DECISION SCIENCES INSTITUTE

Midwest Region

# 2015 MIDWEST DSI ANNUAL CONFERENCE PROCEEDINGS

**Ashland University, Ashland, OH**
**April 25, 2015**

# MWDSI 2015 Detailed Schedule

Friday, April 25, 2015

| TIME | Ridenour Room | Room 105 |
|---|---|---|
| 7:30 – 8:00 | Registration (Lobby) | |
| | | |
| 8:00 -8:50 | Context Scenarios for Teaching Cynefin Framework to Management Students by Khushwant Pittenger | Words Do Matter: Exploring Consumer's Willingness to Pay Premium Price using Text Analysis by Nitin Walia |
| 8:00 -8:50 | Small Business Still Missing the Boat on Social Media and Internet Advertising by Daniel Sullivan | Case Study of CPFR by Robert Stoll & Joseph Mucatello |
| 8:00 -8:50 | Health Information's Role in Deciding on Health Issues by Jonathan Albaugh | Health Informatics Research Paper by Taylor Campbell |
| | | |
| 9:00 -9:50 | Keynote Speaker 1<br>Ron Emery<br>The Dysfunctional Organization | |
| | | |
| 10:00 -10:50 | Treating Epistaxis: A case study examining systemic efficiency, demographics, and economics by Joe Binder | Enhancement of your Online Organizational Development Course with a Business Strategy Project and Video Discussion Forums by Debra Westerfelt |
| 10:00 -10:50 | Systematic Study of Error In Approximations To the One-Sided One Sample K–S Sampling Distribution by Ceyhun Ozgur | Analytic and Heuristic Modeling in Financial Turbulence by George Chang |
| | | |
| 11:00 -11:50 | Political Party Affiliations and Municipal Debt Obligations by Candice Vander Weerdt | Modeling Delivery Performance In Make-To-Order Supply Chains by Alfred Guiffrida |

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|---|---|---|
| 11:00 -11:50 | Promoting Lean Manufacturing through an Emphasis on Environmental Benefits at the Collegiate Level by Chris Harris | Are lean principles applicable to academic processes in higher education? By Daniela Todorova |
| Noon – 1:30 | Lunch & Awards<br>Keynote Speaker 2<br>Brandon Ritchie | |
| 1:30 – 2:15 | The Impact Of The Information Category On The Information Security And Privacy Concern – A Literature Review by Xiaodong Deng | The Analysis of Risks and Value in Information Systems by David Chou |
| 1:30 – 2:15 | Lean Productivity Enhancements and Waste Elimination through Emerging Technology by Gene Fliedner | An Experiment to Assess the Effect on Investing of Switching Auditors from Big 4 Firms to Regional Firms by Arnold Schneider |
| | | |
| 2:20 – 3:00 | A Study on Behavioral Decision Making under Supply Chain Disruption by Sanjay Kumar | Selection of Statistical Software for Solving Big Data Problems for Teaching by Ceyhun Ozgur |
| 2:20 – 3:00 | Towards Agile System Analysis & Design by Amber McConahy & Abhijit Dutt | Adapting an Original Model of Lean Manufacturing Implementation to Rural Medical Practices by Chris Harris |
| 3:00 - 4:30 | | MWDSI Board Meeting |

**KeyNote Speaker 1**

Ron Emery has spent over two years trying to capture a number of personal experiences to include in The Dysfunctional Organization. Fixing broken businesses is difficult, considering the stakeholders still have ownership of the processes and are reluctant to give up control to allow the business to grow and be successful. Based on his "over 25 years of executive experience and his consulting experience," Ron knows how to look for the root cause of the issues and get straight to the remedy. "Many times we try to fix the problems, without understanding the systemic issues that caused the problem in the first place…long story short we will be fixing the problem again and again…"

The Dysfunctional Organization by Ron Emery is a look into many organizations and their reason for lack of competitiveness. Ron has worked with a number of medium to large organizations in a variety of industries over the past thirty years and shares his experiences with the reader on how to make them more competitive.

Ron explains what he has found to be the root cause of many issues within an organization, for example, politics, lack of teamwork, setting the wrong objectives and accepting and rewarding the wrong behaviors. Process development and understanding is key to drive business performance and you can't improve what you don't measure. Some of the reasons for the dysfunction are be-yond the organizations control while others are well within its grasp to change. This is a guidebook for those who want to uncover what might be wrong with most organizations today and how to address them with systemic actions that will allow for peak performance.

We in the US can be competitive once again and can return to unparalleled prosperity if we learn to address our inability to lead and step back and realize years of mismanagement of our businesses have lead us to this point. Ron will take us through his years of experience and how we can watch for the pitfalls of our predecessor's mistakes and prepare for success moving forward. He will show how to reward the proper behavior that will make an organization successful.

There will be time for dialogue and questions as well.

**Keynote Speaker 2**

Brandon Ritchie is a Banking & Financial Markets Analyst at the Federal Reserve Bank of Cleveland (FRBC) where he monitors potential risks and emerging trends in the financial system. He graduated from Ashland University in 2012 with a bachelor's degree majoring in finance, and after, he worked as a Personal Lines Underwriter at Westfield Insurance before joining the Federal Reserve in 2013 as a Statistics Analyst. During his career with the Federal Reserve, Brandon was recognized with the FRBC Premiership award in 2014 for his innovation in financial modeling and data analysis, and his recent data research on the current state of banking conditions will be published in an upcoming article from the FRBC. He currently lives in Northfield, OH and can be reached at Brandon.L.Ritchie@clev.frb.org.

**Conference Best Paper Award**

Modeling Delivery Performance in Make-To-Order Supply Chains by Alfred Guiffrida

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# MODELING DELIVERY PERFORMANCE IN MAKE-TO-ORDER SUPPLY CHAINS*

Alfred L. Guiffrida, Kent State University, Kent, Ohio, USA, aguiffri@kent.edu
Thomas Ngniatedema, Kettering University, Flint, Michigan, USA, tngniate@kettering.edu
Peter A. Reday, Youngstown State University, Youngstown, Ohio, USA, pareday@ysu.edu

**Winner of the Best Paper Award at the *2015 Midwest Decision Sciences Conference*, Ashland, Ohio, April 23-24, 2015**

## ABSTRACT

The delivery process plays a fundamental role in the overall operation of a supply chain and is integral to maintaining customer goodwill. Current models for evaluating delivery performance in serial supply chains are restrictive in that they are applicable only to make-to-stock ordering policies. In this paper we present a generalized supply chain delivery model that can be used to evaluate delivery performance for supply chains operating under both make-to-order and make-to-stock ordering policies. The model is demonstrated using a Monte Carlo simulation.

Keywords: Supply chain delivery performance, Performance measurement

## I. INTRODUCTION

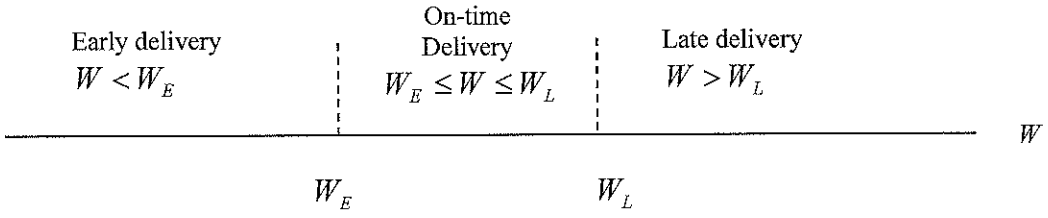
In response to competitive pressures, many firms have adopted the supply chain management (SCM) philosophy as the foundation of their strategic initiatives. Performance measurement plays a key role in the implementation of the SCM philosophy and assists managers in meeting short term day-to-day objectives as well as long term strategic goals (see for example Sillanpää, 2015; Mackelprang et al., 2014; Ramaa et al., 2013). Frameworks for measuring supply chain performance are found in Chelariu et al. (2014), Cuthbertson & Piotrowicz (2011), Azevedo et al. (2011) and Chan et al. (2006) with specific metrics used in measuring supply chain performance are reviewed by Anand & Grover (2015), Gopal & Thakkar (2012), Sambasivan et al. (2009) and Gunasekaran & Kobe (2007).

As identified in Suwignjo et al. (2000) and Bititci et al. (2001) quantitative models are needed to support a formal performance measurement system. In this paper we develop a quantitative model for measuring on-time delivery performance to the final customer in a serial supply chain. The delivery process within a supply chain is of critical concern to supply chain managers since delivery performance directly

impacts customer satisfaction levels (Bushuev & Guiffrida, 2012; Chapman et al., 2011; and Forslund et al., 2009). Delivery performance is also a major component of the Supply Chain Operations Reference (SCOR) model (Huan et al. 2004; Brewer et al., 2000). Numerous empirical studies have also demonstrated the high level of importance that supply chain managers place on delivery performance (see for example, Vunjak et al., 2013; Boon-itt & Wang, 2011; Golini & Kalchschmidt, 2010). As a time-based measure, delivery performance within supply chains is typically evaluated with respect to a customer defined delivery window (Tanai & Guiffrida, 2015; Shin et al., 2009; Garg et al., 2006).

Based on a delivery window, the customer defines benchmarks in time to which deliveries are classified as being either early, on-time or late (see Figure 1). Penalty costs per unit

Figure 1: Illustration of Delivery Window.




Legend: $W$ = random variable defining delivery time
$W_E, W_L$ = benchmark times defining early, on-time, and late delivery

time for early and late deliveries are assigned contractually with no penalty cost assigned for 'on-time' deliveries (Schneiderman, 1996). For a delivery time of length $W$, the duration that the delivery is early ($W_E - W$) or late ($W - W_L$) can be translated into an expected cost of failing to deliver on-time. Early deliveries are subject to a per unit time penalty cost of $C_E$; late deliveries are subject to a per unit time penalty cost of $C_L$. Using the cost-based model defined in Guiffrida and Nagi (2006), the total expected cost ($TEC$) for untimely (early and late) delivery is found by summing up the product of early and late delivery durations weighted by their probability of occurrence, $p(W)$, and is defined as

$$TEC = C_E \sum_{W<W_E} (W_E - W) p(W) + C_L \sum_{W>W_L} (W - W_L) p(W). \quad (1)$$

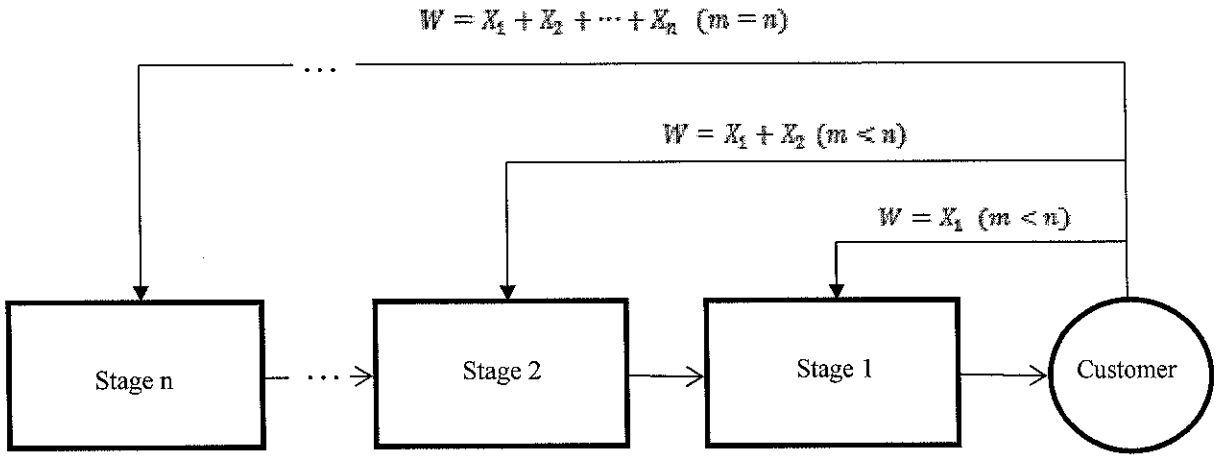
A comprehensive review of cost-based supply chain delivery models that use delivery windows to measure and improving delivery performance is found in Guiffrida (2014). The models reviewed in Guiffrida (2014) are limited in that the models only allow for a make-to-order (MTO) orientation of product flow in the operation of the supply chain and ignore make-to-stock (MTS) product flows. A MTO product flow is characteristic of a pull-type supply chain where the product flow visits all stages on the supply chain whereas a MTS orientation is characteristic of a push-type supply chain where the product flow visits only a subset of the stages defining the supply chain. Birou et al. (2011) identify that differences exist in the return on internal process improvement investment between firms who operate under MTO versus MTS operating policies. Hence, generalizing supply chain delivery performance models to accommodate both MTO and MTS product flows may contribute to improving overall supply chain performance.

In this paper we propose a generalized supply chain delivery performance model that can be used to evaluate delivery performance for both MTO and MTS product flows. The rest of this paper is organized as follows. In Section II we introduce a generalized model structure that can be used to capture the expected cost of untimely delivery in both MTO and MTS supply chains. In Section III we present numerical illustrations of the model using Monte Carlo simulation. Concluding remarks and directions for future research discussed in Section IV.

## II. MODEL DEVELOPMENT

Consider the n-stage supply chain illustrated in Figure 2. Let the random variable $X_i \ (i = 1,2,\ldots,n)$ define the independent activity completion time of the $i^{th}$ stage of the supply

Figure 2: Illustration of Make-To-Order and Make-To-Stock Supply Chain Deliveries.




chain. Under a pure MTO product flow all $n$ stages of the supply chain are involved in satisfying the customer's order and the delivery time to the customer is defined as $W = \sum_{i=1}^{n} X_i$. The functional form of the underlying probability density/mass function for distribution of delivery time $W$ is found by evaluating the n-fold convolution of the probability density/mass functions of the stage activity times $X_i$.

Under a MTS orientation, the number of stages required to fulfill the customer's order becomes a random variable $m$ and takes on values $m < n$ with probability $p(m)$. When the number of stages being summed becomes a random variable, the total delivery time $W$ becomes a *random sum* of independent random variables. The convolution of a random sum of independent variables is typically intractable. Hence, we adopt a Monte Carlo simulation methodology to approximate the true form of the probability density/mass function governing the delivery time distribution of $W$. Under the Monte Carlo methodology, activity times are sampled from the probability density/mass function defining each stage activity time. Over a series of trials the empirical distribution for the delivery time distribution of $W$ can be determined and for a given set of parameters defining the delivery window ($W_E$, $W_L$) and the per unit costs of early and late delivery ($C_E$, $C_L$), the total expected cost of untimely delivery can be evaluated using (1).

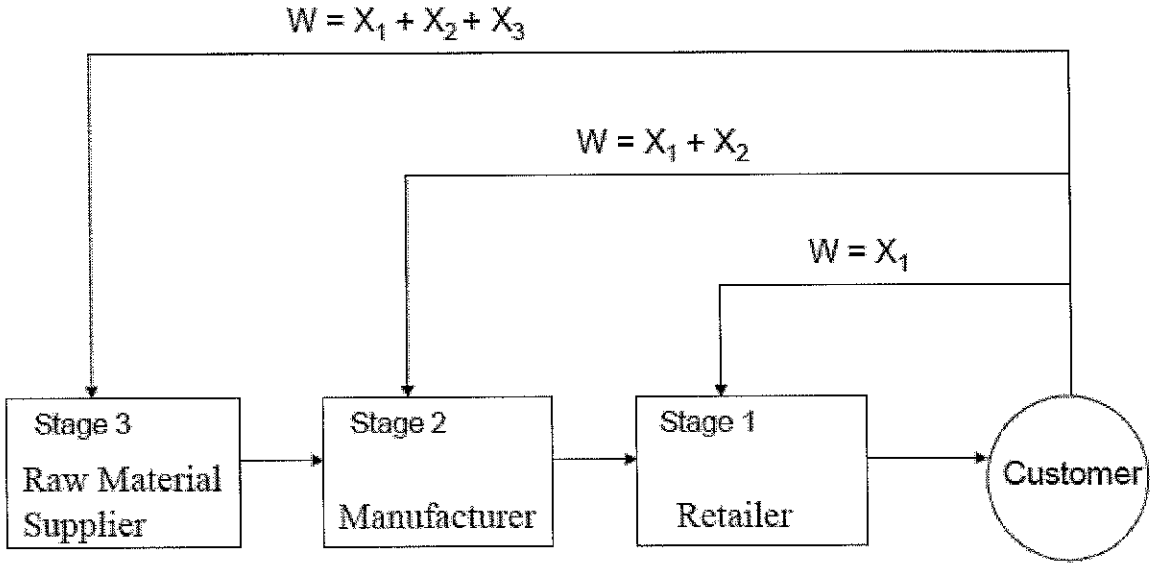
Excel was selected to conduct the Monte Carlo experiments since the array of implicit and user defined functions allows for the convenient modeling of both heterogeneous and homogenous random sums of random variables. A summary of generators available in Excel is found in the Appendix I.

Our generalization the supply chain delivery performance model has the following features: (i) the activity time at any stage of the supply chain may be a discrete and/or continuous random variable, and (ii) the order environment may be MTS or MTO. Under the first feature of our model, delivery time $W$ can be defined in terms of a sum of heterogeneous random variables as opposed to supply chain delivery models found in the literature where $W$ is defined as the sum of homogenous random variables such as the Gaussian. The second feature of our model (as illustrated in Figure 2) allows for the number of stages defining $W$ to also be a random variable thereby defining $W$ as a random sum of heterogeneous random variables which allows the model to represent both MTS and MTO environments.

