may have been hitherto unwanted, unneeded, or unavailable. This data access, in turn, gives managers the ability to draw on data stores for unique opportunities that previously went undetected (Lam & Ching, 1998).

Artificial intelligence and expert systems, which have recently become sophisticated enough to assist with decisions that had only been in the purview of human reasoning, can be a strong asset with respect to strategic planning and decision-making as these are neither straightforward nor simple (Gurbaxani & Whang, 1991; Hitt & Brynjolfsson, 1994). Expert systems rely on programmed sets of "if-then" statements that do not change over time unless specifically reprogrammed (Quereshi, Shim, & Siegel, 1998). Thus, one of the biggest advantages of the use of an expert system is consistency (Jenks & Wilson, 1999), which, in turn, reduces uncertainty.

Bounded rationality, opportunistic behavior, and asset specificity are associated with the market costs of searching for trading partners (Bakos, 1991; Clemons & Row, 1992; Gurbaxani & Whang, 1991) that arise because the organization cannot know everything it needs to know about possible trading partners and their subsequent behavior (Williamson, 1975). Additionally, one partner may feel it is held "hostage" by the other due to its inability to find other trading partners

(Bensaou & Venkatraman, 1995). Adding asset specificity into the equation may cause what Menard (1986, p. 286) calls "bilateral dependency," where the costs of switching trading partners becomes very high for both partners and thus the costs of searching, negotiating, monitoring, and enforcement may well increase.

A firm may reduce the cost of searching for new partners using the Internet and World Wide Web (Clasen & Mueller, 2006). Electronic market places and reverse auctions allow buyers and sellers to investigate suitable trading partners, have access to large amounts of product and pricing data, and find possible partners that may not have been available without the use of technology (Bakos, 1991; Benslimane, Plaisent, & Bernard, 2005; Clasen & Mueller, 2006; Mithas, Jones, & Mitchell, 2008). Nearly instant access to vast amounts of information about potential partners and their offerings reduces the impact of bounded rationality and may offset some of the effect of small numbers exchange, as information about possible (but previously unknown) partners who may not have been known before become available (Clasen & Mueller, 2006; Bakos, 1991). Additionally, the increased availability of possible partners may mitigate the influence of asset specificity as the chances that a new partner may have the needed assets available may be found (Mithas, Jones, & Mitchell, 2008).

The ability to leverage current resources and capabilities externally (Venkatraman, 1997) and to support current strategies (Broadbent & Weill, 1997) while reducing market costs is of prime importance to an efficient IT system (Malone, Yates, & Benjamin, 1987) as indicated by the model shown in **Error! Reference source not found.** above. The above line of reasoning leads to the following supposition:

P1 *Firms using IT systems that emphasize external communication, coordination, and decision-making will have lower market costs than those that do not.*

BUREAUCRACY COSTS. In order to reduce market costs, a firm may choose to change to a hierarchy (Williamson, 1985). However, the move from market governance does not indicate that all transaction costs are eliminated; hierarchical governance incurs its own transaction costs. As Jones and Hill (1988) state: "transaction costs do not simply disappear when firms choose hierarchy over the market" (p. 163). Chandler (Scale, Scope, and Organizational Capabilities, 1988) defined transaction costs as "the cost of transfer of goods or services from one operating unit to another" (p. 475). This definition implies that such costs may be incurred with either market governance or hierarchical governance.

The hierarchical governance costs of enforcement, coordination, monitoring, and negotiation are increased by a move to an internal market. Such operating costs are referred to by Williamson (1975) as "bureaucracy costs." These bureaucracy costs are, in essence, transaction costs that are incurred internally within the firm, and may be attributed to the same basic assumptions as traditional transaction costs (Jones & Hill, 1988). While bureaucracy costs do not, obviously, include contracting or search costs, they do include some elements of both: coordination and negotiation.

Internally, the same problems that create market costs create bureaucracy costs. Opportunistic behavior on the part of agents within the firm takes the place of opportunistic behavior on the part of trading partners in the market whenever control is delegated. Thus, the same types of control problems experienced in the market are present internally, thereby increasing monitoring costs (Jones, 1987).

Information impactedness, when the information deficiency favors the agent, can also create monitoring and coordination costs (Abrahamson & Park, 1994). Often, these asymmetries exist because the information is costly for principals to obtain or principals simply do not have access to the same information as the agent (Eisenhardt, 1989). As Munter and Kren's (1995) study of *Fortune 500* firms indicate, when information is too costly to obtain, a monitoring system will be employed. Bureaucracy costs are also increased by a higher need for monitoring when the tasks of the agent are not standardized or are complicated. This deduction is supported by Welbourne, Balkin, and Gomez-Mejia's (1995) study of 221 employees in two firms, which indicated that monitoring costs increase with complexity, as does Kulkarni and Fiet's (2007) study of 139 firms during the peak of restructuring.

When an agent's position is hard to fill because it requires special skills that are not readily available, small numbers exchange and asset specificity may become issues within the hierarchy as they lead to negotiation and enforcement costs (D'Aveni & Ravenscraft, 1994; Welbourne, Balkin, & Gomez-Mejia, 1995).

As the previous argument shows, the firm itself (as far as transactions between divisions are concerned) may be treated as an internal market with all the costs and benefits associated with market governance.

Knowing what information is available, who needs it, how is can be accessed and used is an essential determinant in the effective use of IT systems (Hackbarth & Grover, 1999). IT reduces the costs of coordination, monitoring, negotiation, and enforcement costs (Brynjolfsson, Malone, Gurbaxani, & Kambil, 1994; D'Aveni & Ravenscraft, 1994) by lowering the cost of information sharing and communication and provides faster processing speeds, less expensive information gathering, and improved tools for analysis and management decision-making (Fiedler, Grover, & Teng, 1996; Gurbaxani & Whang, 1991). Electronic communication, the handling of complex information systems, the use of sophisticated production scheduling techniques, and increased and complex resource sharing (Fiedler, Grover, & Teng, 1996; Gurbaxani & Whang, 1991; Jones & Hill, 1988) also reduce transaction costs. The ability to view information at individual levels as well as departmental or divisional levels, data and application sharing, and the use of other tools such as hand-held computers, optical scanners, and electronic communication reduces monitoring costs (Fiedler, Grover, & Teng, 1996; Gurbaxani & Whang, 1991). The use of Internet technologies such as blogs and job sites reduce negotiation costs, as do knowledge management systems (Caroli, 2007; Hoffman, 2008).

IT systems reduce internal costs by providing information to management regarding the various operations of the organization and providing standardized reports at the transaction level

as well as the department level (Radhakrishnan, Zu, & Grover, 2008; Gurbaxani & Whang, 1991; D'Aveni & Ravenscraft, 1994) that may have been too costly to compile otherwise (Munter & Kren, 1995; Mitra & Chaya, 1996). As Gurbaxani and Whang (1991) point out, the accessibility of inexpensive monitoring is critical to reducing bureaucracy costs: "Information systems contribute to this end by providing an effective tool to monitor agents' actions directly and by keeping track of the performance records of an agent or a functional unit in a firm" (p. 67).

Internal communication systems between departments reduce coordination costs associated with task specialization (D'Aveni & Ravenscraft, 1994; Caroli, 2007) and complexity (Welbourne, Balkin, & Gomez-Mejia, 1995). Electronic communication, unlike personal communication, allows messages to stay in memory (Raisinghani, Ramarupa, & Simkin, 1998) permitting the user to reference saved information, thus reducing uncertainty and increasing efficiency (Barua, Ravindran, & Whinston, 1997). Thus, complexity is reduced as users may effortlessly and repeatedly refer to information that may be complicated, which is not the case with face-to-face communication (Raisinghani, Ramarupa, & Simkin, 1998). Communication within the firm reduces asset specificity (particularly specialized knowledge), information asymmetry, and uncertainty between departments, managers, and employees by providing fast and easy access to disparate and standardized information (Fiedler, Grover, & Teng, 1996; Caroli, 2007).

An IT system also reduces bureaucracy costs through information and resource sharing (Broadbent & Weill, 1997; Goodhue, Quillard, & Rockart, 1988; Galbraith, 1973). Information at the transaction level may be analyzed and quantified, thus reducing information impactedness, asset specificity, and performance ambiguity, thus costs associated with functional specialization and task complexity can be reduced (D'Aveni & Ravenscraft, 1994; Welbourne, Balkin, & Gomez-Mejia, 1995; Daft & Lengel, 1986). Goodhue, Wybo, and Kirsch (1992) suggest that uncertainty caused by task specialization may be reduced through firm-wide integration because "mandatory data integration might reduce the flexibility of an individual subunit to redesign its information systems to address its unique needs." (p. 298).

Data integration allows for all levels of the organization to have a common information base (Bhatt, 2001; 2000) thereby reducing ambiguity and confusion. The result is lowered information impactedness and bounded rationality because information is shared across the organization (Goodhue, Wybo, & Kirsch, 1992) and personnel with different backgrounds bring varied knowledge and experience bases to the decision-making process (Hambrick & Mason, 1984). Information impactedness and bounded rationality create monitoring costs because the manager's ability to assemble, organize, and understand information about divisional performance is limited (Baysinger & Hoskisson, 1989). As the interaction between task uncertainty and information impactedness becomes more pronounced coordination costs increase (D'Aveni & Ravenscraft, 1994). As the need for information increases, the interaction of performance ambiguity and task uncertainty requires more complex internal governance structures (Jones, 1987). Thus, the combination of uncertainty, information impactedness, and coordination create costs associated with strategic decision-making and planning; if the manager does not have the

information to make decisions, or the ability to coordinate internal divisions, planning and decision-making become difficult.

Integration of data provides reduced uncertainty as Goodhue et al (1992) have so aptly stated:

Where uncertainty comes mainly from interdependence between subunits (for example, when the two manufacturing subunits must deal with the procurement unit to purchase material), data integration would be highly desirable because it provides a standardized, formalized language shared by all subunits and facilitates communication between the interdependent subunits.

An IT system uses superior information processing abilities to create "informational economies of scale" (Gurbaxani & Whang, 1991), and perpetuates the reduction in bureaucracy costs by reducing both bounded rationality (Bakos & Treacy, Information Technology and Corporate Strategy: A Research Perspective, 1986) and information impactedness (D'Aveni & Ravenscraft, 1994).

Information may be gathered and evaluated at all levels of the organization allowing for reductions in bounded rationality associated with decision-making (Radhakrishnan, Zu, & Grover, 2008; Williamson, 1991). "Information technology can directly affect the computational and communication abilities of a decision-maker, thus shifting the limits of rationality"(Bakos & Treacy, Information Technology and Corporate Strategy: A Research Perspective, 1986, p. 109), which occurs because additional information is available to the decision-maker, thus allowing him or her to increase the knowledge base upon which decisions are made (Williamson, 1991). Therefore, knowledge management that allows the free flow of information and data increases efficiency and effectiveness of decision-making (Hackbarth & Grover, 1999).

Information technology reduces information asymmetries and bounded rationality of group decision-making as well (Bakos & Treacy, Information Technology and Corporate Strategy: A Research Perspective, 1986). Members of a group can provide more information and differing perspectives than are available to a single individual (Hambrick & Mason, 1984). In support, Turrof and Hiltz (1993), in their five case studies, found that the use of distributed group support systems improved the quality of the decisions, sped the processes, and increased the amount of information available to the decision-makers. The effect is greatly enhanced when data warehousing components are added to the DSS system (Park, 2006).

In addition to using monitoring systems, the use of such technologies as the World Wide Web can reduce the asset specificity associated with negotiation costs. Job sites and telecommuting systems decrease asset specificity by providing a larger potential employee pool than may otherwise have been available (Unknown, Survey Suggests Internet Job Boards an Important Employment Resource, 2008; Hoffman, 2008; Radhakrishnan, Zu, & Grover, 2008), while blogs and social networks provide more well qualified applicants (Hoffman, 2008). Knowledge management and codification can also be used to reduce asset specificity as the need for individuals with specialized expertise is reduced (Caroli, 2007).

Thus, as indicated in **Error! Reference source not found.** above, the following proposal is offered:

P2 Firms using IT systems that emphasize internal communication, coordination, and decision-making will have lower bureaucracy costs than those that do not.

DISCUSSION

Information technology has become an important structural variable over the last decade. Unfortunately, no predominant theoretical platform has emerged in the IT or strategic management fields to explain the overall impact information technology has on strategic choice. However, as efficiency appears to be common theme in most IT literature, an argument can be made that transaction cost economics would serve as an appropriate approach.

Additionally, most research in the strategy–information technology field consists of single IT construct or component investigations. The use of transaction cost economics allows for the examination of IT systems as a whole in the strategy – structure – performance relationship.

By distinguishing between internal (i.e., bureaucracy) and external (i.e., market) transaction costs, specific proposals can be made about how IT can be used to reduce the underlying causes of each.

FUTURE RESEARCH

The investigation of information technology as a structural variable is a relatively new one. Much work needs to be done in the IT and strategy fields in order to test a robust model of strategy – IT systems – performance. The purpose of this paper was to propose a theoretical approach that allows complete IT systems to be used in an investigation of the relationship of information technology and strategic choice, rather than single component constructs.

The next logical phase would be to test empirically the propositions proposed. However, no framework, taxonomy, or typology currently exists that easily allows for a measurable IT construct. Thus, future work in this area must first consist of creating such a classification scheme.

If a classification structure were to prove feasible, the next step would be to test the entire strategy – IT systems – performance model. Williamson (1975) proposes that the strategy a firm adopts (i.e., diversification, vertical integration) will not result in high performance unless the firm embraces structures that optimize the transaction costs associated with that strategy. Strategy and IT literature have indicated that IT systems and the information and use of information are important structural variables (Davis, 1991; Dyer, 1997; Fiedler, Grover, & Teng, 1996). This study, provided a comprehensive typology is available, would allow more encompassing studies that are based on an IT construct than can currently be conducted.

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ASSOCIATION OF CLINICAL DECISION SUPPORT SYSTEMS ON PROCESS OF CARE MEASURES AND QUALITY OUTCOMES FOR PATIENTS WITH HEART FAILURE

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ABSTRACT

Using Donabedian's conceptual framework of structure, process, and outcome, this study explores the relationship between the adoption of a clinical decision support system (CDSS), four heart failure treatment process measures and two heart failure outcome measures. Multivariate regression analysis estimated the association between four heart failure process measures adherence and health outcomes by CDSS adoption level. Hospitals with full CDSS adoption were shown to have significantly higher achievement rates than hospitals with no CDSS adoption after controlling for hospital level and environmental factors. There was a statistically significant difference between CDSS adoption level and readmission rates, after controlling for geographic location. The findings from this study suggest that full CDSS adoption may lead to a more consistent care delivery process and that clinical reminders may be purposeful for non-clinically related care.

Keywords: health information technology; electronic medical record; electronic health record; clinical decision support systems; heart failure; quality; process measures

INTRODUCTION

Healthcare organizations are currently faced with the challenge of identifying, adopting, and integrating electronic health records (EHRs) that facilitate the delivery of high-quality care. In 2009, the Health Information and Technology for Economic and Clinical Health (HITECH) Act was signed into law. HITECH provided $19.2 billion to stimulate the adoption of health information technology with the goal of near-universal adoption of EHRs (*American Recovery and Reinvestment Act of 2009*, 2009). HITECH also created incentive payments and meaningful use criteria to standardize EHR systems. The core components of meaningful use require organizations to not only adopt an EHR, but also integrate clinical decision support tools into the EHR infrastructure.