***Model Application***

Consider the three-stage supply chain defined in Figure 3. The following hypothetical example was used to illustrate the model. All times were in days and we considered only one product for which no order crossing

Figure 3: Delivery Time Realizations for a Three Stage Serial Supply Chain.



occurs in the stream of deliveries. Let $p_i$ (i =1, 2, 3) identify the probability that the customer's order visited upstream stage *i*. The probabilities were assigned as $p_1 = 0.3$, $p_2 = 0.5$, $p_3 = 0.2$. Stage activity time $(X_i)$ are defined in Table 1. Let all delivery times be referenced from a current time of calendar day zero with the on-time portion of the delivery window defined as $W_E = 6$ and $W_L = 8$. The penalty costs per day for early and late delivery are $C_E$ = \$50 and $C_L$ = \$200. An Excel spreadsheet dashboard was created to summarize the results of the Monte Carlo simulation experiment. As illustrated in Figure 4, the dashboard provides cost information on delivery performance and descriptive statistics for the resulting delivery time distribution of *W*. Only the first five trials (out of 1500 trials) of the simulation are presented in Figure 4 to illustrate the logic used in the simulation of the supply chain defined in Figure 3.

Table 1: Generator Definitions for Model Illustration.

| Stage | Form of Generator | Parameterized Generator |
|---|---|---|
| 1 | Lognormal<br>$X_1 = LOGINV(rand(\ ), \mu, \sigma)$ | $\mu = 1.8, \sigma = 0.33$<br>$X_1 = LOGINV(rand(\ ), 6.5, 1.4)$ |
| 2 | Uniform<br>$X_2 = a + (b-a)*(rand(\ ))$ | $a = 2, b = 5$<br>$X_2 = 2 + (5-2)*(rand(\ ))$ |
| 3 | Discrete<br>$X_3$: 4 6 11<br>$P(X_3)$: 0.2 0.5 0.3 | = IF(rand()≤0.2, 4, if(rand()≤0.7,6,11)) |

Figure 4: Spreadsheet Dashboard for Numerical Illustration.

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Monte Carlo Simulation of Three Stage Supply Chain (1500 trials)** | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | **Parameters** | | | **Expected Cost per Delivery** | | | | **Statisitcs on W** | | | | |
| 4 | W_E | 14 | | Early | $122 | | | Mean | 11.4 | days | | |
| 5 | W_L | 17 | | Late | $58 | | | Stdev | 4.7 | days | | |
| 6 | P1 | 0.2 | | Total | $181 | | | Skewness | 0.7 | | | |
| 7 | P2 | 0.5 | | | | | | Kurtosis | 0.1 | | | |
| 8 | P3 | 0.3 | | | | | | | | | | |
| 9 | QH | $50 | | | | | | | | | | |
| 10 | K | $200 | | | | | | | | | | |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | Trial | Stage 1 | | Stage 2 | | Stage 3 | | | | | Costs per Delivery | |
| 14 | Number | RN | X1 | RN | X2 | RN | X3 | RN | W | Early | Late | Total |
| 15 | 1 | 0.044 | 3.4 | 0.284 | 2.9 | 0.945 | 11.0 | 0.814 | 17.3 | $0 | $60 | $60 |
| 16 | 2 | 0.715 | 7.3 | 0.768 | 4.3 | 0.388 | 6.0 | 0.257 | 11.6 | $120 | $0 | $120 |
| 17 | 3 | 0.967 | 11.1 | 0.992 | 5.0 | 0.812 | 11.0 | 0.762 | 27.1 | $0 | $2,017 | $2,017 |
| 18 | 4 | 0.695 | 7.2 | 0.286 | 2.9 | 0.496 | 6.0 | 0.850 | 16.0 | $0 | $0 | $0 |
| 19 | 5 | 0.406 | 5.6 | 0.382 | 3.1 | 0.589 | 6.0 | 0.486 | 8.7 | $263 | $0 | $263 |

Based on the parameters used, the simulation indicated that the typical delivery will incur an expected penalty cost (*TEC*) of $181 due to untimely delivery. This evaluation provides management with a benchmark that is stated in the easy to understand metric of expected cost. This benchmark can be used as an input to a continuous improvement program to increase customer satisfaction through the elimination of early and late deliveries.

For planning purposes, the analyst may want to generalize the simulation results into a best fitting distribution for representing the distribution of delivery times W. One method for selecting a fitting form is to apply the method of moments to identify a fitting distribution. For the simulation run conducted, the sample coefficients of skewness $(\gamma_1)$ and excess kurtosis $(\gamma_2)$ for the coordinate pair $(0.7,0.1)$ which suggests that for the current parameter set used in the simulation that the delivery distribution $W$ can be represented by a Weibull probability density function (see Appendix II). The analyst could then explore maximum likelihood estimation to determine the estimates needed to parameterize the Weibull probability density function.

## IV. SUMMARY AND CONCLUSIONS

Measuring delivery performance with respect to a customer's stated delivery window is a critical input to the continuous improvement of the delivery process in a supply chain. When an early or late delivery occurs, management can study the delivery process and determine the assignable cause(s) for the untimely delivery. Corrective actions can be initiated, and as a result of studying the delivery process, process improvements can be implemented to remove the cause(s) of untimely delivery. A short list of action items for improving the delivery process included: (i) the suppliers gaining tighter control over process flow times, (ii) enhanced coordination of freight transport, (iii) more efficient material handling of outbound and inbound stock by at the stages of a supply chain, (iv) implementation of electronic data

interchange (EDI), and (v) improved communications between both supply chain stage members [13].

Improving delivery performance requires financial resources. In the model presented herein, we use a total expected cost metric (*TEC*) to model the cost incurred due to untimely (early and late) delivery. The *TEC* metric provides management with a bound on the financial investment needed to eliminate untimely delivery. The model presented herein can be applied to determine the *TEC* for serial supply chains operating under a MTS or MTO orientation. This attribute of the model bridges a gap found in the literature on cost-based supply chain delivery performance models.

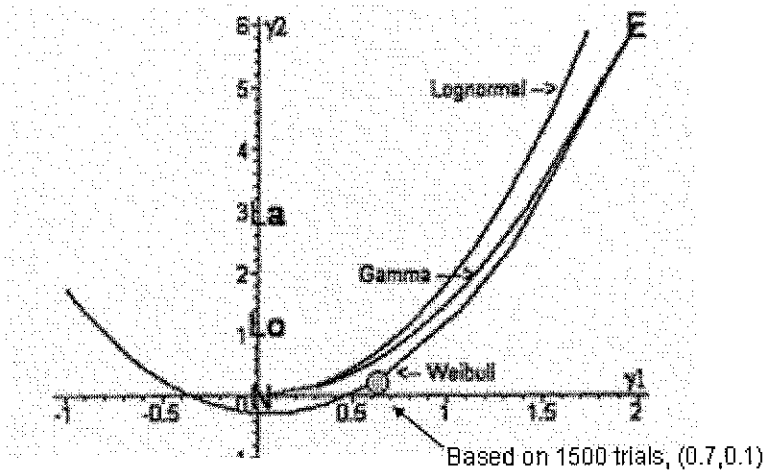
In future research we will investigate extending the model to fit multiple products and different numbers of stages. Further research will also investigate the parametric sensitivity of the final delivery distribution as a function of the levels of skewness and excess kurtosis of the summand stage densities, the width on the on-time portion of the delivery window and the ratio of the penalty costs for early and late delivery.

**Appendix I: Excel Continuous and Discrete Generators for Monte Carlo Simulation.**

| Generator | Formula | Parameters |
|---|---|---|
| beta | $= BETAINV(rand(\ ), \alpha, \beta)$ | $\alpha =$ shape; $\beta =$ scale |
| exponential | $= -(1/\beta) * LN(rand(\ ))$ | $\beta =$ mean |
| gamma | $= GAMMAINV(rand(\ ), \alpha, \beta)$ | $\alpha =$ shape; $\beta =$ scale |
| Gaussian | $= NORMINV(rand(\ ), \mu, \sigma)$ | $\mu =$ mean; $\sigma =$ standard deviation |
| lognormal | $= LOGINV(rand(\ ), \mu, \sigma)$ | $\mu =$ mean; $\sigma =$ standard deviation |
| uniform | $= a + (b - a) * (rand(\ ))$ | $a =$ minimum value; $b =$ maximum value |

| | | |
|---|---|---|
| general discrete | X p(X)<br>$x_1$ $p(x_1)$<br>$x_2$ $p(x_2)$<br>$x_3$ $p(x_3)$ | $X$ = IF(rand() ≤ $p(x_1)$, $x_1$, IF(rand() ≤ [$p(x_1)$ + $p(x_2)$], $x_2$, $x_3$)) |

**Appendix II: Skewness and Excess Kurtosis Plane, Guiffrida et al. (2004).**




Legend: N (Gaussian), Lo (Logistic), La (Laplace), E (exponential)

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# SELECTION OF STATISTICAL SOFTWARE FOR SOLVING BIG DATA PROBLEMS FOR TEACHING

Ceyhun Ozgur, Valparaiso University
Min Dou, Valparaiso University
Yang Li, Valparaiso University
Grace Rogers, Valparaiso University

## ABSTRACT

The need for analysts with expertise in big data software is becoming more apparent in today's society. Unfortunately, the demand for these analysts far exceeds the number available. A potential way to combat this shortage is to identify the software sought by employers and to align this with the software taught by universities. This paper will examine multiple data analysis software—Excel add-ins, SPSS, SAS, Minitab, and R—and it will outline the cost, training, statistical methods/tests/uses, and specific uses within industry for each of these software. It will further explain implications for universities and students.

**KEY WORDS:** Big Data, Excel, R, SAS, SPSS, Statistical Software

## INTRODUCTION

Welcome to the age of big data, a revolutionary era where technology has transformed how businesses make decisions. According to a report by the McKinsey Global Institute, a trusted advisor for many influential businesses, "decision making will never be the same; some organizations are already making better decisions by analyzing entire datasets from customers, employees, or even sensors embedded in products" (Manyika et al., 2011, 5). In addition to intuition and judgment, businesses now use various software to draw conclusions from data sets and to thereby make decisions.

Surprisingly, schools do not teach students the same software that businesses look for. In his article that measures the popularity of many data analysis software, Robert Muenchen notes that discovering the software skills that employers are seeking would "require a time consuming content analysis of job descriptions" (Muenchen, 2014). However, he finds other ways to figure out the statistical software skills that employers seek. One of these methods is to examine which software they currently use. Muenchen includes a survey conducted by Rexer Analytics, a data mining consulting firm, about the relative popularity of various data analysis software in 2010. The results of the survey are pictured in Figure 1. As seen, data

miners use R, SAS, and SPSS the most. Because users of R, SAS, and SPSS are the most among all the software, it can be inferred that these are the software skills that the greatest proportion of employers will continue to look for. However, this method only examines the software that employers might seek if they

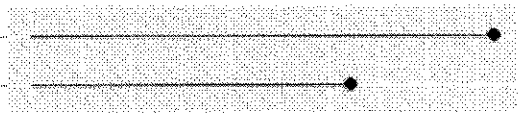
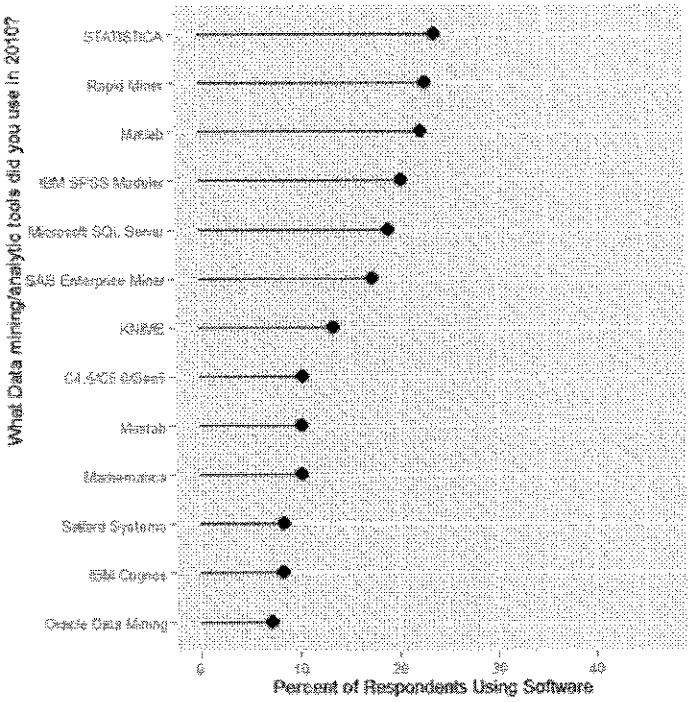
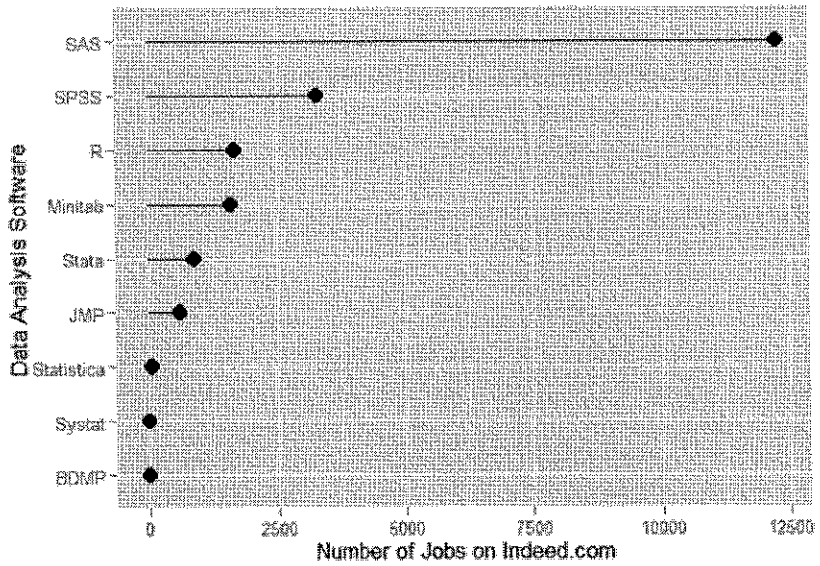



**FIGURE 1: 2010 REVER ANALYTICS SURVEY RESULTS OF ANALYTIC TOOLS (Muenchen, 2014)**




are hiring, so it does not accurately measure the software that they currently look for. Muenchen's other method does this, studying software skills that employers currently seek as they try to fill open positions. In this approach, Muenchen puts together a rough sketch of statistical software capabilities sought by employers by perusing the job advertising site, Indeed.com, a search site the comprises the major job boards—Monster, Careerbuilder, Hotjobs, Craigslist—as well as many newspapers, associations, and company websites (Muenchen, 2014). He summarized his discovery in Figure 2.

**FIGURE 2: JOBS REQUIRING VARIOUS SOFTWARE (Muenchen, 2014)**




As seen—in contrast to R's greater usage by companies over SAS, illustrated in Figure 1—job openings in SAS substantially lead open positions that require any other data analysis software. For employers, SPSS and R skills finish in second and third place. This second estimation method of Muenchen measures the software skill deficits in the job market. It seems that the demand for people with SAS skills outweighs the number of individuals with this capability. One reason for this disconnect could be that colleges and universities are not teaching SAS skills in proportion to the demand for these skills.

To assess this potential disconnect, we surveyed eighteen departments—small and large, state and private, undergraduate and graduate, East and West—and, as expected, we discovered a discrepancy between the software taught and the software sought. The survey results are outlined in Table 1. The responses indicate that although SAS boasts a commanding lead in job openings, data analysis software taught at universities does not reflect this dominance. Only a few more departments teach SAS than R or SPSS. Some departments do not teach any software at all! Although this survey has a small sample size, the results do roughly sketch a trend seen in quantitative, engineering, and business departments across the country. College and university departments have not aligned their use of statistical packages to the skills demanded by employers.

**TABLE 1: RESULTS FROM A SURVEY OF STATISTICAL SOFTWARE PACKAGES TAUGHT (Compiled by Kleckner, 2014)**

| School | Department | Software Taught at Grad Level | Software Taught at Undergrad Level |
|---|---|---|---|
| Large, Midwestern, State University | Actuarial Science | SAS, Excel, Mathematica | SAS |
| Medium, Southeastern, Private University | Biostatistics | SAS, SPSS, Minitab, Mathematica, Fortran, StatExact, Spatial Stat, C, C++ | No Undergraduate Program in Biostatistics |
| Small, Southern, Private University | Computational and Applied Mathematics | Matlab, C, C++ | Matlab, C, C++ |
| Small, Midwestern, Private College | Mathematics | No Graduate School | SPSS, Excel, Minitab, Mathematica |
| Large, Midwestern, State University | Mathematics | None | none |
| Medium, Northeastern, Private University | Mathematics | SAS, R, JMP, Matlab, DataDesk, ActivStats* | SAS, R, JMP, Matlab, DataDesk, ActivStats* |
| Small, Midwestern Private University | Mathematics & Computer Science | N/A | SAS, Excel |

| | | | |
|---|---|---|---|
| Medium, Northeastern Private University | Statistics | SAS, R, Excel, Minitab, JMP, Matlab, Python | N/A |
| Small, Southern, Private University | Statistics | SAS, SPSS, R, Excel, JMP, Matlab, Mathematica, Stata | JMP, Stata |
| Large, Southeastern, State University | Statistics | SAS, R, SAS Enterprise Miner | SAS, R, JMP |
| Small, Midwestern, Private College | Statistics | No Graduate School | R |
| Large, Southeastern, State University | Engineering | Excel, JMP, Matlab, Mathematica, Mathcad | SAS, Excel, JMP, Matlab, Mathematica, Maple, Mathcad |
| Large, Southeastern, State University | Economics | N/A | SAS, R, ForecastX, GRETL |
| Small, Midwestern, Private College | Economics | No Graduate School | Minitab, GRETL |
| Large, Southwestern, State University | Economics | No Graduate Program in Economics | SPSS, Excel, Stata |
| Large, Southwestern, State University | Information Systems & Decision Sciences | SAS, SPSS, Excel, Megastat, JMP, SAP, Minitab, Matlab, Stata, Mathematica* | SAS, SPSS, Excel, Megastat, JMP, SAP, Minitab, Matlab, Stata, Mathematica* |
| Large, Midwestern, State University | Marketing | SAS, SPSS, JMP | N/A |
| Large, Midwestern, State University | Marketing | SPSS, Excel* | SPSS, Excel* |
| * These schools did not specify whether the software listed were for graduate or undergraduate students, so we assumed both | | | |

Paying attention only to job availability, it seems that many schools need to reconsider their software choice in favor of implementing SAS. Nevertheless, there are many factors to consider other than the popularity within the job market. Schools must also consider the cost and time effectiveness of incorporating

each software into their curriculum. Further, specific departments within the school should consider which software best fits their area of study. One aim of this paper is to provide this necessary information by outlining the cost, training requirement, statistical techniques, and specific uses within industry of leading data analysis software.

This paper will not only assist schools in this software choice, though; it also will help businesses decide which software is best to bring them to the next level of capability as big data analysis has become less of a privilege and more of a necessity. As Manyika, Chui, Brown, Bughin, Dobbs, Roxburgh, and Byers state:

The impact of developing a superior capacity to take advantage of big data will confer enhanced competitive advantage over the long term and is therefore well worth the investment to create this capability. But the converse is also true. In a big data world, a competitor that fails to sufficiently develop its capabilities will be left behind (Manyika et al., 2011, 5). In other words, big data can no longer be ignored because companies that take advantage of it are winning the race against their less-modern competitors. More companies must consider implementing this type of analysis to stay competitive, and in doing so, they will need to understand which software is most appropriate for their business. This paper will help gather and condense the necessary information for this type of decision. For those progressive companies that already utilize software to realize their goals, they can reconsider their current software choice in light of this comprehensive information.

Computer software, however, can be written to flexibly support statistical practice (Buchan, 2000). All in all, this paper will focus on SAS, SPSS, and R software because both methods in Muenchen's study indicate that they are the three most competitively sought software in industry. The paper includes a complete collection of the cost effectiveness, training, uses, and specific uses within industry of each of these software. It will begin, though, with an investigation of Minitab followed by Excel and its Add-Ins because of their cost effectiveness, utility, and availability.

## MINITAB FOR TEACHING PURPOSES

Minitab products are uniquely designed to help professionals improve their business processes. Thousands of companies in more than 100 countries choose Minitab. Analyze your data and improve your products and services with the leading statistical software used for quality improvement worldwide. Quality Trainer teaches you how to analyze your data anytime you are online. This multimedia course includes animated lessons that bring statistical concepts to life, and interactive quizzes that give you real-time feedback. Hands-on exercises walk you through applying statistics with Minitab Statistical Software, so you can put your knowledge to use immediately.

Quality Trainer contains nine chapters with 141 interactive lessons you can repeat whenever your knowledge fades. It covers all the statistics you need to analyze your quality improvement data, including Basic Statistics, Control Charts, Process Capability, ANOVA, DOE, and more.

Easily implement your projects using a comprehensive collection of more than 100 tools specifically designed for each task. These built-in templates allow you to work with greater speed and accuracy.

Quality Companion also includes on-demand coaches that provide expert guidance to help complete each step. And you can modify any tool or coach by adding information that reflects your company's unique approach.

### TABLE 2 MINITAB GUIDE USE OF STATISTICAL AND OTHER TOOLS TO MANAGE PROJECTS

| | |
|---|---|
| **Value Stream Mapping** | Establish the flow of materials and information through your organization. Streamline processes to add value that meets customer expectations. |
| **Fishbone Diagram** | Identify every relevant element of your process and refine the scope of complex projects. |
| **On-Demand Coaches** | Receive the expert guidance you need to complete every step of your project. Add your own instructions or information to any Coach. |

| | |
|---|---|
| **Process Mapping** | Construct high-level or detailed flow charts that help you understand and communicate all the activities in a process. Assign variables to each shape and then share them with other tools. |
| **FMEA (Failure Modes and Effects Analysis)** | Identify the potential causes for a product or process failure, anticipate the resulting effects, and prioritize the actions needed to mitigate them. |
| **Pugh Matrix** | Compare product design proposals and improvement strategies and determine which ones best fulfill your customer requirements and organizational goals. |
| **Capture Analysis** | Identify and record the important and relevant sections of your Minitab analyses. |
| **Financial Analysis** | Estimate your project savings and the timeframe for realizing them. |
| **Project Risk Assessment** | Evaluate whether a potential project can be successfully completed on time. |
| **Stakeholder Analysis** | Summarize the impact your stakeholders have on your project so you can more effectively leverage their support and address their concerns. |
| **5S Audit** | Evaluate process conditions relative to 5S best practices and track the ongoing implementation of 5S improvements and controls. |
| **SIPOC (Supplier-Input-Process-Output-Customer) Analysis** | Identify every relevant element of your process and refine the scope of complex projects. |
| **C&E (Cause and Effects) Matrix** | Save time determining what X variables to address by comparing and evaluating their potential to impact your goal. |
| **Y Metrics Chart** | Evaluate the progress of your project over time in relation to its baseline and goal. |
| **Insert Team Members** | Easily add team members to your project from your e-mail address book or other file. |

**Minitab Cost Information**

- Minitab can be purchased from www.minitab.com
  -Single-user: $1,495
  -Academic annual: $49.99

## EXCEL ADD-INS

**What Are Excel Add-Ins?**

Add-ins are programs that add optional features and commands to the traditional capabilities of Microsoft Excel. Excel has created add-ins for a multitude of purposes: data analysis, presentation,

investment, business, personal, utilities and productivity tools, and organization. Within data analysis, some of the most popular add-ins include the Analysis Toolpak, Solver, MegaStat, and PHStat. Both MegaStat and PHStat access codes come with a textbook, however, if you do not have an access code, you can still obtain the PHStat add-in for $14.00, and the MegaStat add-in for $16.00. While the Analysis Toolpak and Solver are free add-ins, MegaStat is not. This section will focus on MegaStat and its usefulness in industry.

**Cost**

MegaStat costs $16.00, and PHStat costs $14.00 and prospective users can purchase MegaStat on McGraw-Hill's website and PHStat on Pearson's website.

**Training**

With the focus on STEM (science, technology, engineering, and mathematics) fields in this day and age, chances are most people have used Microsoft Excel at some point during their lifetime. Though they may not have used the statistical analysis tools of Excel, they have used it to swiftly perform calculations of data, or at least to organize data. The creator of MegaStat, Orris Burdeane, explains, "Since MegaStat looks and works like Excel, almost anyone could use it to generate some output with just a few minutes of training" (O. Burdeane, personal communication, January 29, 2014). After all, MegaStat has dialog and input boxes, buttons, and checkboxes that work largely the same as those in standard Excel. Therefore, the 53-page tutorial Pdf—complete with a step-by-step process to using each test that MegaStat performs, and pictures at every step—will likely provide more than enough guidance for trainees to effectively use this software.

**Other Excel Add-ins**

- Analyse-it can be purchased at www.analyze-it.com
  Standard Edition:
  -Perpetual: $269
  -Annual: $99
- XLStat can be purchased at www.xlstat.com from Addinsoft's website.
  -Annual Student: $50
  -Annual Company: $275
  -Annual Academic: $165

-Perpetual Company: $695
-Perpetual Academic: $395

- NumXL can be purschased at www.spiderfinancial.com/products/numxl
  -Annual: $200
  -Perpetual: $500
- Quantum XL can be purchased from www.sigmazone.com
  -SPC XL: $249
  -Quantum XL: $549
  -DOE XL: $249

**Statistical Methods/Tests/Uses**

As will be seen later in this paper, MegaStat can execute many of the same jobs that more costly software do. According to the McGraw-Hill website, MegaStat can perform a multitude of statistical operations: descriptive statistics, frequency distributions, probability, confidence intervals and sample size, hypothesis tests, ANOVA, regression, time series/forecasting, chi-square, nine nonparametric tests, quality control process charts, and generate random numbers ("Megastat," 2014). The creator of MegaStat himself acknowledges that SPSS and SAS, specifically, have more advanced options, "especially in the area of multivariate statistics" (O. Burdeane, personal communication, January 29, 2014). However, he believes that "MegaStat can handle most things encountered by non-PhD statisticians" (O. Burdeane, personal communication, January 29, 2014).

The major caveat for this cheap and easy-to-use software is its size capability. For example, Burdeane experimented with the number of data points that MegaStat can handle a few years ago. "I did find a file with 10 columns and 152630 rows. That is over 1 ½ million data points and MegaStat did a descriptive statistics analysis on it in about 10 seconds" (O. Burdeane, personal communication, January 29, 2014). While the capability to analyze a million and a half data points sounds like a tremendous feat, and it is, this capability does not meet the demand of large companies like Wal-Mart and Facebook. An article published by SAS called "Big Data Meets Big Data Analytics" puts it plainly: "Wal-Mart handles more than a million customer transactions each hour and imports those into databases estimated to contain more than 2.5 petabytes of data," and "Facebook handles more than 250 million photo uploads and the interactions of

800 million active users with more than 900 million objects (pages, groups, etc. –each day" ("Big Data," 2014). Extracting this data and making use of it using MegaStat is just not feasible.

Burdeane also mentioned a couple other restrictions of MegaStat, including its limitation to twelve independent variables in multiple regression and further restrictions on variables and table size (O. Burdeane, personal communication, January 29, 2014). While MegaStat does have all of these constraints, the fact remains that it is an extremely powerful software given the cost and training required.

### Specific Uses in Industry

The creator of MegaStat believes that this software is used by a different group of people from the major statistical packages. Burdeane (personal communication, January 29, 2014) states:

> I would guess that most use of MegaStat in companies is by people who are not professional statisticians. I think people with formal training in statistics beyond an introductory course would have experience with one of the big packages (SAS, SPSS, Minitab) and would tend to stick with that software even if it was overkill for many analyses.

He suggests that many analyses do not require major packages, like SAS, SPSS, and R, but statisticians stick to them because they are comfortable.

However, companies within industry do still use Excel. For example, a global appliance manufacturer uses Excel "for extensive 'What If' analysis around budgeting" and to forecast (J. Ward, personal communication, January 20, 2014).

## SPSS

### What Is SPSS?

SPSS, originally termed Statistical Package for the Social Sciences, was released in 1968 as a software designed for the social sciences. Since then, IBM has replaced SPSS Inc. as the owner and the software has expanded its user base past this one area. The software's former acronym has been replaced

with Statistical Product and Service Solutions to reflect the greater diversity of its clients. Arguably, it still remains the leading statistical analysis software package for the social sciences.

**Cost**

Obviously, consumers can buy SPSS software packages separately by choosing a particular product that they think will satisfy their need; however, SPSS offers bundles that cost much less than paying for the programs independently. SPSS offers three of these bundles: standard, professional, and premium.

Within each of these bundles, SPSS gives four options: an authorized user license, authorized user initial fixed term license, concurrent user license, and concurrent user initial fixed term license. Thus, when customers decide they want to purchase SPSS, they have to make two decisions: user license versus initial fixed term license and authorized user versus concurrent user. User licenses never expire, while initial fixed term licenses last for twelve months. An authorized user is a single licensee who buys the right to use the program; a concurrent user is the right for a single person to use the program at a given time, but it does not distinguish who this person has to be.

With these descriptions in mind, beneath in Table 2 are the prices for purchasing the three different bundles of SPSS.

**TABLE 2 PRICES OF BUNDLES OFFERED BY SPSS ("SPSS STATISTICS," 2014)**

| Package | Features | Price |
|---|---|---|
| **Standard** | Authorized User License | $5,270 |
| | Authorized User Initial Fixed Term License | $2,320 |
| | Concurrent User License | $13,200 |
| | Concurrent User Initial Fixed Term License | $5,810 |
| **Professional** | Authorized User License | $10,600 |
| | Authorized User Initial Fixed Term License | $4,660 |
| | Concurrent User License | $26,500 |
| | Concurrent User Initial Fixed Term License | $11,600 |
| **Premium** | Authorized User License | $15,800 |
| | Authorized User Initial Fixed Term License | $6,950 |
| | Concurrent User License | $39,400 |
| | Concurrent User Initial Fixed Term License | $17,400 |

SPSS also offers students packages for college attendees. Students can purchase the single user initial fixed term license "SPSS GradPack" software from their college or university, or they can buy it from SPSS's official distributers, like Creation Engine, On the Hub, StudentDiscounts.com, Studica, ThinkEDU ("SPSS Statistics GradPack," 2014). For example, on the Creation Engine website, student can buy the SPSS Statistics Premium GradPack for $98.95 ("IBM SPSS Statistics Premium GradPack 22," 2014).

**Training**

In her article about the use of statistical software for sociology, Ashley Crossman addresses the difficulty—or lack thereof—of using SPSS for the first time. She explains:

> SPSS provides a user interface that makes it very easy and intuitive for all levels of users. Menus and dialogue boxes make it possible to perform analyses without having to write command syntax, like in other programs. It is also simple and easy to enter and edit data directly into the programs (Crossman, 2014).

On the surface, these descriptions make SPSS sound a lot like Excel. In fact, SPSS does look similar to typical spreadsheet applications like Excel, and its ease of use is very comparable to Excel as well.

**Statistical Methods/Tests/Uses**

There are many differences between Excel and SPSS that suit SPSS to better handle statistical methods. For one, "SPSS was designed specifically for statistical processing of large amount of data at an enterprise level," while spreadsheets are broadly applicable to many different tasks outside of statistical computing (Robbins, 2012). An advantage of this specialized design is that SPSS "keeps calculated statistics and graphs separate from the raw data but still easily accessible" (Robbins, 2012). SPSS software furthermore has a much more convenient platform for performing statistical tests. For instance, performing a one-sample T-test in Excel requires some independent calculations by the user, whereas with SPSS, the user only needs to "select a variable and supply the value to compare with [the] sample" and click "Ok" (Robbins, 2012). Another advantage of SPSS is that it links numerically coded data to its original meaning

(Robbins, 2012). With most data being electronically stored in numerical fashion, this feature of SPSS is highly valuable.

For these reasons, SPSS is well-suited to statistical analysis, but what statistical procedures can SPSS handle? SPSS's standard bundle includes its statistics base, advanced statistics, bootstrapping, custom tables, and regression capabilities. Purchasing the professional bundle further supplies the consumer with the categories, data preparation, decision trees, forecasting, and missing values features. The most comprehensive bundle, premium, provides the user with the complex samples, conjoin, direct marketing, exact tests, neural networks, amos, sample power, and visualization designer, in addition to all of the packages from the professional bundle ("SPSS Statistics," 2014).

After the statistical analysis is complete, SPSS is also useful for generating plots of distributions and trends, charts, and tabulated reports.

**Specific Uses in Industry**

IBM's SPSS software has spanned many industries. On its website, prospective clients can read about SPSS success stories in fields like automotive, banking, chemical & petroleum, computer services, consumer products, education, electronics, energy & utilities, and on and on. They can also access a list of SPSS's clients, such as Barclays, Kaplan, and Wimbledon Championships. Below are a couple more specific examples of SPSS at work within industry.

- Infinity insurance uses SPSS's predictive analytics feature to detect fraudulent claims ("Why SPSS Software?" 2014).
- "By mining alumni and stakeholder records, social media and other unstructured data-sets with text analytics software, [Michigan State University] gains insights into the engagement, sentiments and behavior of current and potential donors," which enables smarter fundraising ("Success Stories for SPSS," 2014).

- The Guardia Civil, Spain's very first national law enforcement agency, has investigated crimes and psychology using SPSS ("Success Stories for SPSS," 2014).
- One distinguished hospital uses SPSS to forecast payment behavior. It tries "to better identify patients who are most likely to pay their hospital bills" by what it calls "predict[ing] patient payment potential" ("Success Stories for SPSS," 2014).

## SAS

### What Is SAS?

SAS (Statistical Analysis System) is a commercial statistical package that was developed during the 1960's and 70's at North Carolina State University as part of an agricultural research project. Its usage has grown exponentially since then. Nowadays, ninety-one of the top one hundred companies on the 2013 Fortune Global 500 list use the software ("About SAS," 2014). This paper will discuss the two main SAS starter packages: Analytics Pro and Visual Data Discovery.

An important fact to note about SAS is that the software does not run on Mac computers very easily (one way to run the software is through parallels, where users buy and run the Windows interface as well).

### Cost

An individual license of the Analytics Pro version of SAS costs $8,700 for the first year and $2,436 for each year thereafter. The cost for each renewal is twenty-eight percent of the amount originally paid in the first year. With a few more features than the Analytics Pro system, the Visual Data Discovery package costs $10,800 for the first year of use. Like Analytics Pro, renewing this package costs twenty-eight percent of the original cost, so it costs $2,822.40 for each additional year. However, these prices only apply to customers working with their own data. If a user wishes to perform data analysis for the benefit of some other party, then he must secure a different license by consulting a SAS representative ("Pricing and Licensing Information," 2014).

One of these alternative licenses is a server-based license. These licenses certainly save schools and

businesses money by allowing their affiliates each to access the software through a web-based connection or a network. SAS fills these requests on a case-by-case basis, so interested customers should speak to SAS directly to get a quote ("Pricing and Licensing Information," 2014).

On top of these two versions, SAS has created an OnDemand edition, which is available at no cost to degree granting institutions. Professors can set up an account online, and they and their students can access the software anywhere with an Internet access. Although this free software "has been reported to be slow at times," it definitely provides a great opportunity for schools to teach students the basics of SAS programming (Loomis Lofland & Ottesen, 2013, 3).

While the proper versions of SAS do come at a steep financial cost, they furthermore cost time in the form of installation. Chelsea Loomis Lofland and Rebecca Ottesen speak to this expense in their paper, "The SAS Versus R Debate in Industry and Academia." They explain, "SAS can be difficult for users to obtain and the initial installation is sometimes tricky … long and difficult" (Loomis Lofland & Ottesen, 2013, 3). However, in contrast to some other software (like R, as will be seen later), SAS only requires this initial installation. It does not require users to install any packages in the future. Everything is included in this set-up.

**Training**

Ashley Crossman accurately advises, "SAS is a great program for the intermediate and advanced user because it is very powerful, can be used with extremely large data sets, and can perform complex and advanced analyses" (Crossman, 2014). After all, SAS requires more training than Excel and SPSS because it largely runs on programming syntax rather than point-click menus that other software boast.