Many organizations are meeting the meaningful use criteria by adopting clinical decision support systems (CDSSs). CDSSs are healthcare information technologies (HITs) designed to support patient care through an EHR record that provides clinical guidelines and clinical

reminders. Chassin & Loeb (2011) found the delivery of healthcare is improved by providing physicians ready access to a distillation of evidence in the form of the specific recommendations contained in clinical guidelines. Using a CDSS to integrate guidelines and reminders into an EHR assures physicians have access to evidence-based guidelines at the time of care delivery. Thus, CDSSs promote the delivery of evidence-based care, which should lead to improved clinical outcomes.

The ability of CDSS to influence the delivery of evidence-based patient care and (presumed) resulting outcomes is of interest to policy makers and providers. Avedis Donabedian proposed a now well-known conceptual framework for the effective delivery of healthcare (Donabedian, 1988). His framework suggests appropriate healthcare structures lead to reliable delivery processes resulting in desired outcomes. Applying Donabedian's framework to the HITECH initiative implies the integration of CDSSs (structures) will facilitate the delivery of evidenced-based clinical care (processes) thereby improving patient results (outcomes). This research seeks to understand the relationship between the adoption of CDSSs, the delivery of care process measures and defined outcomes for patients with heart failure. The four heart failure process measures and two outcome measures selected are the ones reported by the Center for Medicare and Medicaid Services (CMS) in the Hospital Compare dataset.

ADOPTION AND IMPACT OF CLINICAL DECISION SUPPORT SYSTEMS

The adoption of EHRs has been well studied and documented, showing that current EHR adoption rates are steadily climbing (Jha, et al., 2010). Despite the increasing adoption, there is tremendous variability in the magnitude of adoption. Studies report 'basic' adoption rates as low as 13 percent for ambulatory physician offices and as high as 62 percent for hospital-based ambulatory surgery centers (Hing, et al., 2010). Jha et al., (2010) reported 12 percent of hospitals had at least a basic EHR system, yet only two percent of hospitals had CDSSs that would qualify for Meaningful Use Stage 1 criteria. Basic EHR adoption requires the EHR system to have at least a basic set of functions including clinician notes. For the purpose of our study, basic adoption means that hospitals reported that their system was fully implemented in at least one unit, while full adoption meant that the hospital reported that their system was fully implemented across all units.

Adoption of EHRs and CDSSs has been recommended as a means to lower health care costs, promote patient safety, and improve processes and outcomes (Bates & Bitton, 2010; Chaudhry et al., 2006; Shekelle, et al., 2006). Recent findings show that independent physician practices with EHRs had approximately a $50,000 higher profit than their non-EHR adopting counterparts (Medical Group Management Association, 2010). CDSSs may lower costs by identifying harmful drug reactions, possible allergic reactions and by helping physicians to manage patients with complex chronic conditions (Hillestad et al., 2005). CDSSs also improve patient safety through the coordination of patient care actions, flagging errors, and providing evidence-based medicine (Bates et al., 2001; Bates & Gawande, 2003; Kupersmith et al., 2007).

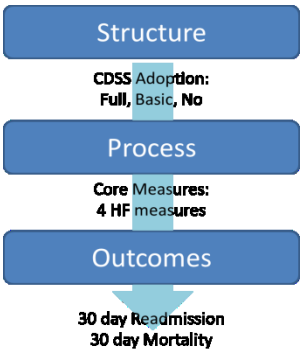
With respect to improvements in processes and outcomes, the literature on CDSSs is indecisive (Asch et al., 2004; Jones et al., 2010; Kazley & Ozcan, 2008; Kazley & Diana, 2011). A national cohort study (Jones, et al., 2010) showed that the availability of a basic EHR was

associated with significant increases in processes/outcomes for heart failure; however, the adoption of an advanced EHR was associated with significant decreases in processes/ outcomes for heart failure. One plausible explanation for the varied findings is due to the diversity of EHR technical capabilities. EHRs which exist within CDSSs provide technical capabilities that standardize decision making through computerized algorithms that remind, alert, and give evidence-based medicine to the provider (Morris, 2002). Institutions with EHRs which exist within CDSSs are better able to assure clinical practice guideline adherence because CDSSs recommend certain medically relevant tests, flag warning signs from blood tests and other abnormal results, and provide patient-centered medicine (Leibovici et al. 1997; Sepucha et al., 2004; Sintchenko et al. 2005). Adherence to clinical guidelines decreased mortality, reduced length of stay, and lowered costs (Dean et al., 2001; Marciniak et al., 1998; Peterson et al., 2006; Santos et al., 2004).

RESEARCH QUESTIONS

The effect of CDSS adoption with guidelines and reminders, on the care delivery process and (presumed) resulting outcomes is not well understood. This research adds to the existing literature by furthering the body of knowledge on the relationship between a fully integrated CDSS structure, treatment processes and outcome measures. Using Donabedian's conceptual framework of structure, process, and outcome, this study explores the relationship between the adoption of CDSSs, four heart failure treatment process measures and two heart failure outcome measures. Donabedian's framework suggests the integration of CDSS 'structures' should facilitate the 'process' of delivering evidence-based clinical care, which should result in improved 'outcomes' for patients with heart failure. This research seeks to understand the effect of adopting a CDSS (structure) on the delivery of evidence-based care (process) and the 30-day mortality and readmission rate (outcomes) for heart failure (Figure 1).

Figure 1: The Impact of a CDSS Structure on Process Measures and Outcomes



Research Question 1: Does the adoption of a CDSS (Structure) impact the delivery of care (Process) measures for heart failure?

Research Question 2: Does the adoption of a CDSS (Structure) impact the 30-day mortality and 30-day readmission rates (Outcomes) for heart failure?

METHODS

The Donabedian model (Donabedian, 2005) is used to examine the impact of a CDSS on the process of delivering evidence-based clinical care and the resulting outcomes. For the purposes of this study, a CDSS was considered a structural element within the Donabedian "structure – process – outcome" paradigm, heart failure delivery of care measures were considered 'processes' and the 30-day mortality and readmission rates were considered 'outcomes'. The Andersen Behavioral Model Andersen (Andersen, 2008) is a multi-level model that incorporates both individual and contextual determinants of health service use. It divides the major components of contextual characteristics in the same way that individual characteristics have been divided. For example, contextual factors predisposing individuals to use health services include demographic and social composition of communities, while enabling factors such as financial and organizational factors that enable the utilization of financial services could include mode of travel and wait time for healthcare.

STUDY DATA

The 2011 American Hospital Association (AHA) EHR Adoption survey (3,615 hospitals), based on data from FY2009, was used to obtain specific information regarding hospital-level CDSS adoption. Hospital performance on the heart failure process and outcome measures was obtained from the Hospital Compare dataset from the Center for Medicare and Medicaid Services (CMS) for the same 2009 time period. (Only hospitals that reported at least one heart failure process measure were considered in this research.) There are four heart failure process of care measures reported by CMS on Hospital Compare and two outcome measures (Table 1). Merging the two data sets (AHA EHR Adoption and Hospital Compare) resulted in a study population of 2,335 hospitals.

Table 1: CMS Process and Outcome Measures for Heart Failure

Process Measures	
HF1	Discharge Instructions
HF2	Evaluation of Left Ventricular Systolic (LVS) Function
HF3	Angiotensin Converting Enzyme Inhibitor (ACEI) or angiotensin Receptor Blockers (ARB) for Left Ventricular Systolic Dysfunction (LVSD)
HF4	Adult Smoking Cessation Advice/Counseling
Outcome Measures	
Mortality	30-day risk-standardized mortality rate for heart failure patients
Readmits	30-day risk-standardized readmission rate for heart failure patients

STUDY VARIABLES

The dependent variables for this study include the four heart failure process measures, a composite score variable for these four measures, the 30-day mortality rate and 30-day readmission rate. The composite variable is based on the four heart failure process measures, and was calculated

using the opportunity method developed by the Hospital Core Performance Measurement Project (HCPM) which controls for individual weighting, missing data, and differences in case volumes (Scinto et al., 2002). The independent variable in this study was the level of CDSS adoption. This variable comes from two questions in the AHA EHR Adoption Survey: "Does your hospital have a computerized system which allows for decision support for clinical guidelines?" and "Does your hospital have a computerized system which allows for decision support for clinical reminders?" If the hospital answered yes to either question, it was considered to use a CDSS, and was further classified based on the self-reported magnitude of CDSS adoption. Hospitals reporting their system was "fully implemented across all units" were coded as 'Full' while hospitals reporting their system was "fully implemented in at least one unit" were coded as 'Some'. Thus, the independent variable used in this research is categorized as Full, Some or No CDSS adoption.

Control variables were conceptualized using both Donabedian's framework for hospital structure variations (Donabedian, 2005) and Andersen's Behavioral Health Model for community-level variations (Andersen, 2008). Structural control variables include management style, bed size, ownership (Government, Not-For-Profit, and For-Profit), Joint Commission Accreditation, critical access status, and teaching status.

STATISTICAL ANALYSIS

Preliminary analysis estimated the rate or percentage of CDSS adoption (full, some, no) by independent and control variables of interest. Adjusted analyses, using multivariable ordinary least squares regression, estimated the association between heart failure process measure adherence and health outcomes by CDSS adoption level and other above-stated control variables.

Both quality of care and use of CDSS may be endogenous, in that hospitals interested in improving quality of care may choose to invest in CDSS. The propensity score method was used to control for selection and confounding biases by adjusting for the likelihood that a hospital will deploy CDSS, based on its rurality, ownership type, size, region, being JCAHO accredited, and being part of a system, and management structure.

Rosenbaum and Rubin (1983) highlight three propensity score techniques for constructing a matched sample: pair matching on balancing scores, subclassification on balancing scores, and covariance adjustment on balancing scores. This study used the regression covariance adjustment propensity score technique. This method reduces bias by adjusting for the pattern of observed confounders (Imbens, 1999).

RESULTS

The study population for this research included 2,335 hospitals of which 46 percent were part of a centralized system, 27 percent were part of a decentralized system and 27 percent did not belong to a system. Approximately half of the study hospitals (1,198) were over 150 beds and approximately half (1,220) were not for profit status. A large majority of hospitals (82 percent) were Joint Commission accredited. Less than 16 percent of the hospitals were classified as critical access facilities. With respect to location, 56 percent of study hospitals are in a metropolitan region,

17 percent reside in the Northeast, 32 percent in the Midwest, 36 percent in the South and 15 percent are located in the West (table not shown).

DESCRIPTIVE STATISTICS ON CDSS ADOPTION

Hospital level adoption of a CDSS was evaluated across each of the data variables. Chi square analyses were performed to identify statistically significant difference in hospital level variables for those hospitals with full, some, or no CDSS adoption (Table 2). The analyses suggest hospitals with full CDSS adoption are more likely to be members of a centralized system (37 percent), have over 150 beds (63 percent), be not for profit (72 percent), have Joint Commission accreditation (89 percent), be non-teaching facilities (67 percent), and reside in metropolitan areas (68 percent).

Table 2: Descriptive Statistics of CDSS Adoption for Study Variables.

CDSS Adoption Level:			Full[1]	Some[2]	No[3]
Hospital-Level (Donabedian)	Management Style**	Not a System Member	34.36	51.08	51.68
		Decentralized System Member	28.59	24.70	25.84
		Centralized System Member	37.05	24.22	22.47
	Size**	<150	36.92	48.20	57.74
		>=150	63.08	51.80	42.26
	Ownership*	Nonfed Gov.	17.56	22.78	21.30
		Not for Profit	71.56	68.35	65.99
		For Profit	10.90	8.63	12.63
	JC Accredited**	Yes	89.10	83.69	75.84
		No	10.90	16.31	24.16
	Critical Access	Yes	8.85	14.39	20.96
		No	91.15	85.61	79.04
	Teaching **	Yes	32.95	23.74	17.59
		No	67.05	76.26	82.41
ZCTA-Level (Anderson)	ZIP Code**	Metropolitan	67.95	56.35	47.98
		Micropolitan / Rural	31.67	43.17	51.35
	Region	Northeast	17.31	17.27	17.17
		Midwest	32.31	30.70	31.48
		South	37.18	37.89	34.34
		West	13.08	13.91	16.50

1 Full: A CDSS, with clinical guidelines and/ or reminders, is available in all units.
2 Some: A CDSS, with clinical guideline support and/ or reminders, is available in at least one unit.
3 No: There is no CDSS system available.
*Significance: * p<0.03; ** p <.0001*

RESEARCH QUESTION RESULTS:

Research question 1, "*Does the adoption of a clinical decision support system (Structure) impact the timeliness of care (Process) measures for heart failure?"* was explored using five multivariable linear regressions. The dependent variables in the regressions were a composite measure, HF1, HF2, HF3, and HF4, respectively. All of the hospital and community level covariates listed in Table 3 were included in the analyses as well as a control variable for propensity to adopt a CDSS. The results (Table 3) suggest hospitals with full CDSS adoption had statistically significant higher achievement rates for the composite heart failure measure, as well as, for three of the four heart failure core process measures when compared to hospitals with no CDSS adoption. Specifically, hospitals with full CDSS adoption had higher achievement rates for the composite measure, the evaluation of LVS function (HF2), ACEI or ARB for LVSD (HF3), and Adult Smoking Cessation Advice or Counseling (HF4). When comparing hospitals with some CDSS adoption to those with no CDSS adoption, only one core process measure was statistically higher; Adult Smoking Cessation Advice or Counseling (HF4).

Table 3: CDSS and Process Measures Association - Multivariate Regression Results

	Variable	Classification	Composite	HF1	HF2	HF3	HF4
	Intercept		88.774**	88.226**	94.798**	82.875**	91.729**
Hospital-Level (Donabedian)	CDSS (Ref: No[3])	Full[1]	1.654*	1.689	1.674*	2.011*	2.571*
		Some[2]	0.112	-0.665	.392	0.773	3.843*
	Management Style (Ref: Centralized System Member)	Not a System Member	-5.537	-11.022*	-5.128	1.304	-3.769
		Decentralized System Member	-2.953	-5.458	-3.251	0.411	-1.282
	Size (Ref: >=150)	<150	-3.212*	-4.288	-4.035*	-0.628*	-3.953
	Ownership (Ref: For Profit)	Nonfederal Gov. (a)	-1.131	1.123	-0.137	-1.393	-3.740
		Not for Profit (b)	1.499	1.998	2.347	-0.211	0.427
	Joint Commission Accredited (Ref: No)	Yes	10.108**	15.252**	8.634**	4.588**	7.728*
	Critical Access (Ref: No)	Yes	-3.673*	-3.167	-5.800**	0.014	-3.323*
	Teaching (Ref: No)	Yes	-.031	-0.483	0.197	1.248	0.600
ZCTA-Level	ZCTA (Ref: Metropolitan)	Micropolitan / Rural	-4.400*	-5.603*	-4.848*	-1.633	-3.114
	Region (Ref: West)	Northeast (a)	6.948**	9.613**	6.241**	1.653	2.133
		Midwest (b)	4.245*	5.458*	3.504*	0.741	0.860
		South (c)	3.005*	3.144	2.627*	-0.222	3.381*
	R-Square		0.2369	0.1142	0.2836	0.0821	0.1506

1 Full: A CDSS, with clinical guidelines and/ or reminders, is available in all units.
2 Some: A CDSS, with clinical guideline support and/ or reminders, is available in at least one unit.
3. No: There is no CDSS system available.
*Significance: *=p<.05; **=p<.0001*

Many of the covariates also showed statistical significance further substantiating the results found in Table 2. Large hospitals were shown to have higher achievement rates across the composite measure, HF 2, HF3, and HF4. Joint Commission accreditation is linked to higher compliance rates across all measures. Critical access hospitals perform statistically worse on the composite measure, as well as, HF2 and HF4. Metropolitan hospitals outperformed micropolitan or rural hospitals on the composite measure, HF1 and HF2 and hospitals in the Northeast and Midwest outperformed hospitals in the West for the composite measure, HF1 and HF2.