The amount of training necessary for individuals to properly use SAS depends on many factors, including the trainee's background and the type of analysis she will need to perform. In terms of background, prospective SAS programmers with prior programming experience will have a much easier time. SAS syntax resembles that of other programming languages, so experience with one language often

helps learn another. For instance, SAS is similar to Java in that both contain data values, function calls, identifying key words at the beginning of each line, and semicolons at the end of each line (Boudreaux, 2003, 1). But, even if the syntax of SAS and a previously learned language are completely different, experience with coding is extremely helpful because the art of programming is a different kind of thinking. The training required also depends on the type of analysis that the trainee must carry out. If the trainee only needs to run the same type of test repeatedly, then she may only need training in a specific aspect of SAS programming; however, if the trainee will need to develop a process based on each new task, then she will need more sound understanding of the software.

Fortunately, experts have written copious texts about how to use SAS, and SAS has a strong user support system, so even if users do not have complete understanding of the software, they can run it. While there exists no easy way to calculate the number of books written about SAS, Robert Muenchen did as best he could to estimate this statistics by searching for books published with "SAS" in their title. He found that close to five hundred of these books were published between 2001 and 2011 (Lofland & Ottesen, 2013). In addition to all of these useful texts, experts really cannot pinpoint any issues with the user support of SAS. Loomis Lofland and Ottesen clarify:

> SAS has extensive online documentation, expert technical support, professional training courses, many excellent books in press, and a tight knit user group and web based community. Problems can be addressed to SAS directly via tech support who replies very quickly and will work with the user to solve the problem (Muenchen, 2014).

They designate the user support service of SAS as one of its main specialties. Therefore, even though SAS requires some programming skill, the strength of SAS's support system makes it more manageable for less advanced users.

**Statistical Methods/Tests/Uses**

SAS's Analytics Pro bundle comes with three of the most popular SAS products: Base SAS,

SAS/STAT and SAS/GRAPH. The corporation's Visual Data Discovery collection includes SAS Enterprise Guide (SAS's only point-click interface) and JMP software to make discovery and exploratory analysis easier.

With either of these toolsets, programmers can perform a number of statistical tests. The Institute for Digital Research and Education website outlines a multitude of statistical tests and their corresponding SAS code. The list includes thirty-two tests that come from statistical categories such as regression, factor analysis, discriminant analysis, ANOVA, non-parametric tests, and correlation ("What Statistical Analysis," 2014). The full list can be seen in Table 3 below.

**TABLE 3: LIST OF TESTS THAT SAS CAN PERFORM**
**(UCLA: Statistical Consulting Group, 2014)**

| | | | |
|---|---|---|---|
| One sample t-test | One sample median test | Binomial test | Chi-square goodness of fit |
| Two independent samples t-test | Wilcoxon-Mann-Whitney test | Chi-square test | Fisher's exact test |
| Kruskal-Wallis test | Paired t-test | Wilcoxon signed rank sum test | McNemar test |
| One-way repeated measures ANOVA | Repeated measures logistic regression | Factorial ANOVA | Friedman test |
| Ordered logistic regression | Factorial logistic regression | Correlation | Simple linear regression |
| Non-parametric correlation | Simple logistic regression | Multiple regression | Analysis of covariance |
| Multiple logistic regression | Discriminant analysis | One-way MANOVA | Multivariate multiple regression |
| Canonical correlation | Factor analysis | | |

SAS can perform many more statistical tests than just these, though. It also functions well with forecasting, time series analysis, and many other advanced statistical techniques. In fact, SAS has created specialized programs for these methods. The SAS website's "Products & Solutions" page has a complete list of these programs.

Also on this page, SAS has additional packages to access that are industry-specific. For example,

there is a "SAS Drug Development" package that "enables the efficient development, execution and management of analysis and reporting activities for clinical research," a "SAS Fraud Management" package that "delivers a full-service enterprise-wide fraud management system that offers real-time scoring of accounts by looking at all card transactions—including purchases, payments and nonmonetary transactions," and a "SAS Risk Management for Insurance" package that "implements the Solvency II standard model approach for calculating risk-based capital with [its] comprehensive solution for preforming risk analysis and risk-based capital calculations" ("Industry Solutions," 2014). On top of these specialized packages for health-care, banking, and insurance, SAS has formulated software with built-in functions for other areas like law enforcement, communications, retail, casinos, utilities, and sports, among others.

SAS's advantageous functions extend beyond just carrying out statistics, though. It has superior qualities for both before the statistical analysis and after. Prior to the actual statistics, it facilitates the reading in and managing disorganized data. Real life data is rarely clean and analysis ready. SAS can interpret messy data sets, convert them to a clean form, and manipulate them in ways that other software cannot (Loomis Lofland & Ottesen, 2013, 3-4). After the user performs the statistics, SAS has impressive graphics and report writing features that will help disseminate the findings in clear and appealing ways. But, these aesthetic products come with a caveat according to Loomis Lofland and Ottesen. They explain, "SAS provides many useful procedures for creating detailed and polished reports," however, "some of the more detailed reporting procedures [...] have a learning curve that takes place before being able to use them correctly" (Loomis Lofland & Ottesen, 2013, 3-4).

**Specific Uses in Industry**

As stated in the previous section, SAS has built-in, functional packages for many specific industries, including health-care, banking, insurance, law enforcement, communications, retail, casinos, utilities, sports, and more. To follow are a couple of real life uses of SAS within some of these industries.

- A leading medical device company utilizes SAS "for clinical study data analysis" (K. Kleckner, personal communication, February 1, 2014). This same company furthermore uses the software "for setting sample sizes for pre-clinical studies and human clinical studies; [and] for setting controls on manufacturing operations" (K. Kleckner, personal communication, February 1, 2014).
- A global appliance manufacturer uses SAS for quality control by performing predictive analyses of product defects (J. Ward, personal communication, January 20, 2014).

## R

### What Is R?

R is a free, open-source statistical software. Colleagues at the University of Auckland in New Zealand, Robert Gentleman and Ross Ihaka, created the software in 1993 because they mutually saw a need for a better software environment for their classes. R has certainly outgrown its origins, now boasting more than two million users according to an R Community website ("What is R?" 2014).

### Cost

R is free and is downloadable from the Internet. To repeat, it has no subscription fees, user limits, or license managers. However, this presents a danger. As open source software, R could be a security concern for large companies because the software can be freely used, changed, and shared by anyone.

Like SAS, R can be expensive in a form other than monetary. While the base for R is very easy to install, users must download packages to perform specific analyses, which can be very time-consuming (Loomis Lofland & Ottesen, 2013, 3-4). For example, as of this paper, there are 5,508 available packages, and this number grows weekly if not daily ("Contributed Packages," 2014). This provides many options, but searching through the assemblage of choices can be difficult and time consuming.

### Training

Again, like SAS, the training necessary for effectively using R depends on the previous computing experience of the trainee. Computing experience is helpful because data analysis in R requires writing

functions and scripts, not just pointing and clicking like in Excel or SPSS. In many ways, though, R is comparable to other programming languages. For instance, similar to many other languages, it is a command line interface. Additionally, its source code is similar to that of C and Fortran, and it supports matrix arithmetic and data structures like APL and MATLAB. Having used any of these in the past could lessen the training time necessary to learn R. As stated with SAS above, though, having any programming experience at all often will speed up the learning process for trainees since programming problems are a completely different type of puzzle.

Sources report varied answers when identifying the training necessary to successfully utilize R. Some believe that R does not necessitate much knowledge of computer programming after all. For example, Daryl Pregibon of Google testifies that R "allows statisticians to do very intricate and complicated analyses without knowing the blood and guts of computing systems" and Ashlee Vance of *The New York Times* informs, "R has quickly found a following because statisticians, engineers and scientists without computer programming skills find it easy to use" (Vance 2009). R is, after all, not as daunting as other languages, having very natural and expressive syntax for data analysis. In R language, "anova(object_1, object_2)" produces an ANOVA table; "coef(object)" extracts the regression coefficient; and "plot(object)" produces plots showing residuals, fitted values, and other diagnostics ("An Introduction to R," 2014). Still, R does require the use of objects, operators, and functions before applying these intuitive commands. Fortunately—as stated earlier—many packages are available for download and use off the Internet, so users do not necessarily have to know the code or write it. This is another reason why some people say that R does not require much programming knowledge.

However, because of errors in some of these packages and lack of user support for R, others believe that advanced training investment is necessary in order to use the software. Two people that hold this viewpoint are Loomis Lofland and Ottesen, who say, "[R] users rely on what others put out there about the software. [....] Packages are not written by the R Development Core-Team; therefore, they are not well

polished and some could have questionable validity. It is also difficult to direct an issue to a particular person or support system" (Loomis Lofland & Ottesen, 2013, 3). Although R may be useable without much coding experience, when a problem arises, the lack of programming knowledge will become evident and costly due to a dearth of documentation and technical support for resolving the issue. In other words, people without sufficient knowledge of the R programming language can implement the syntax in their own use, but they do not necessarily have solid understanding of what the code actually says. This lack of R coding knowledge makes debugging difficult if not impossible, and it could lead to erroneous results with severe decision-making consequences.

Loomis Lofland and Ottesen also explain that report writing in R is difficult. They claim that the extensive programming required to code a report in R is quite a time investment, as "R does not have a defined way of producing reports" (Loomis Lofland & Ottesen, 2013, 3).

**Statistical Methods/Tests/Uses**

R is a comprehensive statistical analysis toolkit. It can perform any statistical analysis desired, but users must either write the code or access the code from someone who has already written it. As stated on its website, people have already designed many standard data analysis tools "from accessing data in various formats, to data manipulation (transforms, merges, aggregations, etc.), to traditional and modern statistical models (regression, ANOVA, GLM, tree models, etc.) ("Why Use R?" 2014). Actually, programmers have designed many more packages than just these. As stated earlier in this section, programmers have already coded 5,508 packages. These include packages for Bayesian statistics, time series analysis, simulation based analysis, spatial statistics, survival analysis, and many, many more ("Contributed Packages," 2014). For a complete list of packages already designed for R, visit http://cran.us.r-project.org/web/packages/.

The key feature of R that differentiates it from other statistical software is its acceptance of customization. On the one hand, the aforementioned software have "data-in-data-out black-box procedures" ("Why Use R?" 2014). In other words, the developers have written the code for a certain function, such as

performing decomposition for a time-series model, and users have never seen this built-in code that runs in the background. All they need to do is use a "decomp" command, or something of the sort, and the statistical package will perform the decomposition for them. On the other hand, R is an interactive language. It requires users to write the code (for the decomposition, or whatever procedure desired) or to paste the code in from someone who already wrote it. Because the function's code is visible in their command box, users can manipulate the commands however they see fit. Thus, R enables experimentation and exploration by allowing users to improve the software's code or to write variations for specific tasks. They can even mix-and-match models for better results. With the pre-packaged functions in the other statistical software, this is not as easy.

After completing a statistical analysis with R, the software is known for generating appealing charts and tables. The custom charting capabilities of R create "stunning infographics seen in *The New York Times*, *The Economist*, and the FlowingData blog" ("What is R?" 2014).

With R, though, it is important to acknowledge that it cannot manage messy data as easily as other available statistical software. Loomis Lofland and Ottesen warn, "The design of R was focused around statistical computing and graphics, so data management tends to be time consuming and not as clean as SAS. [...] Students who have used solely R have an unrealistic expectation of the state of the data they receive" (Loomis Lofland & Ottesen, 2013, 3). But, once the data is organized, as stated, R is an invaluable data analysis performer and graphics creator.

**Specific Uses in Industry**

The usage of R across diverse domains is undeniable. A *New York Times* article cites its practice in major companies, like Google, Pfizer, Merck, Bank of America, the InterContinental hotels Group, and Shell (Vance, 2009). For specific examples, see below.

- Google "taps R for help understanding trends in ad pricing and for illuminating patterns in the search data it collects" (Vance, 2009).

- Pfizer has engineered its own custom packages in R, which allows scientists to manipulate their own data during nonclinical drug studies instead of hiring a statistician to do the work for them (Vance, 2009).
- A financial services company utilizes dozens of R packages to perform derivatives analysis (Vance, 2009).

## CONCLUSION

Excel add-ins are well-suited to small companies and small projects because of their availability and low cost, while SPSS, SAS, and R work well for large projects and large businesses because of their ability to handle large sums of data efficiently. As discovered at the beginning of the paper, Excel's MegaStat option can execute many important statistical procedures that people trying to interpret smaller data sets can utilize for low financial cost and training cost. However, as stated, MegaStat can only manage a certain amount of data. Therefore, larger data sets, such as those accumulated by Wal-Mart and Facebook, require a higher-powered software, like SPSS, SAS, or R. Differentiating between which of these software best fits the analysis of these larger data sets depends on a number of factors, and each statistical package has its own strengths and weaknesses. Hence, this paper has investigated the cost, installation procedure, training necessary, built-in packages, level of desire to manipulate code, user support, importance of appealing graphics, and many other considerations in hopes of providing businesses and universities with details that can ease their choices of software.

## IMPLICATIONS

With the tremendous (and growing) focus on big data in today's society, businesses, universities, and future students should actively participate. The McKinsey Global Corporation explains why. It states:

> The use of big data will become a key basis of competition and growth for individual firms. [...] From the standpoint of competitiveness and the potential capture of value, all companies need to take big data seriously. In most industries, established competitors and new entrants alike will leverage

> data-driven strategies to innovate, compete, and capture value from deep and up-to-real-time information. Indeed, we found early examples of such use of data in every sector we examined (Manyika et al., 2011, 6).

To repeat: businesses are leveraging big data in every sector that McKinsey examined. Hence, businesses need to take notice. McKinsey further explains:

> There will be a shortage of talent necessary for organizations to take advantage of big data. [By 2018,] we project that demand for deep analytical positions in a big data world could exceed the supply being produced on current trends by 140,000 to 190,000 positions (Manyika et al., 2011, 6).

In other words, McKinsey estimates that by 2018, the United States will lack at least 140,000 people with expertise in big data. Big data analysis does not occur by hand, so McKinsey essentially predicts that the United States could need this many more people with expertise in software that can handle big data. For this reason, colleges, universities, and future students should assume the preparatory measures necessary to combat this deficit. After all, future students with training from college and universities will need to fill these gaps.

This paper aimed to help businesses, schools, and students recognize what they can do to improve their performance and utility in this data driven society. To begin, from this paper, businesses can learn the most effective tools to suit their context. New businesses can learn the tools that they should buy (or simply download), while older businesses can learn the software that could better serve their needs than the one they currently have. Finding the suitable software is important because companies that employ the most efficient data analysis software will compete better against competition, by effectively accessing and using their stockpiles of data to make better decisions.

Colleges and universities could improve job placement by preparing students in the specific software that hiring companies use. As seen in the introduction, the majority of companies use the software reported in this paper. Therefore, schools would benefit from teaching students to use these software.

Students can add a "software taught" category to their list of traits sought in higher education in order to prepare themselves for job placement. One of the most important decisions that future students make is selecting a major. Often, a student's desired major can influence the selection set. However, other decisions are growing in importance too. In terms of finding a job, employers are increasingly seeking out recent graduates that have experience with big data software, like SPSS, SAS, and R. Therefore, it is becoming more important for students to seek out a university that will prepare them with knowledge of pertinent software, which will increase their likelihood of finding a satisfying job. Obviously, careers in big data will be abundant, so prepared students will have little trouble finding a job in that area. Nevertheless, students trained on high demand software will have more and better options for job placement.

## FUTURE RESEARCH

We plan to continue our research of software. While we acknowledge that no software is suitable for every project within a specific sector of industry, we do believe that certain software may be best matched to the majority of projects within an industry. By further surveying the use of software by particular businesses, we hope to discover which software is best suited to business, mathematics, statistics, engineering, and other majors. This information should benefit businesses, schools, and students. We would also like to compare this with the software that academics use in their research.

Furthermore, we will study database software in much the same manner that we studied statistical software. As we surveyed businesses and universities about the statistical software that they utilize and teach, respectively, many of these establishments included database software in their responses. After all, database software serves as the means to organize the data sets, so the ability to work with database software is often just as important as the ability to analyze the data sets with statistical software.

Also, we will look at statistical software and their effectiveness in teaching. This paper has focused primarily on big data software and their usefulness for finding a job within the business world. Another avenue to explore is the feasibility of using these software and others as tools for learning statistical

concepts. Perhaps big data software such as SAS, SPSS, and R are extremely effective for business tasks, but they are not as effective for learning statistical concepts in the classroom. Statistical software that may better suit the classroom environment includes Minitab or Statistica. An analysis of the pros and cons for these software (and potentially others) is another future goal of ours.

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## TRADEMARKS

# Lean Productivity Enhancements and Waste Elimination through Emerging Technology

Gene Fliedner
Decision and Information Sciences Department
School of Business Administration
Oakland University
Rochester, MI 48309

Jerry DeHondt
Consultant
Grand Rapids, MI
gdehondt@gmail.com

## Abstract

Lean methods focus on the elimination of waste through numerous techniques, processes, and tools. Current practices have been built upon a body of knowledge dating back centuries or further. An emerging theme within the literature has been to integrate technology into lean to help improve productivity and eliminate waste. This paper surveys several different areas and industries to document examples of technological innovations being used to eliminate waste and provide continuing lean evolution.

## Introduction

The past three decades have witnessed the nature of lean as a systematic transformation process philosophy gain greater understanding. Lean is commonly defined and understood as a systematic philosophy for achieving productivity enhancements through waste elimination (Bhasin and Burcher, 2006). Benefits achieved through applications of the lean principles, practices, and tools are well documented. Often cited benefits attributed to lean applications are lower costs, higher quality, faster order response times, and enhanced transformation process flexibility (Ohno, 1988; Krafcik, 1988; MacDuffie, 1995; Pil and MacDuffie, 1996; Detty and Yingling, 2000; Shah and Ward, 2003; Melton, 2005; Singh, 2010; Fliedner, 2011).