The second research questions, *"Does the adoption of a clinical decision support system (Structure) impact the 30-day mortality and 30-day readmission rates (Outcomes) for heart failure?"* was explored using multivariate ordinary least squares regression analyses (Table 4). Two analyses were performed, one with 30-day mortality as the dependent variable and a second with 30-day readmission rate as the dependent variable. The model included the CDSS adoption variable, the four heart failure process measures, and all of the hospital level covariates listed in Table 3. Significant differences were identified using Wald chi square tests.

Table 4: CDSS and Heart Failure Process Measures Association to Outcomes

		Mortality	Readmissions
Variable	Classification		
Intercept		11.369**	23.750**
CDSS (Ref: No[3])	Full[1]	0.551	-0.237*
	Some[2]	-0.846	-0.297*
Management Style (Ref: Centralized/Mod-Centralized System Member)	Not a System Member	-0.104	0.675
	Decentralized System Member	0.081	0.306
Size (Ref: >=150)	<150	0.044	0.311
Ownership (Ref: For Profit)	Nonfederal Gov. (a)	0.296	-0.199
	Not for Profit (b)	0.122	-0.676**
Joint Commission Accredited (Ref: No)	Yes	0.280	-0.308
Critical Access (Ref: No)	Yes	0.123	-0.435*
Teaching (Ref: No)	Yes	-0.213*	-0.134
ZCTA (Ref: Metropolitan)	Micropolitan / Rural	0.269	0.387
Region (Ref: West)	Northeast (a)	-0.446*	1.086**
	Midwest (b)	-0.308*	0.397*
	South (c)	-0.328*	0.547*
Heart Failure Processes	HF1	-0.244	0.186
	HF2	0.116	-1.023
	HF3	0.049	-0.366
	HF4	0.398	0.441
R-Square		0.0728	0.0563

1 *Full: A CDSS, with clinical guidelines and/ or reminders, is available in all units.*
2 *Some: A CDSS, with clinical guideline support and/ or reminders, is available in at least one unit.*
3 *No: There is no CDSS system available.*
*Significance: *=p<.05; **=p<.0001*

Mortality Results

There were no statistically significant differences between CDSS adoption level and mortality, after controlling for hospital and environment variables. Similarly, there were no statistically significant findings for the heart failure process measures and mortality, suggesting these process measures are not good predictors of mortality. Higher mortality was also found for teaching hospitals, and hospitals in the West.

Readmission Results

There were significant differences between CDSS adoption (full/some vs. none) and 30-day readmission rate, after controlling for hospital and environmental variables. Hospitals with no CDSS adoption had 30-day readmission rates that were higher than those institutions with some and full CDSS adoption. Interestingly, not-for-profit status, critical access hospitals, and geographic region (West) were hospital level variables that were significant for predicting lower 30-day readmission rates, as compared to their respective cohorts.

DISCUSSION

Healthcare organizations are required to adopt EHRs and to demonstrate meaningful use of HIT. Hospital level data on care delivery processes and related outcomes are being used to adjust reimbursements. Understanding the ability of CDSSs to positively effect change in both the delivery of care and/ or the resulting outcomes is an important policy and operational concern. The well-established Donabedian model of structure, process, and outcome suggests appropriate structures positively impact both processes and outcomes. The pressing question is whether a CDSS adoption is the structural impetus needed to assure the process of consistently delivering evidence-based care. If a CDSS is a facilitating structure for assuring consistent, high quality processes, then a second question of even greater interest emerges. The second question involves the choice of clinical care performance measures and their ability to impact the defined outcomes of mortality and readmissions.

The results of this research suggest hospitals with full CDSS adoption are statistically more likely to be members of a centralized system (37 percent), have over 150 beds (63 percent), hold not for profit status (72 percent), have Joint Commission accreditation (89 percent), be non-teaching facilities (67 percent) and reside in metropolitan areas (68 percent). These findings may indicate larger, not-for-profit system hospitals have more resources to implement a CDSS – by definition, not-for-profits reinvest revenues over expenses back into the company. Similarly, the results may suggest an implied need for system hospitals in metropolitan areas to have integrated HIT for the purpose of coordinating care across facilities.

Hospitals with full CDSS adoption were shown to have significantly higher achievement rates than hospitals with no CDSS adoption for the heart failure composite measure, as well as three out of the four individual heart failure process measures, after controlling for hospital level and environmental factors. Specifically, hospitals using CDSS achieved higher rates on evaluation of LVS function (HF2), ACIE or ARB for LVSD (HF3) and smoking cessation advice (HF4).

These findings suggest that full CDSS adoption may lead to a more consistent care delivery process and/ or that clinical reminders may be purposeful for non-clinically related care, such as smoking cessation counseling. In fact, hospitals with some CDSS adoption showed statistically higher scores in adult smoking cessation counseling (HF4) when compared to hospitals without a CDSS.

With respect to the impact of a CDSS on outcomes, the data suggest no statistically significant difference between CDSS adoption level and 30-day mortality, after controlling for hospital and environment variables. This result may be indicative of the concern that the four CMS heart failure process measures are not directly related to patient outcomes, which is supported by prior literature (Fonarow, et al., 2007; Patterson et al., 2010). Unlike the 30-day mortality outcome, there were statistically significant differences between CDSS adoption level and 30-day readmission rate, after controlling for geographic location. Geographic location was the only hospital level variable that was statistically significant for predicting hospitals readmission rates. This result is consistent with a CMS report (Medicare Hospital Quality Chart Book, 2011) which shows significant geographic variation in hospital performance measured by risk- standardized readmission rates after hospitalizations for AMI, heart failure and pneumonia. This research showed hospitals with no CDSS adoption had higher 30-day readmission rates when compared to institutions with some or full CDSS adoption. Evaluation of the relationship between the four individual heart failure process measures and the 30-day readmission outcome showed higher compliance with evaluation of LVS function (HF2) resulted in lower 30-day readmission rates.

LIMITATIONS

While this study makes significant strides in demonstrating the relationship between CDSS, process of care measures and patient outcomes, there are limitations. First, a true causal relationship cannot be proven due to the cross-sectional study design. Although this research does partially control for this deficit with a propensity score covariant adjustment, there is no certainty that a CDSS causes improvements in the process of care delivery or patient outcomes. Second, there was no control for lack of a CDSS use within hospitals. Second, while this study does account for CDSS use in all departments versus some departments, there are no data that evaluates individual physician use of a CDSS. Third, recognizing that hospital financial performance can influence quality, this study does not account for this. We did not include financial data due to the newness of the AHA EHR Adoption Survey. Because of this, and not knowing how long the particular hospital has used CDSS, any correlation to financial outcomes would be biased. Last, with the absence of patient-level data, the linkage between CDSS use and health outcomes should be looked at with caution. While a significant relationship exists between CDSS use and lower 30-day readmissions for health failure, patient level characteristics were not available. Subsequent studies measuring differences in outcomes should evaluate aspects of clinical integration, population management, and reimbursement structures, as these will influence processes and outcomes in the future.

CONCLUSIONS

This research adds to the growing HIT literature by drawing a significant association between CDSS use, care delivery processes and outcome measures. Donabedian's "Structure – Process – Outcome" quality model was used to show the association of a structural component (hospital adoption of a CDSS) with higher percent achievement on specific process of care and outcome measures for heart failure. Healthcare administrators can use these results to justify the tremendous expense of HIT by recognizing CDSS adoption as an investment in quality. Moving forward under the HITECH act, hospitals will be mandated to adopt and meaningfully use HIT. Hospital executives who view CDSSs as an investment rather than an expense, can leverage the CDSS for greater quality and financial improvements, thereby attaining a competitive advantage.

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A GRAMMATICAL APPROACH TO PROCESS DESIGN AND ITS EVALUATION BASED ON PROBLEM SPACE ANALYSIS

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ABSTRACT

Extensive tools exist for modeling, analyzing and comparing processes, but very few tools support the generation of new processes. This paper presents a categorization of the existing design generation methods (Local Variations, Loose-Leaf Binder, Creative Techniques, First Principles) and discusses the benefits and limitations for each of the categories, using Newell and Simon's problem space theoretical framework. It then argues for a grammatical approach which provides many of the benefits such as its ability to make the dimensions of a design space explicit, systematically and exhaustively generate alternatives in a given design space, and embody domain specific knowledge in the form of rules. As such, it provides a powerful tool with which to address the ill-structured problem of process design. The grammatical approach we discuss is focused narrowly on the problem of generating alternatives; it is meant to supplement, not replace, existing frameworks for analysis and design.

INTRODUCTION

Process innovation is a critical component of gaining competitive advantage for modern organizations. While most organizations have made considerable efforts in streamlining existing processes, the challenge of inventing new processes remains. This challenge is particularly salient in the context of, for example, social media, where new technology has enabled a wide range of innovative business arrangements.

The literature on process redesign and re-engineering has grown rapidly, starting with the early calls to innovate (Davenport and Short 1990) and obliterate (Hammer 1990; Hammer and Champy 1993). The rhetoric of reengineering created a huge wave of practical and theoretical interest, a large number of methods, tools, and techniques have been developed to assist in the task (Bucher 2010; Brocke and Rosemann 2010). Sophisticated tools have been developed for analyzing an existing or proposed process, but tools for identifying potential new processes are very limited and ad hoc (Bernstein, Klein and Malone 1999; Lee et al. 2008). This seems unfortunate, because the potential for really significant innovation is constrained by our ability to generate interesting alternatives (Malone et al. 1999).

This paper studies existing approaches to process design from a problem space perspective (Simon. 1996; Newell. 1972) and identify their benefits and limitations. We then argue that a

grammatical approach to process design, such as described in (Lee et al. 2008), provides most of these benefits without inheriting all their limitations. In this framework, our knowledge of what is possible is captured in the form of a grammar that can be used to generate a variety of possible models. A grammar provides a way to represent our knowledge about the space of alternative processes economically and generatively. Not all processes are feasible or desirable in every situation, but a grammatical framework can make the space of alternatives explicit, visible and searchable.

We proceed as follows. We begin with the observation that generating alternative processes forms "weak link" in the overall process design effort. We use the problem space perspective (Newell and Simon 1972; Simon 1973) to review current methods for generating new process alternatives. We then describe an overview of the grammatical approach and how its components—lexicon, rewrite rules, and constraints—allow us to synergize the benefits of the other approaches while minimizing their limitations. We then conclude by summarizing the contributions of the grammatical approach and describing some directions for future research.

GENERATING ALTERNATIVES: A WEAK LINK

Kettinger, Teng, and Guha (1997) provide an extensive survey of process reengineering practices, from which they identify six stages of business reengineering: envision, initiate, diagnose, redesign, reconstruct, evaluate. While Kettinger et al. (1997) identify a remarkable variety of tools that have been used to support BPR, only a few of these tools genuinely address the generation of new design. Nor is any of the over fifty chapters in (Brocke and Rosemann. 2010) is about process alternative generation. Of course people know how to generate alternatives and have done so, remarkably well in many instances, but the question is "Can we do better, and if so, how?"

Obviously, people can and do generate alternatives. Thus, the question is not, "can we generate alternatives?" The question is, "Can we do better, and if so, how?"

PROBLEM-SPACE PERSPECTIVE ON GENERATING PROCESS DESIGNS

To answer this question, we will analyze existing techniques for generating process ideas from a problem solving perspective (Newell and Simon 1972; Simon. 1973). In his classic piece on "the structure of ill-structured problems", Simon (1973) articulates the difference between "well-structured problems" (WSPs) and "ill-structured problems" (ISPs). He argues that real problems fall across a continuum, and that most open-ended design problems, such as designing a house, fall far over toward the ill-structured end (Simon 1973, p. 187):

> It will generally be agreed that the work of an architect – in designing a house, say – presents tasks that lie well toward the ill-structured end of the problem continuum. Of

> course, this is only true if the architect is trying to be "creative" – if he does not begin the task by taking off his shelf one of a set of standard house designs that he keeps there.

Simon identifies several ways in which designing a house is ill-structured: (a) it is impossible to specify entire problem space; (b) a goal state or set of goal states cannot be clearly specified; and (c) there is incomplete knowledge of how changes in the design will affect progress towards the goal. Worse yet, processes often present moving targets: from a problem solving perspective, new information that alters the goal or the constraints can emerge at any time. When confronted with this kind of complexity, it is tempting to just pull a blueprint off the shelf. It is convenient, but not necessarily optimal.

Simon (1973) argues that our best hope for dealing with large, ill-structured problems is to decompose them into smaller well-structured ones. The approach we present here embodies this strategy in two ways. First, we are not attempting to model the overall BPR process; rather, we focus on the sub-problem of generating alternatives. Regardless of how one approaches the overall process design and implementation effort, generating alternatives is an essential sub-problem. Second, the grammatical method we introduce later in this paper encourages us to further decompose the alternative generation problem, which is a large and ill-structured problem itself, into many smaller, better-structured problems. While this does not alleviate process designers from the responsibility of assessing the coherence and effectiveness of the overall design, decomposition is the best available strategy for generating a reasonable set of alternatives to assess.

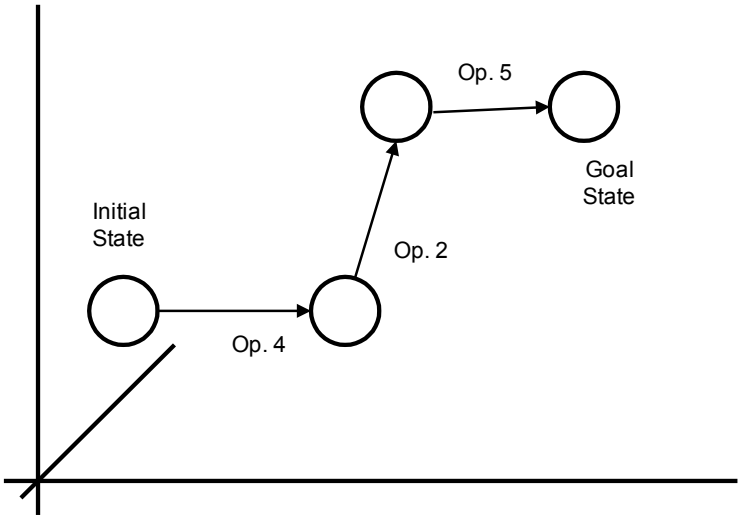
PROBLEM SPACE

Since it was proposed by Newell and Simon (1972), the problem space model has secured a permanent place in academic research across disciplines, notably in psychology, computer science, political science, and management. To be sure, some aspects of the original model – e.g. the overestimated role of pure reasoning and the underestimated roles of domain-specific knowledge or environmental characteristics – have been revealed inadequate and justifiably rectified (Lenat and Figenbaum 1991; Rosenbloom et al. 1991; Rosenbloom et al. 1993).. Nevertheless, the general framework has formed the backbone of many useful results such as in the development and evaluation of the numerous search algorithms (Kanal and Kumar 1988) or in planning research (Laird et al. 1993). For the purpose in this paper, we will use the model to clarify the role of grammars in the design process, especially in relation to the existing ways of generating new process alternatives. Therefore we present a brief characterization of the model here.

"A Problem Space consists of a set of symbolic structures (the *states* of the space) and a set of *operators* over the space. Each operator takes a state as input and produces a state as output", although there may be other inputs and outputs as well. The operators may be partial, i.e., not defined for all states. Sequences of operators define *paths* that thread their way through sequences

of states. "A problem in a problem space consists of a set of *initial* states, a set of *goal* states, and a set of *path constraints.* The problem is to find a path through the space that starts at any initial state, passes only along paths that satisfy the path constraints, and ends at any goal state." (Newell 1981, p.695).

Figure 1.
In the problem space model, solving a problem is viewed as finding a sequence of operators transforming the initial state to the goal state.



For readers unfamiliar with the problem space concept, let's consider a simple, relatively well-structured example: remodeling a kitchen. This problem has your current kitchen as the initial state and a modern kitchen as the goal state. The problem space would consist of the set of all possible states that you could be in while doing the work, and the operators would be any means available to one for getting from one state to another (e.g. "remove old appliances," "install cabinets," "paint walls," etc.). A solution would be a sequence of operators that would move you from the initial state to the goal state. In Figure 1, these are shown as Op 4-Op2-Op5.

A problem space is typically defined by a number of dimensions relevant to the goal in hand, such as cost or time. In Figure 1, these dimensions are shown by solid-line axes. For example, the cost dimension can be included explicitly into the problem space or it could be modeled as an external constraint. Either way, some operators would lead to a state with higher cost than others while the goal state(s) might be all the states where one has "a modern kitchen with X and Y features" and the overall cost is less than $20,000. The problem space model can be refined and extended in many ways, but for the purpose of this paper, this characterization suffices.

TOOLS FOR GENERATING ALTERNATIVES

To explore ways to better generate new process designs?, we will use the problem space model to analyze a representative set of design practice categories: local variations, benchmarks, creative techniques, and first principles. While not exhaustive, these categories encompass a wide range of techniques including, for example, those identified in Kettinger et al (1997). We will use this analysis to develop some criteria that can be used to assess the potential value of a grammatical approach. As background for this analysis, it is useful to distinguish between "variant" and "generative" process planning system (Chang and Wysk 1985; Hallerbach, et al. 2010). Variant-based systems simply store and retrieve existing process plans so that they can be modified or adapted. Generative systems include a knowledge base that allows process planners to generate new process plans from more or less from scratch.

LOCAL VARIATIONS

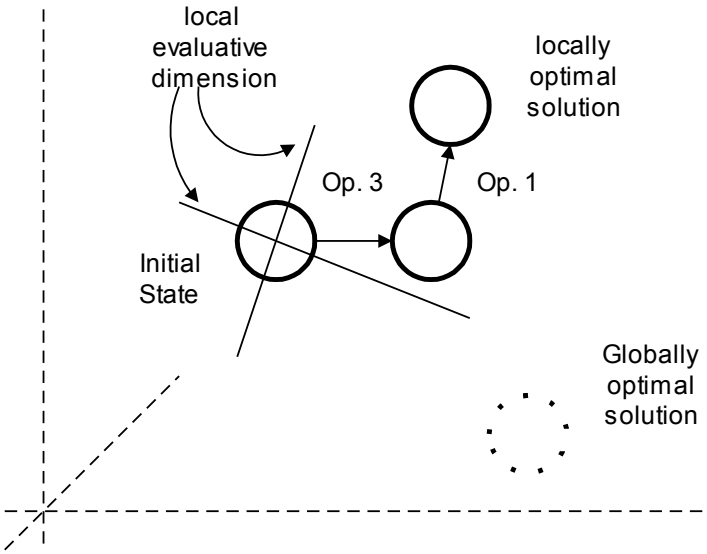
In spite of the rhetoric of radical change, incremental improvement is probably the most commonly used approach to process design (Jarvenpaa and Stoddard 1998). Indeed, Harkness, Kettinger, and Segars (1996) found that many process redesign efforts are based on Total Quality Management techniques, which adopt an inherently incremental approach. Techniques in this category start with an existing process and vary one or two parameters to create alternatives. This exemplifies what Chang and Wysk (1985) call the "variant" approach to process design: one takes a specific design and introduces small variations. In terms of Simon's (1973) analogy to building design, the use of incremental change is like pulling a set of blueprints off the shelf and adjusting them: moving walls, adding doors, etc.

Bernstein, Klein and Malone (1999) have devised a system that extends on the idea of local variations by using process descriptions stored in the Process Handbook (Malone et al. 1999; Malone and Crowston 1994) to generate new process ideas. With the help of a special browser, users retrieve a particular process description from the database and then make substitutions for selected parts of the process using other processes in the database. This approach extends on the basic idea of variant-based process design by allowing users to mix and match significant sections of a process.

From the problem space perspective, local variation allows one to explore small isolated places within the problem space and even provide a set of operators that can be used to do so. However, it does not help us see the overall space, nor the operators for navigating the larger space. Figure 2 illustrates the limitations of this approach. First, it artificially limits the problem space to a set of local dimensions (shown in solid lines) along which a given state can be varied. It also limits the operators that can move along these dimensions. It does not show the global problem space (shown in dashes). Second, it tends to conflate the problem of design with the problem of implementation. In a sense, it constrains the initial state of the design problem to be the same as

the initial state of the implementation problem. While this is one possible choice, it is certainly not the only one. Finally, local variations might give us a locally optimal solution but not a globally optimal solution. For example, the hill-climbing search algorithm that locally optimizes the solution has a set of well-known limitations such as the Foothills, Plains, and Ridges problems where the reliance on local improvement prevents the location of a better solution (Kumar 2008).

Figure 2.
Local Variations Approach shows the local dimensions (shown in solid lines) along which a given state can be improved. But it does not show the global problem space (shown in dashes) and does not help finding a globally optimal solution.



BENCHMARKING AND BEST PRACTICES: THE "LOOSE-LEAF BINDER"

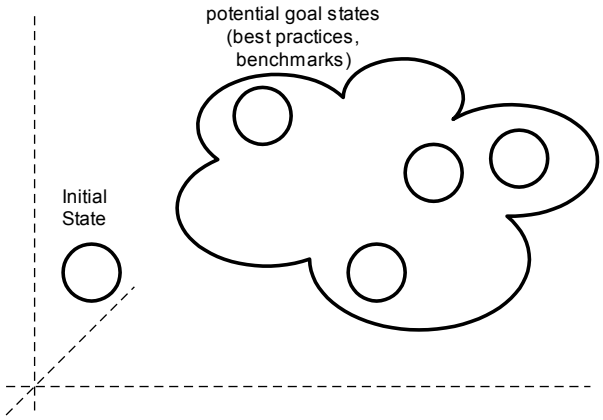
To broaden the search space, one can include additional cases, typically in the form of benchmarks or "best practices" (Reijers and Mansar 2005). These may be documented by a consulting organization (e.g., International Process Benchmark Clearinghouse), or they may be collected as part of a benchmarking study. The IBM approach to re-engineering, as described by Augustine and Aspinwall (1999) makes extensive use of benchmarks as a resource for generating new process ideas. Malone et al. (1999) call this the "loose-leaf binder" approach because interesting cases or best practices are compiled with simple categorization and keyword-based indexing. For example, typical examples might include "order entry", "hiring", "customer service", and so on. Benchmarks and other examples have great value because they convey a set of easily understood possibilities.

At the same time, mimicking an existing process at another company may not be a fruitful strategy for truly innovative design. To return to Simon's (1973) architectural analogy, imagine

an architect who has a library of "excellent houses," with finished blueprints for each one. If one of the blueprints happens to fit your needs, and you choose wisely, then everything works out fine. Still, pulling blueprints off-the-shelf may tend to cut off exploration of the full range of possibilities.

The underlying problem with benchmarking is that it is also an inherently variant-based strategy for process design (Chang and Wysk 1985). Within the design space, a binder of cases or benchmarks is equivalent to a set of scattered, disconnected possibilities. From the problem space perspective, this approach provides us with a set of states that seem desirable. Some of these states may be the goal state that we should try to reach, but the dimensions of the problem space and the operators are implicit, not explicit. They do not tell us which of the differences are important between the best practice s and the current case nor how to reduce such differences. Figure 3 represents this situation by the dashed axes and the absence of any operators.

Figure 3
The Loose Leaf Binder approach provides examples of potentially desirable states without identifying the design dimensions that define the problem space.



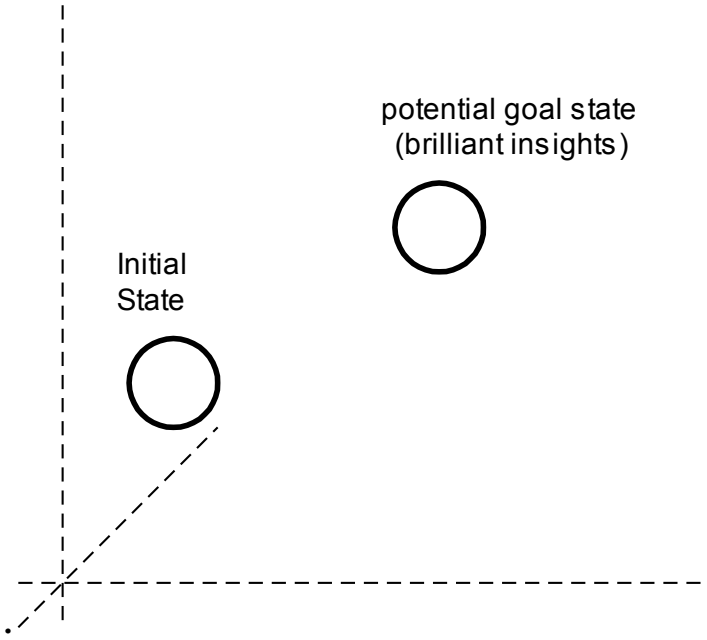
CREATIVE TECHNIQUES

Creative techniques such as brainstorming, nominal group technique, and "visioning" are a familiar part of most BPR toolkits (Anderson, 1999; Kettinger et al, 1997). These techniques rely on the psychological processes of individuals and groups for generating new ideas. They have value because people are often very good at generating intuitively plausible, creative possibilities. This ability is remarkable, but not necessarily consistent or reliable. As Jackson (1996, p.293) reports, some groups are "unable to suggest any way of doing things other than the current way." In spite of this limitation, such techniques are useful in generating a sense of involvement and buy-

in for the implementation of whatever design is eventually adopted. For this reason alone, some kind of participatory technique is probably an essential part of the overall design and implementation process. Similarly, when designing a house, it makes sense to involve the clients in the creative process to make sure they feel a sense of ownership, literally and figuratively.

In terms of the problem space model, these techniques allow us to jump to a potentially promising state in the problem space. In doing so, we rely on human ability to sift through huge problem spaces and focus in on a relatively small set of potentially interesting alternatives. However, we may not be sure what the overall problem space looks like, what its dimensions are, or where the creative suggestions are located in the overall space. Nor do we know the operators that allow us to get from one state to another. Instead, we rely on the remarkable, to be sure, but inconsistent human ability to quickly identify a small relevant set of alternatives. As indicated in Figure 4, creative techniques are very similar to benchmarks: they provide disconnect possibilities, but do not provide the dimensions and operators required for systematic problem solving.

Figure 4
Creative Techniques may reveal a potential goal state(s). But as in the Loose Leaf Folder approach, it does not identify the dimensions that define the problem space (shown in dash)



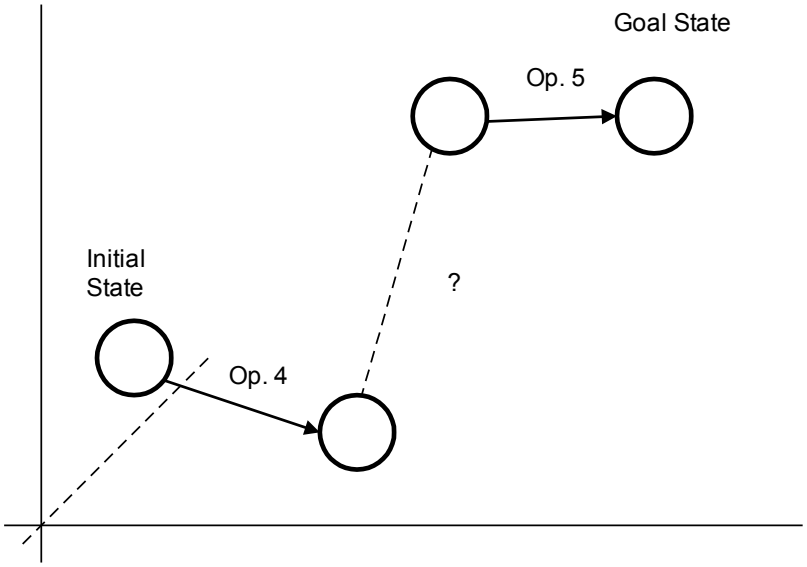
DESIGN FROM "FIRST PRINCIPLES"

In certain domains of engineering design, such as VLSI design, there are well-established principles for creating a design that meets a given set of specifications (Suh 1999; Whitney 1997). So, for example, one can quickly and reliably design a new application specific integrated circuit (ASIC) using tools that embody these principles. In the domain of business process design,

researchers have succeeded in identifying a few such "first principles." Such knowledge may exist in the form of guidelines (Davenport 1993; Senge 1990) domain models (Kling and Scacchi 1982; Mi and Scacchi 1996), theoretical analyses of alternative organizational forms (Malone. 1987) or taxonomy of process pathologies and potential solutions (Nissen 1998). For example, the theoretical comparative analysis of market vs. hierarchy (Malone 1987) provides us with the knowledge of the properties and tradeoffs that we could exploit in process design. Nissen (1998) also uses several such principles (e.g. exploit parallelism) and uses them in a measurement-driven reengineering method.

Figure 5

The First Principles approach, to the extent that they are available, make explicit the problem space and the operators. To the extent that they are not available, however, the problem space defined by them is coarse and often not detailed enough to specify the goal state or the operators specific enough for the solution.



In terms of the problem space model, design principles give us the major dimensions of the problem space and, and possibly some operators, as shown in Figure 5. This is a great improvement on benchmarks and creative techniques. However, we are still quite far away from having sufficiently detailed principles to guide us in generating specific alternatives. For example, we may know that parallelism is helpful, but which segments of the process can be arranged this way? To answer this question, the first principles have to be supplemented by a large number of domain specific and context-sensitive rules that fill in the rest of the problem space.

A GRAMMATICAL APPROACH

This paper describes a grammatical approach to process design which we believe has the potential to meet this need. This approach is based on the concept of formal grammar, which

originated in the field of linguistics (Chomsky 1986) and has been applied to organizations (Salancik and Leblebici 1988; Pentland 1994, 1995), mechanical design (Schmidt and Cagan 1997), manufacturing (Baldwin and Chung 1995; Chung et al. 2001), and a range of other topics (Honavar and Slutzki 1998; Miclet 1996). Grammar augments the use of other tools by suggesting combinations and alternatives that might otherwise be missed. It helps us to explore deep, cross-domain, analogies that go beyond local variations. Because a grammar is an inherently generative mechanism, it can be viewed as a framework for enabling the systematic exploration of alternatives where we formerly had to depend on creative insights.