The true understanding of lean's originations has been somewhat distorted by some suggesting that the roots of lean emanated from individuals (e.g., Toyoda, Ohno, Shingo, Imai, and others) within Toyota in the 1950's. Rather, lean represents an evolving body of knowledge dedicated to achieving productivity enhancements through waste elimination. The true roots of the lean body of knowledge go back centuries.

Individuals at Toyota acknowledged contributions to the lean body of knowledge by numerous predecessors. For example, the Egyptians used an assembly line (flow) practice and divided labor to enhance productivity and speed in the building of the pyramids (Dunham, 1956). The field of ergonomics contributes important lean practices as well. The foundation of ergonomics appears to have emerged in ancient Greece. Evidence indicates that the Hellenic civilization in the 5th century B.C. used ergonomic principles in the design of their tools, jobs, and workplaces (Marmaras et al., 1999). It is estimated that as early as 1104, the Arsenal of Venice utilized a vertically integrated flow process consisting of dedicated work stations to assemble standardized parts into galley ships. This practice of a vertically integrated flow approach combined with standardized parts enhanced ship assembly productivity.

Other contributors prior to the contributions at Toyota include the introduction of interchangeable parts in the U.S. in approximately 1798 by Eli Whitney. Industrial engineers such as Frederick Taylor and the Gilbreths contributed practices such as standardized work, time and motion studies, and process charting during the scientific management era of the late 1890's and early 1900's. Starting in about 1910 through the 1920's Henry Ford extended earlier practices by marrying interchangeable parts with standard work and moving conveyance as well as incorporating vertical integration and behavioral concepts such as worker motivation in order to design a more comprehensive lean system.

The contributions emanating from Toyota in the 1950's, often referred to as the Toyota Production System (TPS), built upon earlier contributions and focused on waste elimination. Three wastes are typically identified; often referred to as overburden (muri), variation (mura), and waste (muda). Since the work by many at Toyota, numerous additional contributions may be cited. To put it simply, it must be acknowledged that lean is a philosophy of continuous improvement conducted in a systematic manner and dedicated to productivity improvements and waste elimination. Fliedner (2011) recognizes that as a system, lean is comprised of four integral components: leadership, organizational culture, and teamwork, as well as the practices and tools identified by many predecessors.

Interestingly, the nature of lean as a systematic philosophy for achieving productivity enhancements through waste elimination is quite broad and somewhat vague. For example, one can eliminate waste in a number of ways, including eliminating avoidable non-value adding activities, reducing unavoidable non-value adding activities, sharing information in a more timely and accurate manner, using more efficient resources, etc.

An emerging theme of lean rests on technological change as a means for achieving significant advancement of productivity enhancement and waste elimination objectives. Increasing anecdotal evidence is emerging which documents the ability of technology to enable productivity enhancement and waste elimination. Technological applications are impacting every industry, including agriculture, automotive, construction, entertainment, healthcare, and manufacturing to name a few. The purpose of this manuscript is to recognize and document examples as well as beneficial evidence of the importance of these technological contributions. These technological applications are enabling and will continue to provide the future of lean achievements.

## Lean Technology Capabilities

Productivity enhancements enabled by technology may be best explained in part to four laws. Chronologically, they are Moore's Law, Nielsen's Law, Butters' Law, and Kryder's Law. Moore's Law, offered in 1965, observes that the number of transistors in a dense integrated circuit doubles approximately every 18 months dramatically enhancing the effect of digital electronics in nearly every segment of the world economy (Moore, 1965). The capabilities of many digital electronic devices we take for granted these days are strongly linked to Moore's Law. Nielsen's Law, observed in 1998, states that the high–end users' internet connection speed (bandwidth), and therefore the ability to rapidly retrieve or exchange information, doubles approximately every 21 months (Nielsen, 1998). While Moore's Law observes that transistors double in speed roughly every 18 months, Butters' Law observes that the amount of data coming out of an optical fiber is doubling approximately every nine months, further enhancing the speed of information exchange over the internet (Tehrani, 2000). Kryder's Law observes that memory storage density or capacity (magnetic disk areal storage density at the time) is increasing very quickly, faster than Moore's Law at times (Walter, 2005).

Taken together, these four laws directly contribute to the capabilities of emerging technology and therefore the productivity enhancements and waste elimination that will be achieved in coming years. These capabilities are embedded in the emerging technologies impacting every industry. Examples of these technologies as well as cited benefits for industries including agriculture, automotive, construction, entertainment, healthcare, and manufacturing as discussed below.

**Agriculture**

Technology is promoting lower costs, higher quality and faster order response times in numerous agricultural applications. Technology has greatly enhanced agricultural practices over the past decade and with the continuing trend for large farms and less labor per acre, it will continue to do so going forward. One current example is real time kinematic (RTK) vehicle auto steering capability. RTK provides hands-free steering accuracy measured to the inch for a variety of tasks including listing/bedding up, row crop planting, strip-tilling, ridge-tilling, post emergence spraying, banding fertilizer, side-dressing, and cultivating. This technology provides benefits of repeatability of these tasks from day-to-day or even year-to-year. It allows one to establish rows in the same spot for several years promoting controlled traffic systems, drip irrigation or any other use where one need to be able to come back to the exact same spot in the field. Benefits cited include significantly reduced driver fatigue which is best understood after one drives a tractor for several consecutive hours. It offers cost savings over older technology that can approach $50 per acre through reduced overlap on tillage passes. On a farm of 10,000 acres, that adds up to $500,000 annually (Anonymous, 2015b).

A second example is drone technology (unmanned aerial vehicle or UAV) which is making its appearance in many industries including real estate, military, distribution, search and rescue, and agricultural applications. UAVs equipped with a multi-spectral camera can survey crops to detect water and nutrition issues, insect infestations, and fungal infections. UAV technology is being introduced to capture aerial field views for soil-moisture information for more efficient (location and duration) watering applications. UAVs equipped with appropriate camera filters and ground positioning technology (GPS) can detect nutrient deficiencies by providing an aerial field view. Overlaying this field view on a soil map can lead to the diagnosis of nutrient deficiencies (e.g., nitrogen or phosphorous) based upon crop coloration. The GPS can provide exact field coordinates so that the appropriate treatment can be applied to the corresponding area. This application can be applied during the growing season promoting yields and avoiding losses. Historically, fertilizer applications are performed before or after the growing season.

UAV technology offers a significant improvement relative to the more common uses of doing it on foot or more expensive and time consuming airplanes. Human sampling on foot or underground sensors lead to less reliable information as sampled areas may not be representative of an entire field. UAV information can lead to more efficient fertilizer and water applications which is particularly appealing for large scale farms. UAV size, cost, and capabilities promote significant efficiencies making UAVs useful for a wide range of jobs. One estimate suggests farmers can save $10 to $30 an acre in fertilizer and in related costs by examining the progress of crops while they are still in the ground (Ramstad, 2014).

**Automotive**

Technology has been applied in the automotive industry for decades and it will continue to be a leading innovator and adopter of technology to come. More than 30,000 people died on U. S. roadways in 2014

according to the National Highway Traffic Safety Administration (NHTSA). NHTSA estimates traffic crashes cost the economy $299.5 billion annually and that approximately 90% of crashes can be attributed to human error. Furthermore, it is estimated that Americans waste about 3 billion gallons of fuel annually due to congestion (Anonymous, 2015a). These statistics suggest most will agree that safety and traffic congestion are significant issues facing automotive transportation.

One example of emerging technology in the automotive industry is being pursued by Denso, a large, international supplier of advanced technology, systems and components. The particular innovation is referred to as vehicle-to-vehicle and vehicle-to-infrastructure (V2X) technology. This technology allows vehicles to wirelessly exchange data with other equipped vehicles and roadway infrastructure (Anonymous, 2015a).

The Federal Communications Commission will allow the use of the 5.850-5.925 GHz band of radio frequency spectrum which the U. S. Department of Transportation (DOT) has set aside for road safety and traffic management. This portion of the radio frequency spectrum is to be used for a variety of dedicated short range communications (DSRC) uses, including traffic light control, traffic monitoring, travelers' alerts, automatic toll collection, traffic congestion detection, emergency vehicle signal preemption of traffic lights, and electronic inspection of moving trucks. DSRC technology data transmissions will use both onboard and nearby roadside transmission facilities. This is part of the national program of the U. S. DOT's Intelligent Transportation System.

Denso's DSRC system utilizes a two-way, short-range wireless communications technology. The more vehicles equipped with DSRC devices, the more effective the technology. When all cars have V2X, it creates a 360-degree situational awareness for each vehicle's surroundings. The embedded computing device on each car can use information about nearby vehicles to calculate current and future positions. This can help predict hazardous situations and alert drivers of precautions to avoid crashes.

V2X technology can be used to give right-of-way to emergency vehicles. When an emergency vehicle is approaching, the technology will change the traffic light at intersections and alert surrounding vehicles to switch lanes.V2X can also support enhanced mobility and environmental responsibility. DSRC technology can provide red or green light timing advisories to in-vehicle systems to compute appropriate speeds for optimized fuel efficiency, reduced vehicle emissions, traffic flow to reduce congestion, and time-saving driving habits. This information-sharing technology has the potential to improve driving quality and save lives, reduce costs, and promote cleaner environment.

**Architecture, Construction, and Engineering**

Late in 2011, construction on the 736 foot tall, 52-story Leadenhall Building in downtown London, England began. This project required many innovative architectural, construction, and engineering (ACE) solutions and significant coordinated cooperation among its numerous stakeholders in order to meet its multiple tight constraints. First, it had an expected construction timetable of two years, which is extraordinarily short for a super skyscraper. Second, there was virtually no logistics support space at the construction location. The storage space for materials was approximately 10 feet wider than the building footprint because it was located immediately downtown in London. With no logistics support space, components and modules arrived during the late evening for consumption during that evening as storage was not possible. This necessitated exacting component and module specifications to ensure each could be slotted exactly into position upon arrival. Third, fabrication was not performed on site which would have allowed for custom fitting as the limited logistic space prevented on-site material and equipment storage. Even a large scale

work force was not feasible given space constraints. The building components and modules were fabricated off-site at several locations, some of which were hundreds of miles away such as in Worksop, England and Enniskillen, Northern Ireland. Some modules were nearly completely outfitted off site with pipe work, electrics, plumbing, and floor plates and transported to the site again necessitating exacting component specifications in the off-site fabrication as on-site storage was not possible. Fourth, the building had to adhere to rigorous downtown London planning regulations.

One example of the lean technology contribution is the three dimensional (3D) modeling (simulation) that was employed. A comprehensive 3D model was created to facilitate construction objectives. This 3D model afforded several waste-eliminating benefits. First, it enabled multiple stakeholders to practice the assembly in a virtual manner. The participants ran the complete simulation to build the Leadenhall Building 37 times. The 3D practice afforded just-in-time delivery of the materials preventing any violation of the logistics support constraint. These practice sessions ensured that the advance time slot for every delivery for each crane lift, beam, bolt, and cable fix met the rigorous construction timetable. It was estimated the project would have been impossible to coordinate delivery and component installations with conventional 2D blueprints. Second, the 3D virtual simulation enabled participants to engage in the simulated practice regardless of their physical location. Third, the asymmetric shape of the building led to the foundations settling differently. The 3D model enabled engineers to plan for settling differences and to provide an innovative solution of jacks and removable steel-plate shims to adjust the lean of the building.

In the end, nearly 40,000 components were assembled on site in under two years which represents a European construction record for a building of this size. The 3D digital engineering model better enabled project feasibility as well as affording the project stakeholders the ability to eliminate tremendous wastes typical of a super skyscraper.

**Rapid Prototyping**

By itself, engineering supports numerous industries beyond architecture and construction. Technology is having a noteworthy impact in numerous engineering and manufacturing applications outside of ACE. Rapid prototyping (RP) is one example. RP is a group of related tools used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data quicker, at lower cost, with tremendous ability to offer customization (flexibility), to exacting specifications (quality), and in small batch sizes thereby eliminating the need for large volumes to achieve economies of scale.

RP has been applied in numerous applications including design visualization (e.g., in the 3D architectural model of the Leadenhall building noted above), CAD prototyping, metal casting (e.g., General Electric's use of RP jet engine fabrication discussed below), education, geospatial analysis, healthcare (e.g., fabrication of implants and prosthetic devices), entertainment (e.g., video games), and retail (e.g., eyeglass frames and shoe fabrication).

RP fabrication is typically performed using 3D printing or "additive layer manufacturing" technology. Historical manufacturing processes have employed subtractive methods such as milling, planing, and drilling. The RP process utilizes computer generated 3D information that is exported to a 3D printer, which then builds up a scale model layer by layer. The scale model is effectively materialized. One of the advantages of RP is that it allows a testable model to be quickly produced to determine proof of concept for a particular application. Generating a model quickly eliminates waste by determining applicability of an

idea or part for its intended use. Additive layer manufacturing greatly reduces the waste incurred in subtractive methods by ensuring only material needed is used to fabricate the part.

General Electric (GE) notes that it has developed a fuel nozzle using RP for the Leading Edge Aviation Propulsion (LEAP) jet engine. GE utilizes a direct metal laser melting process enabling groundbreaking customization of multiple LEAP components. Essentially, parts are created directly from a CAD file using layers of fine metal powder and an electron beam or laser. GE claims that this part is up to 25 percent lighter promoting fuel efficiency, five times more durable than its predecessor, and it is more complex than its counterparts by combining into one part what was assembled from as many as eighteen parts in a multistep manufacturing process in the past thereby reducing system throughput time (General Electric, 2013).

An example taken from the construction industry uses concrete printing, which employs highly controlled cement based mortar extrusion process which is precisely positioned according to computer data. The additive process has the ability to create custom-shaped construction components (e.g., a wall). The process has the potential to create architecture that is more unique in form. Material components do not have to be made from solid material, and so can use resources more efficiently than traditional techniques. For instance, allowances can be made for embedded conduits in components to directly accommodate utilities (e.g., electrical, plumbing, or telecommunications).

Additional reported benefits of RP include increasing effective communications (e.g., concurrent engineering) and reducing engineering design, development time, and error costs. RP enhances communications in part through its visualization capability. People tend to be visual learners. The extent to which representatives from functional disciplines such as engineering, manufacturing, marketing, and purchasing can see a rendered virtual model or hold a physical, 3D representation enhances their understanding of final outcomes.

RP has been reported to have the ability to reduce engineering and development time as well as decreasing error costs. RP allows modifications or corrections to be made early in the process when changes are less expensive to make. For instance, scale models can be used for testing (e.g., wind tunnel testing) as well as for tooling and casting purposes. The impact of technology in these additional engineering applications is enabling the benefits of lower costs, higher quality, faster orders response times, and enhanced transformation process flexibility.

**Entertainment**

Disney Entertainment has recently introduced experimental wearable technology (bracelets) that electronically link visitors to an encrypted big data collection and analysis system. The data collected allows for analysis to promote efficiencies through ride staffing adjustments, restaurant menus, and ride queue information. The wearable technology can also serve as admission tickets, hotel keys, and credit or debit cards. Disney reports that this system helped it accommodate 3,000 additional guests during the Christmas holiday season by reducing theme park congestion which it states results in an enhanced visitor experience (Palmeri, 2014).

**Healthcare**

Technology is providing numerous health-related improvement opportunities in electronic healthcare. Two examples are attributable to the evolution of Multidetector Computed Tomography and Magnetic Resonance

Angiography technologies for medical imaging. These technologies have led to less invasive and more informative radiological diagnosis. These technologies promote enhanced higher image quality and therefore interpretive accuracy (Kido et al., 2007; Meaney and Goyen, 2007).

Telecommunication capabilities along with increased internet bandwidth are promoting tremendous growth in another field of medicine, clinical telemedicine. One estimate of the growth rate for this medical field will be 18.5 percent annually at least until 2018 (Hall, 2013). A 2012 report from Massachusetts-based market research firm BCC Research estimates the global telemedicine market will grow from approximately $11.6 billion annually in 2011 to about $27.3 billion annually by 2016 which represents 135 percent growth over 5 years.

The growth rate of telemedicine is attributable to numerous benefits, including improving access, especially for home-bound people or those located in rural or remote locations, reducing the transmission of infectious diseases or parasites, better resource capacity utilization, shortening report turnaround times, as well as improving the satisfaction of both patients and healthcare providers (Bruce, 2010; Johnson, 2014; Spring, 2011). It goes without question that the drivers for the growth of this healthcare technology are largely overall cost savings, speed, and flexibility; all as a result of productivity enhancements and waste reductions.

There are many specific examples of telemedicine. Some are conducted using asynchronous communications capabilities such as the transmission of electronic medical records and radiological reports and images. Some are conducted using synchronous communication capabilities over phone or mobile devices such as online video consultations. Other forms rely upon various alternative technological devices such as teleconferencing, robotic surgery, or remote monitoring.

There have been disadvantages cited to telemedicine as well. Included among these disadvantages are the costs of telecommunications equipment and medical personnel training, concerns over the protection of patient health information, potential for increased errors, possible decreased personal interactions which may be more revealing than remote interactions, and others. Needless to say, these exist in the presence or absence of the technology.

**Manufacturing**

Technology is enhancing lean capabilities in numerous ways in the manufacturing sector. One notable method is through the use of Value Stream Mapping (VSM) (Khalid, Hashim, and Salleh, 2014). This method provides for an analysis of process and material flow within a manufacturing system to highlight hidden wastes and identify the source of the waste. It also may identify potential alternatives to help eliminate the waste. Focusing on elimination of these hidden wastes means future efforts can be devoted to value-added activities. One of the challenges of VSM is that it is a static, point-in-time model.

Additionally, real-time asset management solutions have been suggested (Anonymous, 2013). Viewing the manufacturing process in real-time, allows immediate replenishment and waste reduction thereby streamlining the entire process and reducing inventory holding costs. This solution will centrally manage and control supplier collaboration, internal supply and facility-wide communication across multiple locations. Coordination and collaboration allows a more efficient process, helping to eliminate waste.