A GRAMMATICAL FRAMEWORK FOR GENERATING PROCESS ALTERNATIVES

Below is a brief description of the major components of the grammatical approach. A particular instantion of this approach, called Process Grammar, can be found in (Lee, et al. 2008), along with a review of the related work and a specific illustrative example. The framework we present here is generic and could be used to represent many different process domains. We will illustrate it with a sales process, using data from the Process Handbook (Malone et al 1999), which contains a large number of sales related processes. Our grammar consists of the usual elements of any phrase structure grammar, each of which is discussed and illustrated below.

- Lexicon (terminal symbols) – put, get, pay….
- Non-terminal symbols – noun phrase (NP), determiner (DE), verb (V)s
- Rewrite Rules -- S -> (DET) (NP) V (NP)

Readers unfamiliar with the concept of formal grammar may find the terminology burdensome and difficult to follow, but the basic idea is very simple. A grammar describes all and only the valid possibilities in some set. In the case of natural language, a "sentential" grammar describes the set of all the valid sentences in that language. Since this set is potentially infinite, direct enumeration is impossible. So a grammar represents the potentially infinite set of valid possibilities by generating them from a lexicon and a set of rules. The process of generating valid possibilities is called "re-writing."

While grammatical formalisms may seem quite distant from the practice of design, many researchers conceptualize design as "a process of *mapping* from one symbol system to another…." (Majkowski and Kalay 1987, p.350, emphasis in original). In a grammar, that mapping is accomplished by the successive application of re-write rules. In terms of the problem space model, the initial state is a highly abstract representation of the design (e.g., "selling"), and the rewrite rules are the operators. Each application of a re-write rule makes the design increasingly specific and concrete.

Because our goal is to supplement existing techniques and human judgment (rather than replace them), our framework includes some semi-formal features that may strike some readers as inconsistent with the use of formal grammar. For example, for reasons that are discussed below, we rely on human judgment to determine the degree of detail (or granularity) that is appropriate to

the problem at hand. As Bernstein et al (1999) have demonstrated, by allowing the combination and recombination of process components, even a partial grammar can generate interesting possibilities. Indeed, given the open-ended nature of the domain, a complete description of all possibilities is not a realistic objective. Likewise, we rely on human judgment to determine when to stop generating alternatives and to determine which process alternatives are best. In this respect, our strategy reflects the state of the art. Even after optimization, Janusz (1997, p.345) notes that users may want to propose "creative" modifications to the activity chain which can "only be performed by human beings."

TERMINAL AND NON-TERMINAL SYMBOLS

The lexicon of our sales grammar consists of the major steps in a sales process, as shown in Table 1.

Table 1.
Terminal and Non-Terminal Symbols in the Sales Grammar

Terminal symbols (lexicon)	Sell, Identify-Potential-Customer , Identify-Customer-Needs, Inform-Potential-Customer, Take-Order, Deliver-Goods, Receive-Product, Maintain-Customer-Relation
Non-Terminal symbols	Act, agent, location, temporality, object, beneficiary, instrument, how, and all the terminal symbols

The lexicon of our sales grammar consists the specific activities such as Sell, Identify Potential Customer, Identify Customer's Needs, Information Potential Customers, and so on. They are the basic building blocks of the process as it is modeled in this grammar. There are also non-terminal symbols, which can be further elaborated or specified. The non-terminal symbols consist of generic categories such as Act, agent, object, location, and temporality, as well as all the terminal symbols.

In formulating this grammar, we have taken the unusual step of including the "terminal" symbols as non-terminals, for the following reason. What we put into the lexicon or the terminal symbol set depends on what we want the surface structure to include. In sentential grammar, sentences that we can utter constitute the surface structure. The surface structure in turn depends on when we want our grammatical analysis to stop. We want to stop rewriting when all the symbols are terminal.

In a process grammar, no a priori stopping point for the level of detail or abstraction can be specified. In principle, one can proceed to an infinitesimal degree of refinement (Abell 1987), which contributes to the ill-structured nature of the problem. But at some point, the practical value is exhausted. The ill-structured nature of the problem is exacerbated by the existence of alternative decompositions and arbitrary boundaries that define the "process" versus the "context" (Alexander, 1964). As in the current state of the art, human judgment is required to determine

when we have interesting processes that are concrete enough to start assessing and comparing. Therefore, if we have a specific level of analysis in which we are interested and if we can characterize this level with a specific vocabulary, then we can define this set to be the lexicon, or terminal symbols. For example, if we wanted to see how a given process model gets implemented in a workflow system, then the lexicon would consist of the constructs for the chosen workflow system.

More often than not, however, there is no fixed level that can be characterized in terms of a set of specific symbols. The interesting level could be quite abstract: "Sell via the Internet." Or it might be quite specific: "Sell support service by establishing a web-based help desk staffed on a rotating basis by members of the development department…". And naturally, much more specific details would be required to actually implement the process. But regardless of the level of abstraction, some of the same terminology is typically used. Because we have allowed terminal symbols to appear as non-terminals, different levels of abstraction can use the some of the same vocabulary. The action SELL, for example, can appear as the initial string as well as at the surface structure we end up with.

A lexicon may be more or less well-designed and there are existing studies on the design or even automatic induction of a lexicon, as we discuss below. However, because our design artifact (a process) can be decomposed and expressed in many alternative ways, there is no canonically correct lexicon (Alexander, 1964; Malone et al, 1999). Again, this indeterminacy of description contributes to the ill-structured quality of the problem (Simon, 1973). Different people will bring different perspectives and use different lexicons, which will generate different alternatives. The same is true of all existing techniques, of course, but these differences tend to be hidden. Whatever lexicon one uses, any one of them will serve the purpose of defining the design space and exploring it to the extent it captures meaningful aspects of the domain.

REWRITE RULES

Our process grammar includes a set of rewrite rules that allows us to generate the set of possible processes from a completely generic sales process (the "deep structure"). These rules are of two kinds: a decomposition rule and a set of domain-specific rules. The generic decomposition rule is generic; it is based on a framework proposed by Fillmore (1968) and can be applied to any action or process. The domain-specific rules, however, reflect knowledge about a variety of alternative sales processes.

GENERIC DECOMPOSITION RULE

The core of our grammar is a generic decomposition rule that can be applied to any process (or part of a process) any number of times, including zero times. This rule can be expressed formally as:

Act → [Act [agent | locality | temporality | object | beneficiary | instrument | how]]*

The rule expresses the fact that there are a number of different cases that can be explored and potentially specified for any given action. This rule specifies that any activity (Act) can be rewritten as itself plus some additional information that makes the description of the activity more specific. The alternatives for what kind of additional information is needed are called "cases" (Fillmore 1975). For example, if our action is "Inform-Potential-Customer" (IPC), this rule says that we can re-write in any of the following ways

IPC → IPC agent
IPC → IPC locality
IPC → IPC agent IPC locality
IPC → IPC agent IPC locality IPC temporality

In grammatical terms, "agent", "locality" and "temporality" are non-terminal symbols that will be rewritten further with domain-specific rewrite rules, which are discussed below. In practical terms, they are aspects of the process design that need to be explored and finalized. For example, if one is selling vacation packages to the Bahamas, one might consider running television advertisements in Northeastern United States during the early January. To express this possibility in terms of re-write rules, we would need to include rules such as: agent → TV, locality → Northeastern US, temporality → first week of January, object → advertisement for the Bahamas. Thus, each of these cases can be elaborated into some specific aspect of the activity.

There are many proposed sets of cases (Chase 1970; Fillmore 1968; Fillmore 1975; Grime 1975; Simmons 1973). Which set to adopt would depend on the domain and the purpose of analysis. For our purpose of exposition, we have chosen to use a set of cases that are most intuitive and also consistent with the original set of Fillmore (1968): agent, object, location, temporality, instrument, result, beneficiary, how. The first four roughly correspond to Who, What, Where, and When. These are essential to the specification of any real activity, and they form the major dimensions of the problem space.

Not all cases need to be fully elaborated. The instrument and beneficiary are less universal but illustrate activity-specific cases. That is, for some activities, it might be valuable to know the instrument with which the activity was accomplished and for whom it was important (e.g., the customer, the employee, and so on). For other activities, this information may not be important. The application of the decomposition rule is, in this sense, optional. The choice of whether to elaborate some aspect of a process description depends on the practical needs of the situation.

DOMAIN-SPECIFIC RULES.

Domain-specific rules rewrite a current process design by elaborating on the cases associated with the process. These cases represent the different aspects of the deep structure (Winograd 1981) such as the agent, object, location, temporality, and instrument. These domain-specific rules are also straightforward way of introducing context-specific knowledge. As in the example of selling vacation packages, one might have a large body of data and experience about geographic regions, market segments, seasons, destinations, and alternative advertising media. It is worth remembering, of course, these dimensions comprise only one step in the overall sales process: Inform-Potential-Customers. Each of the other steps may entail similarly rich domain knowledge.

One of the cases in our grammar, "how", is qualitatively different from the other cases and may embody a particularly rich set of domain specific knowledge. This is because answers to "how" questions tend to involve a combination of the other case slots. For example, when asked how potential customers were identified, the following are plausible answers:

- **Identify potential customers on sales call**
- **Identify potential customers through tele-sales**
- **Potential customers identify themselves**
- **Obtain mailing list of potential customers**

By describing different ways of executing an activity, each "how" case embodies a set of small "off-the-shelf" process models, as one might find in a book of best practice benchmarks. By allowing us to mix and match process fragments, the "how" case embodies the core functionality of the Process Recombinator (Bernstein et al 1999). It allows us to group a complex of other cases that are closely intertwined and treat them as a unit. It also acts as a temporary holder of such cases until they are sorted out into individual cases. Thus the how case can be viewed as an "escape bin" where either the separation of the complex into individual dimensions is difficult or not worth the cost for the purpose in hand. But we should also recognize that by using this escape bin, we are relinquishing the ability for the grammar to generate combinations that require teasing out individual dimensions

CASE INDEPENDENCE.

The grammar presented here assumes that the cases are independent: all combinations of cases are plausible alternatives, unless there are domain-specific rules that indicate otherwise. For example, rules can be added to express the constraints that prevent certain combinations of cases, such as selling liquor across state lines on the internet. We discuss the more general issue of

introducing constraints into the grammar later in the paper. "How" offers an interesting exception to case independence, however. Each alternative case of "how" holds a combination of different slot values encompassing specific cases for who, what, when and where. Thus, the "how" cases may hold important clues about the implicit constraints that may be operating in the domain. If we find certain combinations of cases and not others, it may indicate that some technical or physical constraint is limiting the valid combinations.

The assumption of case independence simplifies the representation, but it is not necessary for the grammatical structure outlined here to be useful. The main issue is the extent to which one relies on automatic processing (versus common sense) to identify and rule out invalid alternatives. By assuming independence, the current grammar will tend to generate combinations that do not seem feasible in the real world. While this would be a flaw in a formal system intended to express only the valid combinations, it might provide an interesting aid to creativity. For example, it may have seemed implausible to sell large durable goods (like furniture) or professional services (like medical diagnosis) over the internet, but these models are now widely accepted as plausible, if not always economical.

WHY NOT "WHY"?

Since we include who, what, when, where and how, some readers may wonder about the exclusion of "why" as an explicit case. After all, processes are often described or classified in terms of their goals, so "why" seems like natural case to include. However, unlike the other dimensions, why is not inherent in the activity itself. A given activity can be used for many different purposes, serially or in combination. "Why" resides in the external relation between the activity and other factors. Treating why as an attribute of an activity unnecessarily limits the potential applicability of the activity.

Methods for building a process grammar and exploring it for process design are presented in (Lee, et al. 2008), along with a software prototype developed to assist the user Also a fuller example of each components described above is presented and used to explore new design alternatives for the sales process, such as the possibility of selling the service to remotely monitor customer's repair needs before any of the registered appliances (e.g. A/C, TV, refrigerator) malfunctions.

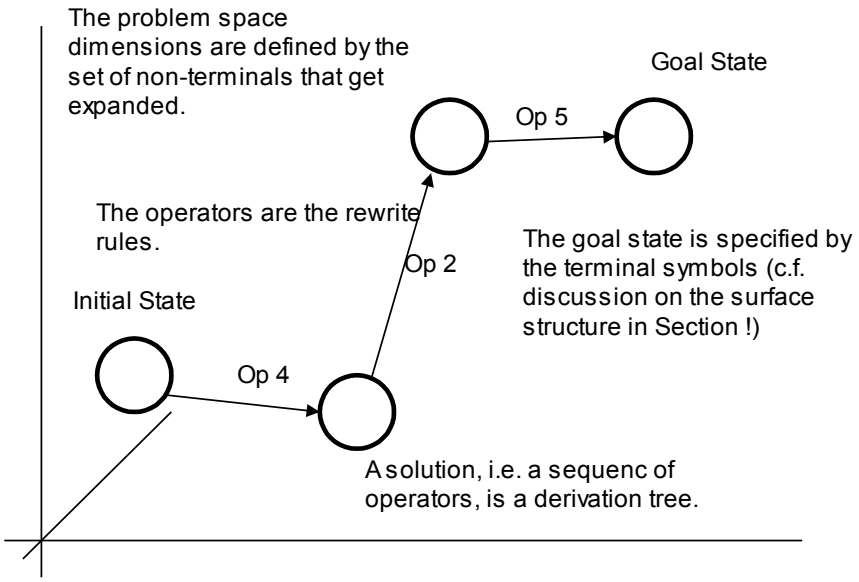
DISCUSSION

The successive re-writing and elaboration of alternatives embodies one of the core issues in design: generating innovative alternatives. The grammatical framework presented here is intended to help generate alternatives in a useful, systematic way, by combining and instantiating alternative decompositions for each of the cases associated with any component of a business process. By having the alternatives explicitly captured in the form of rewrite rules, the

grammatical approach allows new processes to be generated. Because these rules can embody context-sensitive, domain-specific knowledge, they provide a powerful tool with which to address the ill structured problem of process design.

However, a grammatical approach is not a magic bullet. The grammatical approach needs to complement not replace other process design tools and human judgment. Before it can be applied successfully, there are a number of issues that we must attend to. First, it would help to know the conditions under which the grammatical approach would be appropriate. Second, there should be criteria for a well-designed grammar and a methodology for developing one. Third, there must be a good way to represent constraints to prune implausible alternatives from the design space. We see these as fruitful directions for future research, as outlined in the following discussion.

Figure 6.
Grammatical approach makes the design dimensions for the problem space and the operators explicit.



SCOPE OF THE GRAMMATICAL APPROACH

As with other tools, successful application of a process grammar requires knowing the conditions under which it is useful. A full specification of such conditions is an ongoing research topic, but there are some minimal conditions that we have been identified so far.

1. When the main task involves the *generation or recognition of valid alternatives*, as the grammar was originally designed for these tasks.

2. The domain must be relatively stable so that the rules do not have to be changed or updated constantly.
3. The domain objects and constraints have been already identified or should be relatively easy to identify.
4. Significant innovation in the process is both desirable and feasible.

These conditions embody an implicit cost-benefit-feasibility trade-off. For example, there is no point in developing a grammar for process where only incremental changes will be allowed. In addition, one may speculate that some process domains are more amenable to grammatical representations than others. For example, it has been argued that VLSI design is more amenable to automation than mechanical design (Whitney 1997). The factors that may facilitate or hinder the success of grammatical process representations remain to be worked out.

COMPARISON TO OTHER PROCESS REPRESENTATIONS

There are many other process representations such as those used in systems analysis and design (e.g., state diagram, data flow, the UML family of diagrams, Petrie net). These representations have formal grammars that can be used to distinguish "valid" from "invalid" diagrams, for example. If so, why should a representation like that suggested here be used in place of, or in addition to, these other, better established representations?

To answer this question, we point to the original purpose for which the concept of grammar was developed – namely the generation (and recognition) of valid sentences (Newmeyer 1983). Our grammar is a good representation for the purpose of generating useful process design alternatives because it is based on alternative *functional* decompositions of the process. Some process representations – such as logical or algebraic characterization of processes -- are not meant to be used for process design let alone generation of alternatives. Others, such as systems diagrams, can be used for process design and diagnosis, but do not offer strong support for the actual generation of alternatives beyond the local variations that the associated methodology might suggest. The grammatical representation of process, though inferior in some respects to these other representations (e.g. comprehensibility), it excels in the systematic generation of valid combinations from a given set of rules embodying domain knowledge.

REPRESENTING CONSTRAINTS IN THE GRAMMAR

One of the most useful functions that a grammatical approach can serve is to help us identify the constraints that make some combinations invalid ("ungrammatical"). When we find such examples, we can "think backward" about why such combinations are implausible or impractical. By representing them in the grammar, we can prevent them from being generated, thus circumscribing the design space. These constraints are linguistic, psychological, or

sociological in the case of grammars for natural language. They can be categorized as physical, technological, organizational constraints in the case of process grammars (Pentland 1995). In the following, we illustrate how constraints of each type can be represented and identified in the grammar using the sales process design example from the previous section.

PHYSICAL/LOGICAL CONSTRAINTS.

Some process descriptions are logically or physically impossible. A product cannot be delivered before it is manufactured or a physical good cannot be delivered electronically. The grammar should reflect this type of constraint. It can do so by creating different non-terminal categories that correspond to the different properties and have separate rules for them. For example, that is why we distinguish Physical-Goods from Electronic-Goods and have rules such as Deliver Electronic-Goods how -> Deliver Electronic-Goods over-the-web.

TECHNOLOGICAL/ECONOMICAL CONSTRAINTS.

Some possibilities are logically and physically possible, but impossible with current technology. For example, it is not currently possible or at least economically not feasible to remotely detect the potential malfunctioning of a house, but it would be someday. So the above repair-service business model might not work or might not be cost-effective for many of the home appliances now, but it may be soon. Economic constraints are treated in the same manner as technological constraints because from a business perspective, a technology is useless unless it becomes cost-effective.

Again in the grammar, we express a constraint by differentiating non-terminal categories. So we create a category called *remotely-monitorable-and-repairable-product* and update which products belong to that category. It would be desirable to separate categories whose membership would change over time from ones whose membership is fixed by the law of nature or logic. This kind of representational issue provides a variety of interesting research challenges, as discussed in more detail below.

ORGANIZATIONAL/INSTITUTIONAL CONSTRAINTS.

Organizational policies and regulations restrict what is legal and what is not. Tele-marketing may be illegal in some countries, thus *Sell how -> Sell via-tele-marketing* should not be a rewrite rule in the grammar for that organization. Again there should be a way to mark such constraints from other types of constraints so that we are aware of what is invariant across organizations or not. Social institutions also embody "softer" constraints, which may take the form of social norms or values. For example, even among countries where tele-marketing is legal, it may be regarded as unacceptably rude and intrusive in some cultures. In the process grammar,

this can be expressed by either having separate grammars or by using context-sensitive rules. For example, if there is a strong norm against tele-sales in Group A but not in Group B, then the rule *Sell B how -> Sell B by-tele-sales* would ensure that tele-sales would be an option only when the location case of the Sell process is Group B, but not in Group A.

USABILITY OF THE GRAMMATICAL APPROACH

The use of a grammatical approach clearly involves trade-offs. Building a grammar for a given process domain requires significant effort. Furthermore, the rule-based representation may not be easily comprehensible to lay managers. For these reasons, we would expect that the most likely adopters would be individuals whose main job is to understand and analyze processes, such as process consultants and process engineers. These individuals are most likely to be willing and able to invest time in getting used to the grammatical way of thinking and the particular process domain ontology.

It seems clear that, in principle, a grammatical approach embodies a significant improvement on existing techniques for generating process alternatives. The question is whether the potential payoff from this approach is worth the investment. While it does not seem likely that one would want to invest in developing a grammar for a single process design effort, it may be significantly more attractive in situations where the grammar could be re-used. This could occur in situations where a process needs frequent revisions or re-designs, driven by factors such as dynamic networking and mass customization (Miles and Snow 1986; Jarvenpaa and Ives 1994; Lampel and Mintzberg 1996). In an effort to compete more flexibly, many firms are engaging in relationships and transactions that have short duration. It is unrealistic to think of designing a process as solving a problem defined by a static context. As a result, practical guides to reengineering (e.g., Kubeck 1995) emphasize the need for continuous improvement and revision of processes to adapt to changing environments. Like buildings, processes are in constant need of maintenance.

CONCLUSION

Just as you cannot write Othello by randomly generating grammatical sentences, designing a successful organization requires much more than generating a collection of grammatical processes. The approach described here does not substitute for good judgment or analysis. Yet just as grammar reveals many insights into language, we believe that a process grammar can reveal many insights into the process and contribute to effective process design.

A grammatical approach complements the existing approaches in several ways. A process grammar can express, with a relatively compact set of rewrite rules, the invariants of a process (decomposition rule) and its numerous variations (domain-specific rules). Each domain-specific rule focuses on one dimension (case) along which the process can be specialized. Thus, a

grammatical representation provides us with a principled way to represent and organize the existing practices collected, for example, in best practices databases. A process grammar also allows us to go beyond the collection of existing practices and systematically explore various generation of alternative process designs. While context-sensitive rules (e.g. Inform-Potential-Customer locality -> ..) can keep the scope of rewrite rules in the proper domain, context-free rules allow our exploration to go beyond the local variations. Furthermore, because non-terminal categories represent various levels of abstraction in decomposition or in the amount of details, a process grammar allows us to weave our exploration in and out of varying levels of abstraction, not restricted to the surface level (bottom up) or to the top level (top down). Thus it provides an overall framework within which the existing tools such as the process modeling and case-based technologies can be used. Articulating a grammar also enables us to identify the different types of constraints and explore the implications of such constraints or their relaxation.

As Scheer and Allweyer (1999) note, there is a need to shift our emphasis from one time design ("re-engineering") to continuous process adaptation. Thus, an interesting question concerns the time scale for adaptation or re-design. At one extreme, the "reengineering" metaphor seems to suggest one-time changes. At the other extreme, the mass customization metaphor suggests the possibility of a new process for each new transaction. Clearly, some middle ground is appropriate. We believe that an explicit process grammar provides a representation could be adapted to serve a broad range of this continuum. It may not be that helpful for the one-time redesign; but for near-continuous adaptation, it would be essential.

Other topics of research include the identification of grammatical cases for specific processes so that we know what kind of information to collect or how to represent existing processes. Other research would be empirical -- e.g. collecting the data that will provide a basis for the rewriting rules. It will be a hard work, but we believe that the grammatical approach, when buttressed by such work, lays a solid foundation for the study and exploration of process or business model design/redesign from both theoretical and practical perspectives.

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GROUPWARE DESIGN, IMPLEMENTATION, AND USE: A CASE STUDY

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ABSTRACT

Groupware capabilities include e-mail, electronic conferencing, discussion forums, and document handling as well as additional facilities that enable database customization and perhaps help coordinate other groupware and desktop products. Groupware enables individuals to interact, communicate, coordinate, and negotiate to meet company challenges. An extensive body of research on groupware discusses the effects of the software on the organizations that it serves. In most cases, people and organizations have to adapt the ways of accomplishing tasks to fit the groupware. The current case-based study of the Colruyt Company, on the other hand, discusses a groupware specifically designed to fit company, cultural and organizational conditions. Hence, unlike many situations where implementation requires the organization to adjust to the groupware, in this case the groupware was specifically designed to fit corporate conditions. This paper discusses how Colruyt successfully created an organizational culture that enabled its workforce to accept groupware yet still experienced significant difficulties as a result of the implementation of this groupware—difficulties that were only resolved when the company rethought its approach to the use of its customized groupware. This paper should be of interest to managers who contemplate acquiring and implementing groupware.

Keywords: Groupware Design, Groupware Implementation, Groupware Use.

INTRODUCTION

Groupware capabilities include e-mail, electronic conferencing, discussion forums, and document handling, as well as additional facilities that enable database customization and perhaps help coordinate other groupware and desktop products. Groupware is a collaborative tool that requires group members to want to share their work, collaborate, and cooperate. Employees, however, may resist sharing their knowledge because of a culture that stresses personal rewards and a perception that their position depends on their personal expertise (Wasko and Faraj, 2005). Unequal distribution of the effort required to share information is yet one more impediment to using groupware. That is to say, individuals who benefit least from sharing information face the task of making it available to other organizational members who benefit most (Rogers, 1994).

Therefore, obtaining business benefit from groupware can be elusive (Aldenberg et al., 1999; Lou et al., 2006; Orlikowski, 1996; Orlikowski and Yates, 2006).

As far back as the 1990s, researchers have tried to determine the reasons for success and failure of information systems in general and groupware in particular (Halloran et al., 2002; Orlikowski, 1996; Tan and Kondoz, 2008). Halloran et al., (2002) reported the non-uptake of Lotus Notes in a classroom setting. Students in this case used regular e-mail instead of the available Lotus Notes to report on the progress of group assignments. Failure in this case arose from a misunderstanding by tutors and students concerning the value of Lotus Notes. Tan and Kondoz (2008) argued that collaborative systems are often implemented without consulting potential users or without assistance being offered for living with the system. A case study by Orlikowski (1996) exemplifies additional reasons for failure. Alpha, the case company, at the behest of its CIO, implemented Lotus Notes with the purpose of leveraging the firm's expertise. The CIO actively promoted Lotus Notes by giving many presentations describing the software's features. Yet, in spite of these efforts, many employees remained ignorant about why Lotus Notes was installed on their computers at all. Furthermore, a lack of instructions on how to use Lotus Notes proved to be a major obstacle to the use of all the software's features. Users were expected to learn the software on their own personal time, which they refused to do. Even though the firm was initially ill prepared to adopt Lotus Notes, it eventually changed organizational processes that in turn resulted in the company's reaping the benefits from Lotus Notes (Orlikowski, 1996).

In these and other cases, the adoption of groupware has required employees to change the ways of performing—and even understanding—their jobs. When employees refuse to make those changes, adoption of the groupware can be problematic. In another case study involving Lotus Notes, Aldenberg et al. (1999) noted that groupware requires employees to accept more responsibility because they have access to more information. That is to say, because team members have broad access to more information, they have the responsibility to initiate contacts for further needed information, resulting in empowered employees who are then expected to do more for themselves. Furthermore, using Lotus Notes to organize meetings resulted in information capture in the form of meeting minutes and decisions that could be accessed by all relevant staff. This information formed the basis for analysis and review of decisions long after the particular issues discussed were acted on.

An analysis of Colruyt, a large Belgian retailer that designed, implemented and used groupware, provides a counter-example to the typical story of groupware adoption and use. Since its founding in 1965 and before designing and implementing its groupware, the company developed an organizational culture that emphasized devolution of power, decentralization of decision making, and acceptance of responsibility by staff at all levels. One of the most important aspects of the company's organizational culture stressed interpersonal communication, which research shows is essential to enabling collaborative work processes. Given these conditions, it was a natural step for the company to consider using software to support individuals in their daily work assignments. During the early 1980s, the company designed, developed, installed, and

commenced using a groupware with limited features known by the name Interactive System for Information Dissemination (ISID). During ongoing development of the company's culture and information technology, ISID was enriched by the new millennium to a full-featured groupware system that proved essential to the company's daily operation and future expansion.

Unlike the organizational impacts where groupware effects took place within the organization alone, Colruyt's implementation of the software extended outside the firm's boundaries. In particular, the groupware's introduction was one of the reasons for a clash with the unions who in turn used a nation-wide TV broadcast and published a book to make their displeasure known to the buying public (Adele et al., 1984). These actions seriously damaged the firm financially and negatively impacted its brand recognition with clients. This case analysis demonstrates the company's ability to overcome the difficulties just mentioned by using its groupware to improve the relationships with the unions and the buying public.

This paper discusses the Colruyt Company and shows how the company successfully created an organizational culture that rendered its workforce able to accept groupware yet experienced significant difficulties as a result of the adoption and use of the groupware. These difficulties impacted relationships between the company and its employees, clients, and unions in essential ways that ultimately led to a serious set of negative consequences. Finally, actions taken by the firm to overcome the groupware's implementation difficulties are discussed.

PRIOR RESEARCH

Groupware, which features e-mail, calendaring, document management, and task management, has been the focus of attention during the most recent twenty-year period (Aldenberg et al., 1999, Hogarth, 2007; Orlikowski, 1996; Orlikowski and Yates, 2006; Palos, 2012 ; Rogers, 1994). The research focuses on a variety of issues, the most important being the need of organizations for, and difficulties of, obtaining value from groupware. Palos (2012) stated that organizations operate in a "data-centered" economy. Therefore, using groupware to turn data into knowledge is essential to an organization's success and survival.

Groupware's essential purpose is supporting teams drawn from all organizational levels that are engaged in problem solving (Hogarth, 2002, 2007; Grudin, 1994). That is to say, groupware makes possible a change from hierarchical to networked organizational structures (Mark and Poltrock, 2003; Yoo, 1998). Therefore, groupware makes organizations more efficient because, with fewer organizational levels involved, decision-making and problem solving require fewer team members.

Implementing groupware does not automatically lead to its adoption by organizational members. Orlikowski and Hofman (1997) explain that in contrast to ordinary software, implementing groupware is open-ended and context-specific. There are reasons that team members do not wish to work together in a meaningful manner. Denton (2006) and Richardson and Denton (2007) mentioned additional difficulties in getting groups to work together, which is required if

groupware is to be successful. Mistrust is one reason why teams may not want to use groupware. For example, a question that comes to mind is, "Will every team member make the same contribution or will I have to do most of the work in the interest of someone else?" Additional reasons not to cooperate are conflicting goals or a reward system that rewards individual work instead of group performance. The authors suggest that providing members with timely feedback is a way to get groups to work together.

Groupware implementation should attend to the need of groups to be successful. Grudin (1994) highlights several problem areas related to successful groupware implementation. First, groupware necessitates work from employees who may not directly benefit. Calendaring is one function that requires extra work from every employee without explicit payoff. The direct beneficiaries of calendaring are managers who call for meetings. Second, a lack of top management support may cause groupware to not attract a sufficient number of participants. Third, groupware can result in undesirable social behavior. One employee creating a dossier on a colleague would exemplify such behavior. Fourth, groupware requires more careful attention to implementation than other information systems. It has been shown, for example, that "intention to use" usually is a good indication of future application of a software package. This, however, is not so with groupware because it generally requires different ways of working. For example, Grudin (1994) notes that decision-making may be subtle with participants holding hidden agendas. Because these factors must remain unknown to others, they run counter to efficient use of the groupware.