Lean manufacturing considers it wasteful to use resources for any other purpose than delivering value to the customer, and provides a set of tools to reduce or remove waste (Womack and Jones, 1996). The major

contribution of Lean manufacturing is being able to integrate a single, consistent view of value and utilize that for overall performance. (Simboli, Taddeo, and Morgante, 2014). From an environmental perspective, lean can be measured by pollutant reduction. Previous manufacturing processes simply transferred pollution downstream in the production chain. Porter and Van der Linde (1995) identify pollution in the form of scraps, harmful substances, and excess energy as resources that have been used inefficiently, and are therefore economic waste. Awareness of the problems caused by these methods has shifted focus from reacting to problems to proactively eliminating them. This lens of Industrial Ecology (IE) aims at reducing waste and pollution by using by-products or waste derived from certain production processes, as raw materials or inputs into other processes. Fully integrating the environmental variable into the production process should lead to a more rational and eco-efficient use of resources and reduction of pollution and wastes (Simboli, Taddeo, and Morgante, 2014). Simboli et al. (2014) proposed a renewed perspective of integration of Lean and Clean approaches and tools by introducing the environmental load as another type of Muda. In their study, King and Lenox (2001) show that Lean Manufacturing can positively contribute to the adoption of green strategies, acting on the marginal costs of pollution prevention to enhance firm's competitiveness. While useful as part of a larger strategy, Esty and Porter (1998) caution that despite serving as a useful tool for discovering new sources of competitive advantage, IE must be part of a larger strategy to obtain competitive advantage over other firms.

## Conclusion

It should be evident that the industries noted above are but small sample of the many pursuing the enabling advantages technology offers. Technology applications might start out within a localized portion of a process or it might enable global supply chain trading partners to collaborate on design issues using a 3D virtual model while being located on different continents. The application scale of technological applications being adopted is quite varied. Regardless of the application scale, technology is enabling lean benefits including reduced costs, faster response times, higher quality and greater flexibility all through enhanced productivity and reduced waste. Technology represents the frontier of Lean.

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# Towards Agile System Analysis & Design
## Improving Knowledge Transfer Across Domains Using Layered Framework

Amber Lynn McConahy
Pennsylvania State University
Information Science & Technology
amber@psu.edu

Abhijit Dutt
Pennsylvania State University
Information Science & Technology
aud18@psu.edu

*Abstract*—**An ongoing problem plaguing system developers is the inability to effectively transfer knowledge from domain experts to IT experts. This is due to many factors, such as not having a systematic and standardized methodology in order to conduct system development tasks, tendency to embed business rules and processes in source code without codifying them, and incomplete documentation of software architecture. In order to address this problem, we propose a layered framework in order to encapsulate system development activities and standards the process of migrating from a business problem into the actual implementation of a software solution to this problem. By providing such a systematic approach to the development process, we improve the ability of project participants to make key decisions about the design of the system and it architecture. Utilizing accepted techniques for modeling, this framework better supports the evolution and maintenance of the system by providing multiple layers of abstraction, as well as providing an environment conducive to iterative development.**

***Keywords—framework, SA&D, OOAD, layered architecture, software architecture, software development methodologies, modeling techniques***

### Introduction

Since the 1960s, the use of computers and information systems (IS) in business has steadily increased, featuring more robust and comprehensive solutions. Historically, information technology (IT) was only used for the backend of businesses, which often focused on the storage and management of data resources. In recent years, the widespread use of the Internet has led to the increased acceptance of electronic commerce and mobile commerce both in business-to-business (B2B) and business-to-consumer (B2C) transactions, whereby employees and customers utilize IT systems in order to automate mundane day-to-day operations (Koufaris, 2002). These business processes typically vary in complexity and require developers to embed both business knowledge and business rules into the underlying source code. As the paradigm shift from single, monolithic solutions to software ecosystems continues, system developers must support increasingly complex systems, often with components from multiple sources while maintaining a high level of usability.

In addition to increased complexity, IT system development relies on two distinct stakeholder groups and is a joint effort between IT experts (system analysts, software engineers, software architects, etc.) and domain experts (people who have domain or background knowledge about the system being developed) (Dennis 2005; Evans 2003). Business knowledge must routinely be transferred from the domain experts to the IT experts, and communication challenges between these two stakeholder groups often inhibit the timely and effective transfer of such knowledge. Currently, capturing domain expertise into IT systems remains one of the greatest challenges in IS development. This can be attributed to the fact that there are no formal analysis and design methodologies, which facilitate a systematic and standardized transition from domain expertise into system design (Alter 2005). In other words, the success of a system development effort is highly correlated with the ability to effectively transfer knowledge from domain experts to IT experts. Discrepancies that arise between these two stakeholder groups ultimately lead to delays, budget overruns, and project failures.

In cases where knowledge transfers are effective, an additional challenge presents itself because these transfers are never formally documented. In other words, knowledge that was transferred either exists as tacit knowledge that is never codified or is embedded in the source code. To further complicate this problem, the system development team is often disbanded upon completion of the project, and developers leave without formally capturing this tacit knowledge and extracting it from the source code, which requires both IT and

domain expertise. Furthermore, the design patterns utilized in the implementation typically provide key nonfunctional requirements, such as performance, security, availability, etc., from the source code. Consequently, any third party tasked with extracting knowledge from the source code must understand design patterns and the quality attributes each pattern promotes. This inhibits the ability to make informed architectural decisions about the evolution and maintenance of the system.

Due to the vast problems in the transfer of knowledge between stakeholder groups, we propose a comprehensive framework for system development. Utilizing a layered structure that examines the system at different levels of abstraction, our framework standardizes the underlying system development process in a systematic manner that provides the following improvements when compared to current methodologies:

- Standardizes knowledge transfer between domain experts and system developers
- Records knowledge transferred between domain experts and system developers
- Minimizes reliance on source code to extract knowledge
- Promotes modifiability and extensibility to support changing business needs
- Improves productivity of the system development team by increasing efficiency while facilitating robustness
- Enables agile development through ability to utilize framework for iterative development

The remainder of this paper is organized as follows. First, we will examine related work and review some of the important issues in software development. Second, we will look at software architecture in practice. Third, we shall describe our framework in detail. Finally, we shall discuss our plans for future research.

## Related Work

### Software Development Methodologies & Modeling

IS development has received attention from researchers as well as from practitioners. Four different phases could be identified in an IS development project: requirement elicitation (analysis), design, implementation (coding), and testing. The importance of such models during system development has been recognized since the 1960s. Consequently, several modeling methods have been developed, such as Chen's Entity-Relationship (ER) diagrams (Chen 1977) and Unified Modeling Language (UML), but these modeling techniques have not been very effective in eliciting requirements during the analysis phase due to a disconnect between the models built and final system code (Wand 2002). This disconnect can be attributed to two primary reasons. First, UML is an IT-oriented modeling technique, which makes its use challenging and prone to errors when utilized by domain experts due to their lack of comprehensive IT knowledge. One the other hand, domain experts are generally more accustomed to Business Process Modeling and Notation (BPMN), and although BPMN is similar to UML's activity diagrams, it lacks the robustness and versatility necessary to document all necessary perspectives needed to fully model the systems architecture. In other words, the current system development methodology lacks a standard and efficient modeling technique that enables the transfer of knowledge across domains. To further complicate this, current outsourcing trends often separate the domain experts from the IT experts causing additional knowledge transfer difficulties due to cultural differences among globally dispersed team members (Krishna 2004). Secondly, many system development projects still adhere to antiquated waterfall models that lack an iterative process that better supports changes to the requirements. In such cases, last minute changes are generally integrated into the source code without updating the associated models and documentation, which leads to a disconnect between the design documentation and the actual implementation.

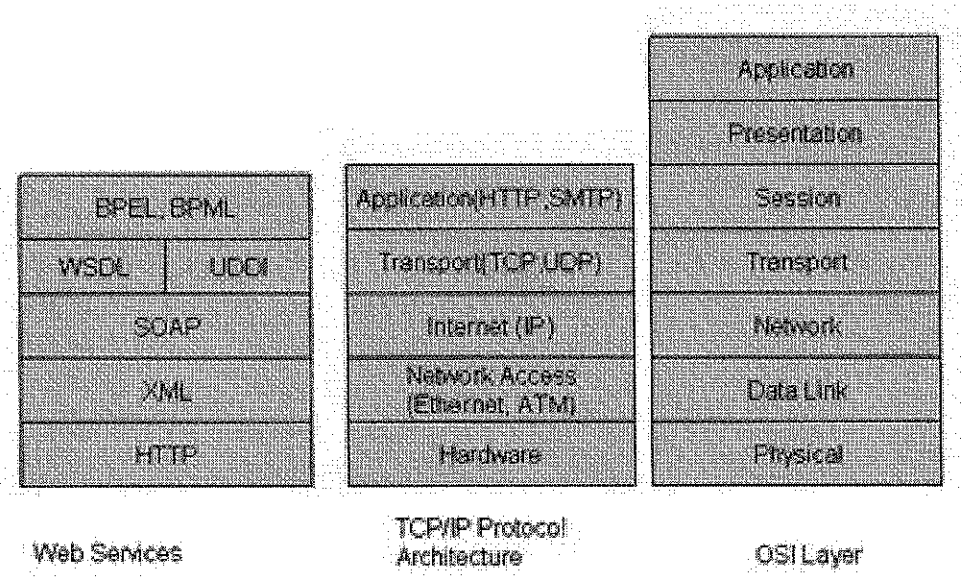
Due to these problems, it can be concluded that there is an immense need for a holistic formal framework that enables domain expert to effectively capture business rules and knowledge in a format that can be easily translated into a system design. Such a framework would standardize the transfer of knowledge from domain experts to IT experts thus enabling domain experts to better elicit the necessary requirements and translate these with the IT experts into a reasonable design for the system.

Recently, Hevner et al. (2004) discussed the importance of conducting design science research, and they observed that research into design methodologies was lacking in the MIS community. Additionally, Bajaj et al. (2005) showed that although "System Analysis and Design" (SA & D) appears in almost every IS curriculum where it is considered a core IS course, only 3% of research articles in IS journals are devoted to SA & D. The observation of this teaching-research gap by Bajaj et al. causes an inability to keep SA & D courses up to date. Therefore, our research attempts to fill the aforementioned gap by providing research into SA & D using a decision science approach.

Software Architecture

When documenting the software architecture, four types of architectural drivers are typically defined that correspond to the system's requirements: functional requirements, nonfunctional requirements, business constraints, and technical constraints. Functional requirements are generally the easiest to elicit from stakeholders and refer to the overall functionality of the system. For example, a e-commerce system might include functional requirements, such as catalog of products searchable by consumers, a shopping cart, shipping calculator, and payment processing. The business constraints refer to the requirements imposed by the organization, which includes budget, delivery time, number of developers, documentation policies, compliance requirements, etc. The technical constraints refer to any technology that must be used or supported by the system, including hardware support, programming languages, software support, etc. For the e-commerce solution, perhaps the system must be deployed on a Tomcat web server and implemented using a Java frontend combined with a MySQL backend. The nonfunctional requirements or quality attributes are the most challenging of these architectural drivers and refer to the properties that the system must have, including performance, security, usability, availability, extensibility, modifiability, etc. Although domain experts may understand that the system needs to be secure, it is often challenging to express the level of security in a manner that is quantifiable and testable. For instance, the security may be defined as the number of unauthorized accesses to the system in a period of time, such as no more than 1 unauthorized access per month. Establishing reasonable nonfunctional requirements and translating these into the design of the system is extremely challenging.

**Figure 1: Examples of Layered Architectures in Networking and Web Services**




Due to the complexity of software architectural documentation and the need to ensure its completeness, there is yet another layer of disconnect between the domain experts and IT experts. Business processes and views are typically only evaluated by domain experts from a dynamic perspective, and they generally do not concern themselves with how the system is implemented or what hardware is needed to support the system. As a result, lack of knowledge about static and physical perspectives hinder the ability of the domain experts to comprehensively identify the necessary components of the system. Furthermore, the difficulty in establishing nonfunctional requirements compounds this problem. As a result, it is frequently necessary to change a system, which leads to cost and budget overruns. Additionally, changes that must be made to the system during later phases of the development lifecycle cost exponentially more than changes made during earlier phases (Boehm, 1981).

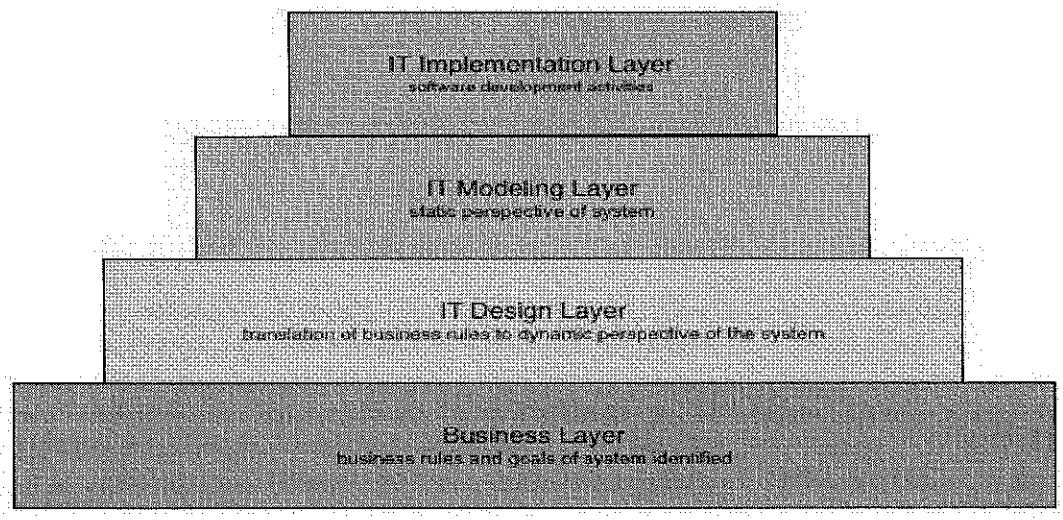
## Methodology

During the last forty years, many different system development methodologies have been adopted, such as structured analysis, object-oriented analysis and design (OOAD), component based software development, etc. (Blaha 1998; Vitharana 2003). Although there are important differences among the aforementioned methodologies, concepts, such as information hiding, modularity, reuse of code, and adoption of architectural design patterns remain common features in most methodologies (McConnel 2000 ; Wasserman 1996). Consequently, we recognize that any system development framework should be based on those concepts. Furthermore, layered structures are common in most companies. For example, consider the management structure of an organization, where employees can be organized in layers that correspond to their job responsibilities. For example, the CEO takes an overall view of the company, whereas lower level employees concentrate on specific jobs. Similarly, layered structures have been successful in other areas, including networking, database design, web services, protocols, operating systems, etc. Consequently, we reviewed three areas where the concept of layering has improved understanding and enabled the construction of effective and interoperable systems.

First, in the networking world, the seven-layer OSI model and the practical four-layer TCP/IP model have enhanced the understanding of networking concepts through the separation of concerns. This allows system developers to focus on smaller pieces of overall problems and encapsulates implementation details. For instance, when developing components belonging to the Internet layer, developers can develop applications that utilize packets for data transmission without knowledge of the how each bit is transmitted. Alternatively, developers working in the hardware layer implement the efficient transmission of bits without a need to consider the implementation of the user interface. In the web services domain, utilizing different levels of abstraction to conceptualize the service enables developers to identify the business needs efficiently, while simultaneously ensuring that individual components of the system can adopt different protocols without cumbersome integration issues.

In our framework, we propose a layered model of system development. Layering provides the following advantages in system development. First, it simplifies the complexity of system development by using information hiding. This is achieved through the adherence to the principles of layered architecture where a given layer can only access components within its own layer or from the layer immediately below it. All other layers are invisible and their implementation does not matter to the current layer. By providing this structure, a system developer or a domain

**Figure 2: Layered Framework for System Analysis & Design**




expert focuses only on a small subset of the system and can complete the required activities without needing to worry about the overall system. Second, dependencies among layers are minimized and the design is modular and supports reusability. The framework can be utilized in an iterative fashion, which better supports agile methodologies. Finally, the system development

process is completed in a systematic and standardized fashion. The four layers are shown in Figure 2. The framework is composed of the following layers:

- **Business Layer:** The business problem is identified and described allowing a domain expert to represent business logic, business rules, and business processes unambiguously. This requires the identification of all functional requirements. Additionally, any business constraints will be identified. Activities in this phase will be driven by the domain expert with the support of the IT expert will also be involved.
- **IT Modeling Layer**: Using the information from the business layer, the IT expert will translate the business processes and rules into a dynamic perspective of the system. This requires the identification of nonfunctional requirements, and feasible tests to ensure adherence to these. Assuming the use of UML, this would include the construction of use cases and activity diagrams or sequence diagrams. Additionally, the identification of persistent elements would be completed and an initial ER diagram constructed. Activities in this phase will be driven by the IT expert with the support of the domain expert, and most of the knowledge transfer from the domain expert to system analyst will happen here.
- **IT Design Layer:** Using the information generated as part of the IT modeling layer, the detailed design of the system is made by system developers. This includes a static perspective of the system as well as the modification of any dynamic perspectives. Some

  of the IT artifacts produced in this layer would be class diagrams, package diagrams, data dictionaries, and database schemas. Activities in this layer are driven by IT experts.
- **IT Implementation Layer:** This layer depicts the actual implementation of the system. Technical constraints must be identified here, and a physical perspective of the hardware needed for the system must be completed. Some of the artifacts which belong to this layer are source code, executable, external libraries, software dependencies, and hardware. Activities in this layer are driven by IT experts, specifically software developers.

## Using the Framework

### Business Layer

In this section, we discuss the details of the business layer of our framework. This layer is not technology dependent, and it captures the business processes that we wish to solve through system development. One of the main functions of business layer is to identify and document the purpose for building an IS as well as the full functionality of the IS. It also is necessary to capture all the business rules, which determine the workflow of the business process we are trying to map through this system.

The framework consists of six concepts, and no hierarchy exists among these artifacts since each concept belongs to the same layer. However, there are interdependencies among these concepts. These six concepts and their dependencies should be documented in a manner that is conducive to migration into written use cases. The six concepts that compose the business layer are discussed below.