Yoo (1998) also noticed that companies are changing from hierarchical to networked organizations. He argued that the only way to support flat organizations is by groupware. However, the software's success relies on its acceptance by the intended users, something that is far from certain. Yoo conducted a field study based on the technological acceptance model and tested the following hypotheses: 1) People's computer use can be predicted reasonably well based on their intentions measured after a short introductory course, 2) perceived usefulness is a major determinant of people's intentions to use computers, and 3) perceived ease of use is a significant secondary determinant of people's computer use. However, Yoo found that groupware differs in this respect from more traditional computer usage in that intentions to use measured immediately after a short course does not predict use at a later date. In summary, his findings call for an extensive training program before users will embrace groupware.

The review of the research shows that in many cases the organization and the way of achieving results have to change in response to implementing groupware. In the case of the Colruyt Company, the situation is the reverse. That is to say, implementing groupware was the natural outcome of the organization, its corporate culture, and the way of working.

RESEARCH METHODS

The purpose of the research is to gain an understanding of groupware's construction and use by the Colruyt Company, Belgium's third largest retailer. During a twenty-year period starting

in 1993, thirty-four semi-structured interviews were conducted with twenty-four individuals. Seven individuals were interviewed either two or three times. The interviewees included top-level and middle-level managers, operational personnel, union officials and stewards (Table 1). The interviews, on average 1½ hours in length, were conducted in Flemish, tape-recorded and transcribed for later analysis (Wengraf, 2001).

During the interviews, extensive notes were taken of the interviewee's disposition, his/her office environment, and our impressions with respect to the interview. Conducting preliminary analysis immediately after completing each interview proved to be very helpful during later analysis (Patton, 2001). Then, at a later time, the interviews were transcribed to text in their entirety. Each set of interviews served as a basis for structuring new questions, requesting access to additional personnel and attending additional meetings (Table 1). As an additional effort to ensure accuracy, that is to say, descriptive validity, several transcribed interviews were returned to informants for inspection and, when necessary, their correction.

Table 1. Interview Schedule

Interviewee	1993	2000	2001	2003	2006	2010	2012
Director Distribution				X			
Director Marketing	X		X	X			
Former Chief Executive Officer	X			X			
Former Chief Information Officer	X	X					
Former Director Distribution	X			X			
Former Director Marketing	X	X					
Manager Logistics					X		
Manager Marketing				X			
Manager Outsourcing					X		
Manager System Design			X	X	X		
Manager Systems Application					X		
Manager Technical Services			X		X		
Moderator – Human Relations					X		
Current Executive Officer				X			
Current Information Officer				X	X		
Store Clerk	X						
Store Manager	X						
Systems Developer-1					X		
Systems Developer-2					X		
Systems Developer-3							X
Official Socialist Union Headquarters				X			
Official Socialist Union Headquarters						X	
Official Christian Union Headquarters						X	
Union Steward-1			X				
Union Steward-2			X				
Union Steward-3						X	
Union Steward-4						X	

In addition to the interviews some ten meetings were attended which were one to three hours in length. Most meetings had five to fifteen attendees, making tape recording awkward. Therefore, the data gathered was in the form of copious notes taken during the meetings. Moreover, one or more attendees were interviewed afterwards to obtain a better understanding about topics, issues or events that had come up during meetings (Denzin and Lincoln, 1994).

Over four hundred written company records augmented the interview data. These records include the 1975, 1980, 1984, and 1991 to 2012 Annual Reports, minutes of meetings, and company documents published in book form (Penneman, 1985). Furthermore, the Socialist union also published its views in book form, further enriching the interview data (Adele et al., 1984).

Data analysis started while historical documents were gathered and the first set of interviews had been conducted. While studying interview transcripts, annual reports and other internal company documents, we strove to comprehend how actors perceived changes in their environment. Understanding of the subjects' interpretations was based on and validated against the historical background of the broader social, economic, and political conditions in Belgium. This data analysis formed the basis for the second interview round and company record collection. Six sets of interviews were conducted in this manner. Interpreting and understanding human action is essential to the research, and therefore an interpretive research method suited our purpose best. Because of the iterative nature of interpretive research, several hermeneutic circles were completed before arriving at a satisfactory understanding of the data (Klein and Myers, 1999: Remenyi et al., 2000).

THE COLRUYT COMPANY

The company was founded in 1965 when Jo Colruyt became the company's CEO. The Belgian grocery distribution industry had changed because of the rising popularity of supermarkets during the 1950s. These developments led the company to open a "discount store" that reduced costs by making the cash-and-carry concept available to the public. The discount store concept proved a most successful strategy.

The first discount stores were housed in rehabbed buildings. The environment was stark and lacked the ambiance regularly found in other stores. Food items were stored on metal shelves, electrical wiring and other fixtures were left exposed, lighting levels were lower compared to other supermarkets, background music was lacking, and customers had to pack their purchases. Today, the company's stores are newly built, yet the ambiance has been left unchanged. Savings arising from the unadorned store interiors are passed on to the customer.

Today the company operates some 300 stores in Belgium and 44 stores in France and has annual turnover of US $7.8 billion (Table 2). The company's success is noteworthy considering Belgium's business conditions: wide-ranging governmental regulations, domination by large well-established food retailers, paper-thin profit margins, stringent ecological laws, and the presence of three combative unions.

Table 2. Annual Sales (Billions €)/Income (Millions €)/Personnel

Year	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12
Revenue	2.9	3.1	3.8	4.5	4.7	5.0	5.7	6.3	6.8	7.2	7.8
Income	164	203	313	306	320	372	401	430	469	472	485
Employees	11,400	12,400	15,000	16,100	16,500	17,300	18,000	20,000	21,600	24,100	25,200

Mr Colruyt, the company's CEO until his premature death in 1994, resolved that informatization was crucial to ensuring business success:

> "*We organized our first discount store around a revolutionary concept: the immediate integration of the computer [into the entire food distribution chain]. Today, this definitive choice of using informatization in food distribution appears to have been an excellent decision. [Because] of informatization we are more efficient than our competitors. We are convinced that we have a seven-year jump on the competition*." (Jo Colruyt, 1983, pp. 11-21)

The company's informatization in 1965 meant store customers placed food items along with accompanying IBM punch cards in their shopping cart. Store clerks at the checkout register deposited the punch cards in a card reader attached to an IBM tabulator that produced a billing statement for the customer's approval. Later in the 1960s, the IBM tabulator was replaced by an in-store minicomputer. Using these point-of-sales data allowed for automated reordering of supplies from food producers and restocking of stores. In 1987, when the company replaced punch card readers with scanners, the switch was uncomplicated because, unlike its competitors, the Colruyt Company could leave existing back office information systems unchanged.

The company's philosophy with respect to its price guarantee is summarized as follows: "When we promise the lowest price, we are ethically bound to deliver on this promise." A computer software application package keeps track of the company's pricing levels and that of its competitors on a product-by-product basis. A team of Colruyt employees check prices in stores throughout Belgium on a daily basis. These prices, some 44,000 each day, are entered into the company's central computer for further action. If a competitor sells any food item at a price lower than that charged by the company, the price in Colruyt stores is adjusted downward (2012 company Annual Report). Since its inception in 1965 the company has been remarkably successful in beating competing food retailers on price while maintaining profitability. A recent price

comparison study by an independent agency found that Colruyt was less expensive than any of their Belgium-based competitors (www.testaankoop.be, October 2012)

Even though the company engages twenty employees to daily check competitor prices, oversights do occur which may then be noticed by a shopper when he/she visits a competitor's store. Therefore, each company store provides the customer access to a "Red Phone" to report a competitor is charging a lower price for some item. The price for the item in question is adjusted downward immediately. A red label is attached to the item to alert other shoppers that the reduction was made to beat a competitor's price.

Jef Colruyt, who became CEO after his father's untimely death in 1994, continues to focus on price levels. In effect, during times of economic difficulties, low prices are especially important because they encourage customer loyalty. Reichfield and Deane (2004) reported that Colruyt enlarged its customer base thanks to its single-minded attention to price and quality.

In response to the proliferation of ecological legislation, the company in 1990 initiated its "Green Line" charter that focuses on reducing waste in water, air, and soil usage, limiting miles driven by company trucks, reducing noise pollution, and efficiently using space (2011/2012 company Annual Report). An action by a Colruyt employee exemplifies the ecological concern. He noticed that a certain box contained carton dividers to separate wine bottles. His suggestion was that the carton dividers could safely be removed without any deleterious effects to the wine bottles. The measure led to a considerable reduction in waste material. Moreover, a green sticker identifies store items, which are considered environmentally friendly. In addition, shoppers receive information as to why a store item warrants the "Green Line" sticker.

The company invests heavily in advanced technologies. These include innovations for data recording, data mining, automated warehouse systems, automated truck routing systems, logistical systems, and Internet-based bidding and contracting systems that are accessible to pre-approved companies.

COMPANY CULTURE

Jo Colruyt's founding of the company accords with participative ideals that informed corporate culture and norms since the company's origination in 1965. He stated:

> "*We try to develop the company ... work methods and jobs ... avoid alienation ... it enters because of counterproductive conditions under which we are forced to work and by counterproductive organizational forms that subject [people] to oppressing power conditions. [Alienation is] caused also by the absurd manner by which organizations reduce workers to mere robots rather than considering their human characteristics, energy, and emotions*." (Jo Colruyt, April 1984, pp. 53-56)

The company seeks to reduce power asymmetry inherent in hierarchical structures by using temporary work teams where membership is self-selected and anyone with an interest and a need to know can join. Much effort is expended toward rational decision-making that occurs after extensive discussion in work groups.

Since the company's inception, Jo Colruyt and upper management strove toward rational discourse, reducing power differences between company management and employees, and fostering personal initiative toward action at all corporate levels. Striving toward rationality does not preclude attention to consideration of the emotional. Stated Jo Colruyt:

> "*Rationality by itself does not work, the more computers [one] introduces the more one has to pay attention to [human] communication and human relations. [In absence of all this] people will come to behave like computers and that leads to a society that would have no place any longer for humans*." (Jo Colruyt, 1993)

Decision-making and rational discourse require communicative ability resulting in investment in employee education and on-the-job training that is unique in Belgium's retailing industry. During 2006, for example, the company allocated US $300 million (3.3% of its annual wage costs) to train 16,000 employees in, among other topics, corporate and interpersonal communication in the Flemish and French languages, group dynamics, intercultural differences, and information technology (2006 company Annual Report).

A concern for emancipation of and participation in decision-making by employees throughout the company characterizes corporate culture since the company's founding. During the late 1960s behaviorism dominated organizational development thinking. The company's upper managerial team participated in sensitivity training in the expectation that it would make for better interpersonal understanding and communication and improved decision-making. Top management recognized that realizing the benefits of such training required participation of employees at all levels of the company. Stated the former CIO:

> "*Groups composed of individuals drawn from all managerial levels – e.g., Jo Colruyt and an inventory clerk – participated in sensitivity training. It resulted in a complete restructuring of corporate culture and relations between management and workers. We started to discuss the issues that evolved into collaborative decision-making. Then came the realization that what got discussed during meetings needed to be permanently recorded - you instantly grasp the need for communication*." (Former CIO interview, 2000)

According to the former CIO, employees at any managerial level may be impacted by decisions taken during meetings. Therefore, decisions needed to be permanently retained and made available to those affected. These considerations, which took place during the late 1970s, were the rationale for developing and implementing a rudimentary computer-based system that stored and

distributed documents. The system became known as the interactive system for information dissemination (ISID) and was the start of a long series of developments that by the mid-1980s had evolved into a rudimentary groupware package.

ISID's capabilities during the mid-1980s were quite limited. The system's essential abilities were retention of and access to documents, notes, and letters. ISID was entirely mainframe-based and used the VSAM database application software for document storage. Because ISID is crucial to organizational norms, culture, day-to-day operation, and business success, it was consistently improved by adding new functions. During the first decade of the new millennium, ISID was extended to include many more functions.

A major addition was e-mail capability that has two features. In the interest of efficiency, e-mail runs side-by-side with ISID so that users can read e-mail unencumbered by having to scan documents. One kind of e-mail that is not urgent is marked as such and delivered to the recipient once every three hours. The second kind of e-mail is marked as time sensitive and is delivered to the recipient immediately. E-mail that is not urgent can be read at the recipient's leisure, whereas urgent e-mails have to be read on receipt.

The current version of ISID's capabilities is discussed in turn. First, group reports are written by a working group chair, entered into ISID and sent by e-mail to meeting participants. Second, any individual can dictate a message using a tape recorder that is then converted into an ISID memo by the typist pool and entered into ISID. Third, any store clerk with a suggestion for improvement has access to a "Green Phone" to contact the CEO's secretary, who will turn the phone message into a typed document stored in ISID and sent to the appropriate person for further action. Any recipient receiving a "Green Phone" message is obliged to answer the store clerk within three weeks. Several thousand "Green Phone" ISID documents are created annually. Fourth, incoming and outgoing documents are stored in ISID. Fifth, the company has an extensive body of microfiche documents that are presently being converted to ISID documents. Finally, ISID has a calendaring function.

THE CRISIS WITH THE UNION

Since its start as a food discount store in the mid 1960s the firm's personnel count grew from a few hundred at origin to approximately 1,000 in 1975 and 2,400 employees in 1980. Hence, compared to other retailing organizations that employed many thousands of employees, the Colruyt Company was too small to be a focus of unionization efforts. During the '60s and '70s, the firm was considered a startup that, unlike more established retailers, pioneered the use of mainframe and mini computers to support inventory and sales activities. During this early period, the company was fighting to survive and accepting a job at the firm was taking a significant risk. Only individuals believing in the company's eventual success were willing to accept this risk. Such employees strongly identified with the firm and were not particularly interested in joining unions. Moreover, because of the fight to survive, company management was mostly internally focused

and did little to build lines of communication with the unions or society at large. However, over the years the company became more established and continued to grow; by 1983, the workforce had reached some 4,000 workers, a size that drew the attention of the labor unions.

In Colruyt there existed an atmosphere of trust because of great openness concerning the release of information that creates and maintains trust (Former CIO interview, 2000; Former CFO interview, 2010). Starting from the early 1970s employee relationships with the company had changed in accordance with Jo Colruyt's managerial philosophy and company growth. Company change and worker identification also arose from management and employees attending identical seminars:

> "*Identification with the company as long as it (company) is willing to change. The company has to change its orientation … when many individuals attend seminars. That company cannot maintain the same philosophy … it becomes a different organization*." (Jo Colruyt, Former CEO, interview, 1993)

The unions felt the organization's participative character meant workers were constantly pressed to find ways of working that increased efficiency. *Dossier Colruyt* (Adele et al.) even accused the company of Tayloristic tendencies. In short, there was little love lost between the company and the unions:

> *"[The company] has to maintain tight control over informing the workers. Of course the unions have a right to exist, but they should not get exclusivity to inform workers [of topics discussed during meetings]. If that happens [we will] be lost. This happened in the steel industry – the CEO and union delegates felt superior to the workingman. This led to the workingman being informed by the union only. Of course that is catastrophic. Therefore, I instructed the [HR] director not to forget that he negotiates on behalf of Colruyt employees. The union negotiators should not be able to absorb our [HR] director in their little clique. The current [HR] director does an excellent job and communicates directly with our workers concerning negotiations with the unions*." (Jo Colruyt, Former CEO, interview, 1993)

Figure 1 illustrates communicative relationships among the company, employees, clients, and unions before ISID's installation. There are in total six lines of communication: 1) Colruyt versus employees, clients, and unions, 2) unions versus Colruyt, employees, and clients, 3) employees versus clients. First, Colruyt and employees communicate verbally and in written format. Second, Colruyt and clients share a limited written communication channel in the form of in-store fliers. All lines of communication, except Colruyt to clients, union to employees and clients that are written only, are verbal or written.

Figure 1. Communicative Relationships Before ISID

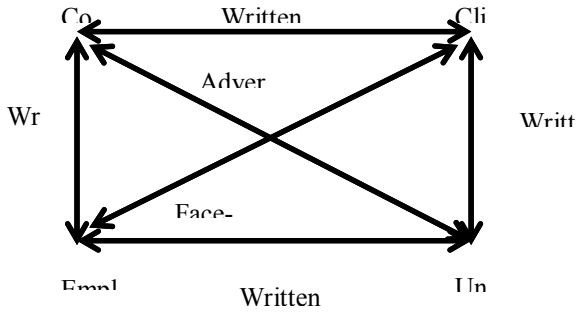
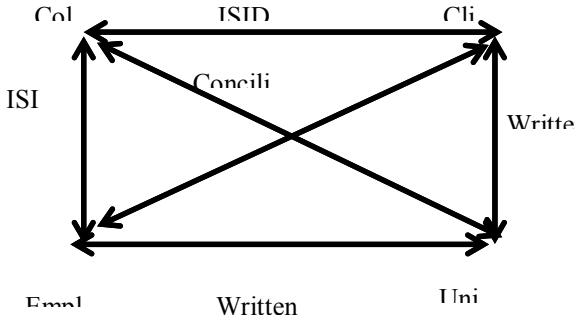


Figure 2 reflects the communicative relationships between company, employees, clients, and unions in an ISID environment. First, Colruyt and employees share verbal and ISID-supported electronic written communication channels. Second, Colruyt and clients share extensive written communication in the form of in-store and Internet announcements. Third, a limited written communication channel between clients and unions existed in the form of, for example, newspaper reports. Fourth, the unions and employees share a limited written communication channel taking the form of documents sent by regular mail. Fifth, employees and clients participated in face-to-face communication. Finally, between Colruyt and unions there are two-way face-to-face exchanges, and written and a company-to-unions one-way ISID-supported communication.

Figure 2. Communicative Relationships with ISID



It is important to notice that the company and the union are necessarily in a dissimilar situation when communicating with employees. Assume, for example, a meeting between the company and the union during which important contracts are discussed. Furthermore, both the company and the union want to inform the employees about the meeting's outcome. Because of the large number of employees the most efficient way for the company to inform them is in written

format using ISID. The union is in a similar situation in that its impressions of the meeting's outcome are also in a written format. The only difference between the two modes of communication is that, unlike management that uses ISID supported- e-mail, the union has to use the public mail system. Thus, management is always first in providing the employees with its version of the meeting with the union.

The efficiency and effectiveness of using ISID to inform workers helped build trust among workers and management because it was seen as assisting the development of that relationship. The unions, on the other hand, did not perceive ISID in a positive light:

> "*The unions could no longer … be the gatekeepers of information which came from the workers and went to top management and vice versa. We in the firm thought the unions should stay out of it … ISID provided support for communication and enabled a [direct] relation between management and workers*." (Former CIO, interview, 2000)

A different union concern involves the evaluation of store clerks by their manager that occurs on a three weeks basis. Both manager and clerk determine the meeting's agenda. The discussion, among other topics, concerns the clerk's activities and difficulties of the previous three weeks and the manner in which the difficulties were resolved. Furthermore, the clerk's activities for the next three-week period are planned and discussed. The union charged that in effect the company establishes a dossier on each employee that is then accessible by searching ISID. The suggestion made is that the dossier is open to misuse and can easily serve to sack someone for reasons unrelated to job performance.

In 1984 the Socialist, Liberal, and Christian Unions published *Dossier Colruyt* (Adele et al., 1894) that listed a series of complaints concerning the firm's working conditions and treatment of employees. The book's publication led to a national television program that seriously damaged the company's name and resulted in a large decline in clients and sales revenue. Among the issues bothering the unions were hiring procedures that used psychological testing procedures, job rotation practices, employee training, working schedules, and the firm's in-house developed information system for information dissemination (ISID). *Dossier Colruyt* claimed that the hiring procedures invaded a job candidate's privacy, and job rotation procedures prevented workers from forming personal relationships with fellow workers and [*sic*] some times were a way to discharge someone. The document's authors considered employee training a form of indoctrination. Another claim was that the company's process of establishing working schedules was inflexible and lacked real worker input (Adele et al., 1984).

The publication described in detail, according to the union, concerns with the company in general and ISID in particular. *Dossier Colruyt* (Adele et al.) stated:

> "*The computer has other applications. A memo [sent to an employee] does not get thrown in the waste paper basket or disappears [sic] in some messy, disorganized file cabinet. No,*

that memo stays in computer memory and gets microfiched. That way it is easy to establish a dossier on someone."

As mentioned, the union participated in a TV program where the concerns were aired nationwide. Both the show and the book's publication were serious blows to the company because its name was besmirched in the eyes of the buying public; that result led to a significant drop in sales revenues and good will.

We emphasize that *Dossier Colruyt* reflected the period during which the Berlin wall still stood and certainly in the Belgian unions Communist influences remained significant (Colruyt, Former Financial Officer, 1992). Commenting on the *Dossier*, Jo Colruyt, the former chief executive officer, reported that the document's author was a Marxist who also led the union. Referring to Marxism, Colruyt stated:

"*Marxism becomes successful by force and terror. The Colruyt Company is successful and therefore I (as CEO) must behave like some Stalin*." (Trends.be, January 14, 1992)

Each company employee received a copy of *Dossier Colruyt*. Fewer than five employees agreed somewhat with the union but the vast majority of workers reacted angrily to the union's charges concerning the company, working conditions, future career prospects, decision-making abilities, and interpersonal relations. Approximately two hundred of such worker responses were collected by the company and published in book form with the title, *There are No Gentlemen Here, Sir*. (Penneman, 1985)

The above description makes clear that the relations between the company and the unions as discussed in *Dossier Colruyt* (1984) and *There are No Gentlemen Here, Sir* (Penneman, 1985) were strongly confrontational. After the publication of *Dossier Colruyt* and union charges made during a nation-wide television broadcast company, management took the initiative. It was recognized that the sole management attention during the previous twenty-year period was on achieving market share, while relations with unions and the public had been neglected. Furthermore, significant numbers of senior management, including the then chief executive officer, were of retirement age and started to leave the company. This resulted in a new management team, the members of which started with a blank slate and improved relationships with the unions and the buying public.

A study of the union's book reveals that several union representatives illegally drew some of its content from ISID. This was also the opinion of company upper management:

"*They [unions] used information from ISID that they had acquired with the help of a radical union steward [who was a company employee and thus had ISID access] to start a campaign of misinformation. They [the union] shifted commas and periods, left out various*

words and sentences in such a way that [ISID] documents took on a different meaning." (Former CIO, interview, 2000)

The reactions among the workers were mixed with some requesting that the perpetrators be sacked and others arguing for strict control of access to information. However, the former CIO recalls, Jo Colruyt was against repressive measures. He was also not in favor of controlling access to ISID either. Instead he said, "We should educate workers to use information responsibly instead of making information inaccessible." After a public debate a clause was included in each employment contract:

"*The employer provides each employee with an extensive system for communication that is based on the daily exchange of confidential or not so confidential memoranda. Any release of information external to the company is forbidden and amounts to breaking the work contract*." (Jo Colruyt, Former CEO, interview, 1993)

Nevertheless, the event made obvious that completely open employee access to ISID created too high a risk for the company that could not be justified. As a result, access to highly confidential information in ISID was restricted. Currently:

"*Seventy per cent of ISID documents are not confidential and 30 per cent are confidential. Anyone in the company has access to non-confidential ISID documents whether he was listed a recipient or not. Twenty per cent are confidential ISID documents [that] can only be read in their entirety by recipients, and non-recipients can only read the keywords [and with special permission the whole document]. The remaining 10 per cent are accessible to recipients only*." (Former Manager of Marketing, interview, 2003)

However, top management realized that restricting access to ISID would not improve its relationships with the unions or the buying public. Jo Colruyt commented:

"*We have marketed the idea of being less expensive. We avoided speaking to the press and the public. We decided not to waste time on such efforts. However, we have conceded that Colruyt has become so large and so well known that we cannot maintain the above attitude. The outside world forces us to informatize in its direction. Absent such action people with much fantasy will make up untrue stories about Colruyt*." (Jo Colruyt, Former CEO, interview, 1993)

Implementing these intentions resulted in an extensive overhaul of organizational philosophy, its relations with the unions, and extensive interaction with the buying public. The

Internet and ISID were keys to successfully achieving the goals of better relations with the buying public and the unions.

Figure 2 illustrates the six necessary steps for conflict resolution without unduly compromising ISID features. First, the company added some mild restrictions on ISID's use by limiting access to 15% of the stored documents. Next, the firm added a statement to employee contracts that laid down sanctions on unauthorized ISID use. Finally, the company used ISID to establish continuous communication with the buying public. The content of this communication varies but it includes the company's actions concerning green energy creation by windmills and store-mounted solar panels.

During the most recent twenty-five year period the company has taken meaningful and significant steps to improve relations with the public and unions. In a country where the population is committed to sustainable development, the company succeeds in being almost 100% energy neutral by creating electrical energy through windmills on its property and solar panels on some four hundred stores.

An interesting example of combining concerns for workers and the ecological environment is the firm's bicycle program:

> "*The 'mobility policy' means the company bought a bike for each employee who wanted one. The company erected a covered building next to the local train station. The purpose of the policy was to enable workers to use the train to come to the railroad station and then use a bike to travel to the workplace. This policy is deeply appreciated by the workers*." (Union Representative, interview, 2010)

The bicycle program leads to reduction in air pollution that would result if workers were to use their cars to report for work.

The company instituted a series of annual working meetings with union representatives. That is to say, the company and the union formed an advisory council that includes representatives of company and union management. Company members of the advisory council meet regularly to inform union representatives of business and financial conditions, planned business initiatives, and information concerning labor conditions such as working schedules, wages and employment. Moreover, management seeks advice on important business decisions from union members of the advisory council. Union members are informed in writing whenever management decides a course of action that deviates from the advice. Most importantly, unlike in the past, the company management no longer considers the union an adversary.

As a result of the actions just described there has been a great improvement of the relations between the company and the unions. Stated a union representative:

> "*The company refrains today from the in-your-face confrontation and plays the role of the 'conciliator*." (Union Representative, interview, 2010)

Moreover, interviews with company managers confirm a greatly improved relationship between the company and unions. One union official stated his wish to continue in good relations with the company:

> *"… A book was written and this led to a situation that we don't want anymore. We are very concerned about the press … the press has been used extensively [by Colruyt] to improve public relations. We are the largest union and represent the large majority of Colruyt employees. The last thing we want to do is have [bad relations with the company]."* (Union Official, interview, 2010)

In addition to the two issues just mentioned, relations between store clerks and clients are as they have always been, that is to say, face-to-face. Communication between the union and employees occurs via an Internet site. Communication between the union and clients is by written mode only and seldom takes place. In the interest of the company, the four communication streams shown in Figure 1 were changed to those in Figure 2.

DISCUSSION

Business is in an age of flux and ambiguity, where "the quickening pace and deep consequences of globalization for innovation and wealth creation are not fully understood" (Tapscott & Williams, 2006, p. 28). In fact, we are past the tipping point: "Mass collaborations are changing how goods and services are invented, produced, marketed, and distributed" (p. 10). The consequences are not yet fully understood due to rapid, never pausing changes in the ways that businesses use technology. Tapscott and Williams argue that one force that is disrupting the status quo in business is peer production communities "where the basic rules of operation are about as different from a corporate command and control hierarchy as the latter was from the feudal craft shop of the preindustrial economy" (p. 25). Groupware is an example of technology that allows collaborative communities. The authors predict that emerging digital tools like groupware will continue to rapidly expand global net collaboration and create business solutions.

Rogers (1994) contends that achieving collaboration among individuals requires modifying working practices and customizing groupware so as to agree with corporate norms. Rogers further states that this process of co-evolution is complex, likely to run into many obstacles, and may even overwhelm an organization. Our analysis of ISID's construction and implementation demonstrates that the Colruyt Company's needs were in effect the driving force behind ISID. To illustrate, during an ISID planning meeting attended by one of the three authors, an IT design manager defined the responsibilities of his design group as follows:

> "*I am responsible for the ISID [design] group's planning such that the [Colruyt] organization obtains in a timely manner [collaborative and communicative] services that are optimal in terms of performance, quality, and cost. In [close] collaboration with [ISID] users I have a responsibility for constructing a vision for ISID that optimizes its potential while keeping in mind technological limitations*." (IT Design Manager, interview, May 2006)

According to Grudin (2006) top-level managers were always crucial to selecting and obtaining software packages but they hardly ever operated or interacted with the software. Grudin (2006) further remarked that managers were frequently technologically ill-prepared to use computer software applications. Finally, Grudin (2006) claimed that top-level managers would insist that software should always support their information needs. Our analysis demonstrates that individuals at all managerial levels as well as operational personnel at the Colruyt Company are active and daily groupware users who also engage in asking the IT department to extend ISID's features when work processes require it.

To illustrate, during a planning meeting attended by one of the authors, users brought to the attention of the design group some concerns about ISID's email service. Users stated that the great number of emails overwhelmed them without actually knowing which were urgent, needing immediate responses, and which could be read at a later time. Users further stated that not knowing which emails were urgent obliged them to read all incoming emails frequently. That, in turn, interfered with discharging work assignments. To resolve these problems users suggested adding a command to the email service that separate urgent emails from non-urgent emails. Thus, a user could choose between sending his/her email either as urgent or non-urgent. A further stipulation was that urgent emails were to be sent immediately and non-urgent ones on a three-hour basis. The users' request was installed during regular ISID updates.

Palen and Grudin (2002) questioned whether groupware can be successful if its use is discretionary. These authors argued that collaboration technology adoption is compromised by having to be attractive to all corporate members without receiving long-term top-down support. They further claimed that in the case of groupware widespread availability is a necessary but not sufficient condition for successful adoption. The Colruyt Company's groupware ISID was designed in response to and in support of existing and developing corporate practices. Moreover, even though a mandate for ISID's use is lacking, no Colruyt Company employee can successfully participate in his or her day-to-day employment without using this groupware. Thus, the Colruyt Company avoided the problems cited by Palen and Grudin (2002) by implementing a groupware that responded effectively to widespread processing needs.

CONCLUSION

Many case studies analyze and discuss reasons why groupware is often not used to its full potential. After a close reading of the literature on groupware, we detected few recommendations that would result in the successful implementation of groupware. This paper illustrates the far-reaching consequences resulting from implementation of a groupware package. These consequences affected relationships that went far beyond the company and included relationships between the company and its employees, clients, and unions in essential ways that ultimately led to a serious set of negative consequences. These consequences were resolved only with the company's willingness to totally rethink its approach to the use of its groupware and the business.

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