1. **Business Work:** Since most IT systems are designed in order to automate or solve a specific business problem, we define business work as an overall view of the business problem described using plain English. Business work helps users understand an overview of the system being developed. As an example, business work could be "Ticket Purchase."
2. **Business Process:** A business process is defined as a clearly identifiable workflow, which has a specific business meaning. In most businesses, a workflow evolves as a set of well-defined steps for achieving an objective. As we discussed earlier in this paper, there is often variability in business processes. As an example, let us consider an organizational process "Ticket Purchase". A ticket could be purchased through various ways such as the Internet, window, phone, etc. Each of these correspond to a different business process yet achieve the same overall goal of purchasing a ticket. Although there is similarity among those business processes, there are also be important differences. As a result, in order to describe business processes, it is important to first quantify the variability in the process using the methodology suggested by Pentland (2003). The business processes, which are variable, are complex, and hence, those processes need to be modeled more carefully. For representing business processes, several methods are

available, but Business Process Modeling Notation (BPMN) appears to be most popular and very effective. BPMN is one of the three specifications that Business Process Management Initiative (BPMI) has developed. The other two are Business Process Modeling Language (BPML) the standard business execution language and Business Process Query Language (BPQL) a standard management initiative.

3. **Activity:** An activity is a simple atomic task or a collection of tasks and is defined as a series of steps needed for accomplishing a business process. If a person is purchasing ticket using the Internet, an activity involved is "Processing Credit Card Transaction". An activity will be described using plain English, and it should be easily understandable. Although there are instances where an activity is not related to a business process, the activities should be identified by first inspecting the business processes. Then, one should look outside the process for additional activities. In many cases, activities can be broken down into sub-activities. In such cases, it is up to the modeler to determine the level of detail needed to sufficiently document an activity.
4. **Actor:** An actor is either a person or a device (equipment), and it plays an active role in a business process. An actor initiates or participates in or reacts to an activity. An example of an actor is a customer of a business or a truck, which transports goods in a "Supply Chain". An actor could have many instances and usually has information associated with it.
5. **Event:** An event is a significant occurrence in time or space (Eriksson) or in other words, a particular, specific, and unique instance of an activity. The main difference between an event and an activity is that there is only one specific instance of an event, whereas there can be many instances of an activity. In most cases, an event will have specific start time and specific end time. Hence, making a backup of database is an activity; however, making a backup of a database on Friday at 5:00 PM is an event.
6. **Business Objects:** Business objects are defined as either concepts or documents that are used for conducting business. Business objects cannot initiate or be active participants in an activity; however, they can be used in business processes. Some examples are tickets, invoices, purchase orders, etc. Business objects contain the necessary information pertaining to physical objects without containing any operation or activity.

Once the aforementioned 6 concepts are identified, a business model of the system using BPMN is constructed.

Transformation to IT Design Layer:

In order for this framework to be effective, it should be straightforward to move from a lower layer to higher layer. Knowledge is transferred from domain experts to IT experts, and a dynamic view of the system is generated. The IT design layer transforms the artifacts from the business layer into IT design layer artifacts as follows:

1. Inspect all actors and identify the actors, which are outside the system. These actors will map to the actors in the use cases.
2. For each of the actors, identify the activities they participate in.
3. Using the above information, draw use case diagrams, and complete written use cases.
4. Map activities and business processes to a dynamic perspective of the system. Identify nonfunctional requirements and adopt design patterns that are conducive to these quality attributes. If using an object-oriented approach, any objects must be identified and the relationship between these objects.
5. Map BPMN diagrams to UML activity diagrams using the standard procedure.
6. Identify, business rules embedded in activities. Incorporate business rules into the UML diagrams already drawn and ensure that design adheres to nonfunctional requirements.
7. Inspect all the business objects, activities, and connections between activities and actors. Then consolidate the business objects and the activities into objects and classes and then draw the UML sequence diagrams. Some of these objects are persistent, and for those objects, create ER diagrams in order to begin database design.

Transformation to IT Modeling Layer

Once the IT design layer artifacts are generated, we transition to the IT modeling layer. This involves using the dynamic perspectives and persistent models from the IT design layer to construct static perspectives of the system and update current dynamic models. In order to

transition from the IT design layer to the IT modeling layer, the following tasks are completed:

1. Objects identified in IT design layer are formalized into classes. Class hierarchies are established, and instance variables and methods are defined.
2. Using dynamic perspectives, create static perspectives of the system, including class diagrams.
3. Adopt design patterns that ensure adherence to nonfunctional requirements for static perspectives.
4. Use ER diagram to construct data dictionary and database schema
5. Adjust dynamic perspectives if needed to support static perspectives.

Transformation to IT Implementation Layer

In order to complete the system, we must transition from the IT modeling layer to the IT implementation layer. In this layer, we must identify all technical constraints and implement the actual system. In order to transition from the IT modeling layer to the IT implementation layer, the following tasks are completed:

1. Technical constraints are identified, including programming language, IDE, operating system, libraries used, software dependencies, and hardware.
2. Physical perspective constructed that depicts the hardware aspects of the system.
3. Using the models completed during the IT modeling layer, source code is written.
4. Unit testing is completed.
5. Integration testing is completed.
6. Completed system is deployed.

## Future work

This work will be extended in the following way. First, a comprehensive model for a system using the framework will be developed. Second, we shall do a laboratory experiment in order to test the usability of the new framework. Another interesting area where this work could be extended relates to the work done on patterns. Gamma et al. (1994) introduced the concept of "Design Patterns" and solved common problems using robust solutions based on patterns. Fowler (1997) identified similar patterns, which occur in the analysis phase of software development, and he named them "Analysis Patterns." Similarly, further research could be undertaken in our "Business Layer" to uncover business patterns in a similar way, which would assist domain experts in modeling the business layer of an IS project.

## Conclusion

In this paper, we investigated a problem frequently faced by domain experts. Specifically, domain experts need to participate in system development, but there is neither a guideline nor a methodology to effectively permit their participation. Our work adds to the current literature in the several ways. First, it identifies disconnect between domain experts and IT experts as an interesting problem. In addition, it proposes a comprehensive layered development framework, which approaches the system development process using different levels of abstractions. Furthermore, the proposed framework incorporates common technologies, such as BPMN and UML. Therefore, it does not require the use of any unfamiliar or new modeling tools, but rather it shows how the existing modeling tools, such as BPMN and UML can be used to better model a system. Similarly, it uses the existing facility to convert BPMN to UML. Finally, it proposes how to convert business models into an actual IS implementation.

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**Enhancement of your Online Organizational Development Course with a Business Strategy Project and Video Discussion Forums**

Dr. Debra Westerfelt
Associate Professor of Business Management
Ashland University

All students in the MBA Program at Ashland University take a course in Organizational Design, Development and Change Management. This course explores the theories and concepts managers can apply, on their own or in collaboration with an OD consultant, to drive effective change management initiatives within their departments or organizations. Students learn the techniques that would be effective if they were to serve as internal consultants in their organizations or external consultants assisting new business.

This particular course is taught by the presenter/author and put in Quality Matters format for Ashland University's MBA program. The presenter has been teaching this course for ten years and is the lead professor for this course. Students who take this course have actually received promotions in the workplace because of the intervention proposal that they have prepared for this course.

In this course, students complete a Business Strategy Project, which is implemented throughout the duration of the course.

The purpose of the BSP project is to help students gain experience in managing and understanding the dynamics of short-term, positive, planned change through goal setting and intervention. This project is based on Robert Schaffer's *The Breakthrough Strategy.* In other words, Schaffer's project model utilizes short-term successes to build high-performance organizations.

According to Schaffer, in his book, there are five barriers to performance improvement:

1. Psychological Myopia: Viewing the world in ways that are comfortable and reassuring.
2. Wasteful Work Patterns: Shaping work patterns to stay with familiar routines to avoid anxiety-producing situations.
3. Weak Performance Expectations: Asking employees for less than they are capable of to avoid uncomfortable situations.
4. Misuse of Work Management Disciplines: The tendency to be casual or cynical about work planning, measurement, and tracking procedures.
5. Invisible Conspiracy; The Underside of Corporate Culture: Debilitating patterns that are reinforced by formal and informal mechanisms. (Schaffer, 1988, p. 19)

Often times, organizations fail because there is a complacency on the part of managers and subordinates to *shake things up* and create new plans and procedures to improve performance. There is lack of proactive initiative to properly maintain the status quo or identify and anticipate potential problems, not to mention plan for future growth.

Managers often feel that their first step in improving performance is finding new programs or making radical changes to produce results. Leaders will bring in external consultants and pay exorbitant fees to produce grandiose initiatives when they could work within their own confines to achieve improvement within existing systems and structures. This decision is sometimes based on ego and/or a lack of trust in employees already in place to carry out such an initiative.

Many Total Productive Maintenance (TPM) culture changes have both knowingly and unknowingly followed BSP steps to achieve significant results. Changing the work culture often means changing both individual and collective behaviors of people at the workplace. (Williamson, 1997, p. 3)

As Robert Schaffer stated in his 2010 *Harvard Business Review article,*

> "Everyone has seen senior managers announce major directional changes or new goals without spelling out credible plans for achieving them or specifying who's accountable; for instance, "We are going to reduce the use of cash by 40% next year" or "We are going to cut train accidents significantly" or "We are going to shift focus from midmarket

> customers to the upper end during the next two years." Such efforts go nowhere." (Schaffer, 2010, p. 1)

In the Business Strategy Project for this Organizational Design, Development, and Change course, students complete their change initiative in three parts:

Part One: Proposal; Background information and identification of issues
Part Two: BSP Action Plan; Creation and implementation of SMART Rubric
Part Three: BSP final report; Application of theories; Project outcomes, and follow up

The presenter/author shares the *specifics* of the BSP project, as well as *actual completed projects* that students either plan to implement or actually implement in their organizations. For those students who are *not* currently working, they are encouraged to do extensive research (and SWOT analysis) on a company that they are familiar with, identify a process or procedure that needs intervention, and create a specific plan for change.

The area for improvement that students select is an intervention that can be completed within one to three months, such as attendance, rewards, customer service, or a new procedure. Through the use of initial start-up components and a SMART rubric for action planning, the students develop their plan in stages. The SMART rubric identifies goals as: Specific, Measurable, Achievable, Realistic, and Time-Bound.

Throughout the paper, students are to cite theories from the text that they have chosen to assist them in their interventions (ie. Kurt Lewin's Equilibrium Theory, Action Research, Positive Model, team building). Their papers culminate with a discussion of actual project outcomes, modifications made, etc. Conclusions and recommendations are also offered, which include a look at their personal observations throughout the process.

**Use of Videos for Course Enhancement**

The author also shares videos (some of which are actual scenarios) that are used to reinforce lecture material related to theories in the text and examples of interventions. Videos

are also used to stimulate effective discussion forums in the course. Situational videos from *The Profit* are excellent learning tools in the field of consulting. The students themselves are encouraged in their discussions to include videos or share books that they enjoy that relate to the content in the course. The use of videos rate high praise in the end-of-course evaluations.

## Conclusion

The use of actual work projects and real-life video scenarios can make an online class come alive. The author has had consistently high evaluations in the course for ten years. Some MBA students have actually entered the consulting profession after taking the class because they have been given the proper tools to begin that venture, and they are excited about the field.

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# Context Scenarios for Teaching Cynefin Framework to Management Students

Khushwant K. S. Pittenger
Ashland University

## Abstract

In the global business environment decisions are made in an increasingly dynamic environment that is often influx for analysis with many traditional management tools that assume an orderly, rational and static world. In the recent years, Cynefin framework has emerged as a comprehensive framework for understanding and analyzing systems in the new environment so that managers are better able to lead. This paper is a resource for developing new managerial skills related to the use of Cynefin framework among management students. After a brief explanation of Cynefin framework, four real-life based scenarios are provided. Instructors can use these scenarios to teach students the four key contexts of the framework in an applied setting. Also included in the paper is the analysis of each scenario to help instructors facilitate a guided discussion in the classroom.

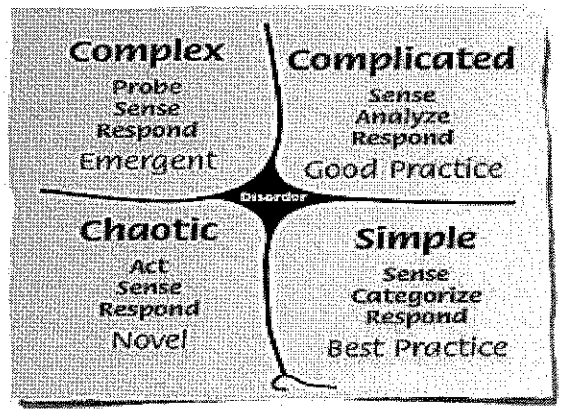
*Keywords:* Cynefin framework, decision making, leadership, new business environment

## Introduction

As per Snowden (2002), management education tends to be based on the assumptions that organizations operate in a world that is orderly where managers, through deliberate actions, can make rational decisions using prescribed tools. These assumptions hold true under some contexts but breakdown in many others. As a result, managers are not prepared for facing the range of situations that confront them throughout their professional careers. Cynefin framework is proposed to make sense of a world that is not always orderly and static (Snowden & Boone, 2007). Given below is the brief overview of the framework which is grounded in complexity theory. A graphic representation of the framework is provided in Figure 1.

Figure 1: Cynefin framework

Source: Snowden, D.J. and Boone, M.E. (2007).




The Cynefin framework consists of four primary domains of interpretation and action: Simple/Known, Complicated/Knowable, Complex, and Chaotic. These domains can be used to analyze decision maker's contexts, situations or work. According to Fitch (2009), the Simple/Known domain, "encompasses situations where cause and effect, as well as solutions and strategies, are known and at hand, the Knowable domain encompasses causes and effects, solutions and strategies that are not readily at hand but can be acquired through research or consultation with experts. The Complex domain is the area of complexity theory in which cause and effect exists, but they are too complex or distributed to be knowable ahead of time. Patterns emerge in retrospect and do not necessarily persist. The Chaotic domain considers conditions in which the system is turbulent and no cause-and-effect relationships are discernible. The Cynefin framework describes strategies for sense making and action around the boundaries and contexts of these domains (pp. 1-2).

In its abstract form, the framework can be profusely theoretical. The purpose of this paper is to provide a ready resource for teaching Cynefin framework in an applied manner through the use of scenarios. This resource can be used for developing managerial skills of recognizing and differentiating the four major contexts of the framework to lead appropriately rather than

heuristically.

The four scenarios fitting each context of the framework are described along with discussion questions and our responses. The scenarios are fictional but realistic.

## Literature Review

Decision making is a complex process, but since the beginning, the decision theory has provided strategies to guide decision making (Edwards, 1954). These strategies, however, must fit the logic of mainstream decision theory and research (Svenson, 1979). The underlying two key assumptions that often pervade the practice and the theory of decision making are: first, *the existence of order* as presented by Fredrick Taylor (1911) and supported by other research scientists such as Gantt (1919), Emiliani (1998), Forza (1996), and Hirano (1995). It is assumed that human interactions and markets are governed by cause-and-effect relationships which can be discovered and hence predicted. There is one best way or ideal way of doing things. These systems of order also have been manifested in recent phenomena like business process reengineering (Hammer & Champy, 1993). The second assumption is *the existence of rational choices,* which implies decision makers tend to maximize profits, and pleasure and minimize losses and pain. Decision makers in both policy-making and operational levels, are increasingly coming to deal with situations where these assumptions are not true, but the tools and techniques which are commonly available assume that they are (Kurtz & Snowden 2003). The existing models based on these assumptions have not been able to guide the decision makers in the present context of permanent crisis (Heifetz, Grashow, & Linsky, 2009). In order to respond effectively in today's highly changing environment, organizations need managers that can perceive, understand and effectively work with complex and chaotic systems (Fitch, 2009). Literature already proposes problem categorization framework such as systems framework approach (Flood & Jackson, 1991). One amongst such framework is Cynefin Framework

(Snowden & Boone, 2007) which is most pertinent in defining the various situational variables in which the decisions have to be taken in the present environment. The Cynefin Framework provides a useful way to integrate domains of complexity and chaos into conventional views of decision making and strategy, which is essential in light of the view that complexity is rapidly increasing (Fitch, 2009). Cynefin Framework is an outcome of action research projects conducted over a period of ten years, and has been successfully applied to government and broad range of industries like U.S. Defense Advance Research Agency. It has been applied to counterterrorism, and it is currently a key component of Singapore's Risk Assessment and Horizon Scanning Program (Snowden & Boone, 2007). Cynefin Framework researchers report that despite increasing complexity, intuitive decision making is often a favored mode for decision makers which can be very costly for organizations. Hence training management students on effective decision making in different environmental context as suggested by Cynefin Framework can equip them to make better decisions in real life situations.

We have developed four scenarios for training students on decision making in management education programs.

**Scenario I**

You are the Head of the Maintenance Department of a medium-size steel plant which was established two decades back. Eleven shift supervisors and five managers report to you. The plant operates 24X7 in three shifts round the year. There are 110 company employees and 236 contractual employees. The company employees are in the category of skilled and semi-skilled workers. They have well defined progressive salary structure and good benefits. The employment terms and conditions as well as policies and procedures are well documented in an employee handbook. The company employees also have one registered trade union. The contractual employees are in the category of unskilled and semi-skilled laborers and technicians.

They do not enjoy the same salaries and benefits as the permanent employees .

John – a shift supervisor is an old hand and has been working for you for six years. He is a very meticulous manager and a good planner. He maintains timesheets for all the employees. He lists all the work at the beginning of the shifts, makes estimates of the resources required to complete the task, and then allocates work to all the subordinates. It is hunting season. A common problem during this period is availability of employees as a good number of them hunt. A major task that your department has in hand is relining one of the three blast furnaces that the plant has. The deadline to complete this project is approaching. John calls you on your cell and says that one of his foremen has reported two hours late for work. The foreman is involved in the relining project and is a temporary employee. John is not sure whether he should permit the foreman to work or send him back for coming late. You know that there is a tardiness problem in general, but the availability of workers during hunting season is another pressing issue to be handled.

After some thought, here are the alternatives that you have outlined.

Alternative 1: This is a simple context. There are well defined policies and procedures for permanent staff. The same policies can be applied to temporary workers as well. John is an experienced shift supervisor and you trust his judgment. You ask him to do whatever he considers would be the right decision.

Alternative 2: It is a complicated context. Your human resource manager is asked to review the previous decisions and the company's attendance policy to determine the best way to handle the situation and advise the shift supervisor.

Alternative 3: It is a complex situation which requires input from various sets of people. You call for a communication meeting of all the shift supervisors and managers to discuss and brainstorm as a group and then jointly develop and implement a new attendance policy.

Alternative 4: It is a chaotic situation. You need the foreman for the completion of the critical project. The union's reaction to a firm action against a temporary employee is unknown. You tell the shift supervisor to permit the foreman to work. You also ask him to decipher a pattern of tardiness from his records to suggest changes in the attendance policy.

**Analysis of Scenario I**

The following five prompts can be used for leading discussion on the analysis of scenarios.

*Prompt 1*: Identify the context of the problem according to Cynefin Framework. Give reasons for your choice.

*Response:* The context of the problem is Simple. Simple contexts are characterized by stability and clear cause-and-effect relationships that are easily discernible by everyone. Often, the right answer is self-evident and undisputed in the realm of "known knowns." Repeating patterns and consistent events in the past are available. Decisions are unquestioned because all parties share an understanding. Since in the given situation policies of late coming are well in place, all the information necessary for dealing in this domain is well known to the employee as well as the manager.

*Prompt 2*: What style of decision did you choose prior to knowing about Cynefin Framework and why?

*Response:* The participants would offer different solutions based on their preferred decision-making style. The facilitator needs to bring the participants closer to the concept of choosing an option based on the context rather than preferred decision-making style.

*Prompt 3*: In light of the analysis using Cynefin Framework, what solution would be the best and why?

*Response*: As per the Cynefin Framework, while facing a simple problem, the manager

should sense, categorize and respond. They assess the facts of the situation, categorize them and then base their responses on established practices. It involves fact-based management. Adhering to best practices makes sense. Directives are straight forward, decisions can be delegated and functions are automated. Exhaustive communication among managers and employees is not usually required.

In the given scenario, pertinent facts to the problem are: the employee is late to work by two hours, the availability of workers in general is less due to hunting season, and the employee is involved in relining the blast furnace whose deadline is approaching. Besides these facts, the manager also needs to know the pattern of previous decisions on similar cases, as well as policies for dealing with tardiness. Since all of this falls into the realm of known-known and all the information is available to both the manager as well as shift supervisor, the-fact-based management relies on best practice of the past. Such can be used in resolving this issue. Since proper policies are well in place, the decision maker (head of the department) can delegate it to the shift supervisor.

*Prompt 4*: What could turn this simple context into a complicated or chaotic context? Give your reasons.

*Response*: The purpose of this question is to facilitate discussion on identification of boundaries. This will also reinforce better understanding of a given context. The decision context can become complicated if new policies are announced like change in labor laws that protect the interests of temporary employees, even in tardiness cases. In a situation like this, the context has shifted to a complicated system and hence requires expert advice from the labor lawyer of the company. A simple context can easily shift to chaotic if the senior managers start micromanaging routine activities.

*Prompt 5*: In your world, identify the issues that reside in simple context? How are these

issues handled? How should they be handled as per Cynefin Framework?

*Response*: This prompt is meant to bring hypothetical to reality. To do so, ask students about issues that have been standardized, have procedural norms, are well documented and have become best practices of the organization, such as grade processing, class registration, and financial-aid. It would be interesting to have a discussion on how these issues are handled, and how they should be handled using Cynefin Framework,

**Scenario II**

You are a Vice President at a multinational company that provides clients with proprietary tools such as software, databases, search portals and engines. You have a degree in Computer Engineering. Your technical abilities are legendary and you build strong rapport with clients. Coeus is an online portal your company developed six years ago. It has been immensely popular since its launch and is used frequently by 90% of your clients to search your database of 5500 companies. Your clients appreciate its speed and efficiency but feel the addition of companies from emerging markets will give them a better advantage. You admire your company's fast-paced, time-sensitive and performance-oriented culture. Currently you are working on six international projects that take you around the globe to meet with high profile clients. During these visits, you have heard much about Coeus. As a result of your travels, you have excellent knowledge about the emerging markets and do understand the clients' need for access to information related to companies located in these regions. You feel the coverage of these regions will require the database to expand at least three fold. As a computer scientist you understand that financial modeling of each company is laborious and complex. In addition, a client's query going through 5500 company database in order to find 50 suitable matches is taxing for the system and yet the clients expect quick results. The time performance of the system with the current number of companies in the database is satisfactory, but it will not meet

expected standards if the total number of companies in the database exceeds 6000.

You are wondering about the possibilities of enhancing the efficiency of the query system, the scalability of the project, redundancy and partitioning of data, data security and much more. Technology has changed so much in the last six years. Computer memory is cheaper, computing speed is faster, and the availability of open source solutions is exploding. New proprietary applications and tools are also regularly launched for specific uses, and users are becoming more sophisticated and demanding; and threats to corporate data by viruses and hackers are increasing. Much has changed in the environment as well. The economic landscape since 2008 financial meltdown has not returned to the previous normal, government financial regulations are constantly in flux, economic growth patterns are shifting away from the developed world to other parts of the globe, European Union is in turmoil, and Arab spring has turned into the fall of some mighty kingdoms and cold-blooded wars in other kingdoms in the middle east and northern Africa. You feel fortunate to have a dedicated team of professionals. Each one of them is an expert in his/her field. You are confident in your technical abilities as well as your people skills. You are sure that up-dating of Coecus is in order but it is not an issue of crisis at this time.

Here are the alternatives you have decided after some thought:

1. You already have a good idea about the advances and changes in the field of technology, as well as the economic and political landscape of the world. The information you have is sufficient for making a quick decision. In your mind, it is a simple situation where Coecus' scope needs to be expanded and so you are going to be expedient and quickly get the job in the hands of an intern. He has nothing but time on his hands and would love the challenge.

2. Your team is really strong and each person is an expert in his/her own area. The specialization of each member is different and will yield understanding from multiple

perspectives. Listening to the ideas of the intern will be helpful since he is not initiated into any specialization and many times thinks outside the box. There are other "experts" in the company that you plan to consult. You think it is a complicated situation in which you must gather information on customer needs, possible alternatives, benefits and risks of each alternative and various combinations of solutions across disciplines. Some computer modeling of possible solution will be conducted and data analyzed for efficiency and effectiveness of the solution. It is time consuming but you consider gathering the experts together and generating and analyzing all this data prior to making your decisions and implementing them.

3. You were surprised to hear the same need from various clients located in different regions. You sense a pattern emerging related to shifting markets. The emerging markets are slowly becoming increasingly important to all your clients. If you take control of the situation, you can implement solutions (it might be beyond just modifying Coecus) that will address clients' future needs that they do not even see at this time. In your mind, it is a complex situation where you need to recognize emerging patterns and shape them in your favor. You plan to increase the interaction between your team and the clients to make sure you are responding to the emerging patterns quickly.

4. All the political and financial changes are causing you anxiety. You believe the world is changing alarmingly fast and your work could get impacted in an unexpected fashion at any time. You believe it is a chaotic situation and you really do not have time to think, gather data, do analysis or anything else. You need to just go with your gut and start implementing some changes immediately.

**Analysis of Scenario II**

*Prompt 1*: Identify the context of the problem according to Cynefin Framework. Give reasons for your choice

*Response*: This context is complicated. The client needs are stable, the current system is stable and the constantly changing variables are not the central part of your context or the decision criteria. The clients want Coeus to accommodate their emerging needs for information on companies in the growing markets. Coeus was developed and refined over many years and it has many sub-systems that have to work together to produce a quick result for the client's query. You as an engineer can make a change but you have to ensure that the change does not disrupt the performance of the other sub-systems causing sub-optimization or failure in the rest of the system. For example, you could add companies from the other regions but your query system is likely to become sluggish because of the increased size of data which will make the customer unhappy. In addition to the size, you have to look at the speed. While you are looking at the speed and size, you also need to be concerned about security and stability of Coeus. Regardless of the speed and size, if the system crashes and is down often, it will not make the clients happy. Similarly, do all clients need access to all regions of the world or do they specialize and you need to build fragmented system that can be sold/bought in chunks as per the needs of the clients? Also, what is the incremental cost for updating the system and/or building the new modules/segments? What is the price elasticity of your client demands? What do you need to develop in house, what do you need to out-source, and what is available through open source and what are the respective advantages and disadvantages of each? The system is complicated because while there are answers to each of these questions, they need to be identified and aligned with each other. Each change causes a ripple effect which requires feedback from other affected systems to make further adjustments.

*Prompt and response 2*: Same as scenario I.

*Prompt 3*: In light of the analysis using Cynefin Framework, what solution would be the best and why?

*Response:* As per Cynefin Framework, while facing a *complicated* problem, the manager should sense, analyze and respond. Procedures suggest you carry out a careful needs assessment of the clients, taking into account concerns for speed, accuracy, reliability of the system, coverage of regions and tolerance for price increases. Do a study on the adequacy of your current system in light of these criteria, explore various options and their advantages and disadvantages to fix the inadequacies and make a determination on a right solution based on the expert advice. It is a domain of "knowable knowns" where experts dominate. The danger is of experts being overconfident or being entrenched in their thinking. Getting an outside perspective can keep a check on such dangers. As a result, the role of the intern is crucial. He is yet not entrenched in his thinking. Also, using multiple experts together might help you see the limitations/strengths of their respective perspectives. Your goal is to focus on analysis to choose a solution that meets the clients' needs, ensuring that other alternatives have been assessed and eliminated.

In light of the above, alternative 2 from scenario will work the best. It pools all the resources together, including you. It will be the most time consuming for you. It will allow you to seek relevant perspectives (sense), use tools and models to evaluate the various perspectives in relationship to each other and make adjustments in your possible solutions (analyze) and respond. You must guard against analysis paralysis, however.

*Prompt 4*: What factors can easily change the context to a different context (e.g., simple or complex)? Give your reasons.

*Response:* Kurtz and Snowden (2003) emphasize the need for the participants to understand boundary crossings between the four domains. There are conditions that can happen naturally to change the characterization of the context. Kurtz and Snowden also discuss intentional movement across these borders for various reasons. All such discussion is beyond the scope of this paper.

This context could become complex if the political situation in developing markets such as BRICS becomes politically unstable undermining their economic growth and hence attractiveness to your clients (client needs keep changing unexpectedly in a rapid fashion), a competitor comes up with a product that makes Coecus look ancient (it is six years old after all), and there are technological changes affecting Coecus about which you or your experts are not aware (disruptive technologies). These are just some examples to get the discussion going on the boundary defining conditions.

On the other hand, it will become a simple situation if you find out that when the Coecus was originally built six years ago, it was designed to be a scalable model (solution already exists somewhere in the organization and you were not aware of it), or the detailed procedures for financial modeling of companies are archived and your team knows about it (best practices are already developed, documented and made accessible through formal channels). Again, these examples should get the discussion started. The participants should offer other suggestions.

*Prompt 5*: In your world, identify the issues that reside in a complicated context. How are these issues handled and how should they be handled as per Cynefin Framework?

*Response*: Ask students about issues that require assistance of experts; when solutions are available but need to be researched; when solutions are known but require coordination among a wide range of professionals, and such.

**Scenario III**

You work for a pharmaceutical multinational company that has a strong reputation for being socially responsible. You were hired to manage their social programs. One of your very successful products is infant baby formula which can help with nutritional needs of a new born. Recently the news of severe food shortages in an African country, which is one of the poorest in the world, caught your attention. You decided to donate the surplus capacity of formula

production to the country through a partner NGO (non-government organization) with whom you work frequently. It assured delivery of the product to the needy villages. Soon after the first shipment was made to the NGO, you were caught by surprise to hear a blurb on international network news about an African country blaming your baby formula for causing infant deaths. They showed people in the news threatening rallies and calling for global boycott of your products. You quickly made some calls to your contacts in the NGO in the country but were unable to talk with anyone. Through the world headquarters of the NGO, you learned that there had been a coup in the country. The local offices of the NGO in the African country had been ransacked, but they had delivered the formula to the needy villages prior to the coup. However, their personnel had moved to safer places in the country and were keeping a low profile. It was not clear who was governing the country and who controlled the media, but militia roamed the streets and there were clashes among warring factions.

For the baby formula to be safe, it has to be mixed with clean water, which is not readily available in the villages of this country. You were counting on the NGO personnel to educate these African women to boil water prior to mixing. Is it possible that the women are mixing the formula with contaminated water and actually causing harm to the babies? You wondered. In conversations with the NGO personnel, you also learned that in the culture of this country, men are fed first, women next and children last. The reason is that men need their strength to do the physical work to provide for the family and women do not wish to invest in the infants because birth and infant mortality rates are very high. The average birth rate in the country is seven children per women and infant mortality rate is one death for six births. In light of the food shortages, the formula might be getting consumed by the adults. As per the NGO, the new government could possibly be blaming infant deaths on the formula in the media to deflect blame. Ethnic rivalries run deep and actual poisoning of the formula by rivals gangs was a

possibility that could not be ruled out.

UNO had set up a camp on the border of this country and the arriving of refugees was being sporadically being reported by the media. It was clear that reliable news facts were hard to get because of it being a small and poor country where not many outside news media were located. In light of this, NGO personnel worried about news being a guise to cover up the atrocities of militia and rebels. At the same time, it may also be possible that the deaths were being exaggerated to provoke international sympathies and extort monies from multinationals with deep pockets. The threat of law suits crossed your mind too. The second shipment of the formula was already on the way and you already had committed the excess capacity for the production of formula for donation to this country for the rest of the year. Disposing off this excess to other poor countries may not be viewed favorably if the impression is that the formula is poisoned and dangerous. This impression could also hurt your global sales of the formula since there are many substitutes of similar quality and prices easily available. Actually, one of the competitive advantages was your company's reputation for social responsibility. Your clients are young, well educated, well traveled, environmentally and socially responsible. The NGO is pleading with you not to cancel the program because they know that once the dust clears, the need for food would be even greater in the country and the neighboring UNO camps. Also, you are not sure how the cancellation of the program will play out in the media, and among your partner social agencies. Cancelation will not save your company significant resources because of the way purchasing agreements are written.

Before you go to bed, you make a list of your alternatives:

1. It is a simple situation. The media does not have its facts right. Your job and the reputation of the company could be at risk. You know the best decision is to call a press conference and get the facts out. You have enough experience and you have handled many

stressful situations before. You are a pro at these press conferences and could conduct one with minimal effort.

2. You have collected some information today and you are going to gather more by continuing talking with additional sources and experts. Once you have all the information you need, you will be able to analyze it using the standard information organization tools and make a good decision. The situation is complicated but nothing that cannot be sorted through with the help of expert analysis.

3. You believe that the situation is complex and you do not have all the information. You are not sure there is anyone, expert or not, who could give you all the facts of the situation. So, you plan to get all the groups that can be of help together. Hold a large group meeting and form into subgroups if necessary. Listen to all the voices to see if there is a trend or pattern in their thinking. In the mean time, the situation in the country may become clearer or at least better known to the outsiders. Your focus is in deciphering a pattern in the events through the eyes of multiples perspectives to see what you should do next.

4. It is nothing but chaos you think. Who has time to think, consult or analyze, you wonder? Something must be done now and so you plan to immediately stop all the future shipments and give firm directives to your staff about talking with the media and let NGO know what they can expect from you in the future.

**Analysis of Scenario III**

*Prompt 1*: Identify the context of the problem according to Cynefin Framework. Give reasons for your choice.

*Response:* This is an example of a complex situation where the relationship between an X and Y is characterized by feedback loops and uncertainty. You are facing a situation where the news about your product being deadly when used for its intended purposes is being reported.

You do not know the facts to offer a rebuttal or a corrective action. If there is a problem with the product, you do not know the cause of it. The product might be deadly if there has been intentional sabotage (warring factions), incorrect use (contaminated water use), or absence of use (adults using it or corrupt officials stealing it and depriving the babies but blaming the product nonetheless). Even if you knew the cause of problem, the system is in a flux for you to implement a solution. For example, if contaminated water was the problem, you cannot reach the users because NGO is not able to go to the villages and villagers may be on the move to the UNO camps. If adults are using the formula, there is no way for you to make enough available because of disruption of distributional channel beyond your control. The environment in the country is in constant flux. On the other hand, it is also possible that there is no problem with your product or its use at all and it is all media manipulation for other ulterior motives (new government covering up its own abuses or atrocities) of warring factions beyond its control or the new government wanting to extort monies. There are just too many "unknown unknowns".

*Prompt and response 2*: The same as scenario I.

*Prompt 3*: In light of the analysis using Cynefin Framework, what solution would be the best and why?

*Response*: As per Cynefin Framework, while facing a *complex* problem, the manager should probe first, then sense and then respond. A manager should allow time for reflection and interactions for patterns to emerge. Experimentation might be required. Creative and innovative approaches must be welcome. The use of *Large Group Methods (LGM) is* recommended (Snowden & Boone, 2007). In this case, probe could be in the form of an open, interactive, democratic session with the NGO personnel, experts in the country/political situation from local educational institutes, UNO representatives, citizens of this country living in your city, your city/state government officials, your production, public relations and the top management

representative. You just have to be flexible and open minded to respond as the patterns emerge.

The following tools are also recommended by the authors of Cynefin Framework (Snowden & Boone, 2007):

Set Barrier: Put simple, easy to understand principles in action. For example, no bribes or corruption, no risking human lives, no taking sides in the conflict, communication with media only through designated representative, and no knowingly floating of false information.

Stimulate attractors: Implement quickly any idea that seems reasonable and is easy to implement with relatively low risk and monitor the response (e.g., having NGO spokesperson call the press conference).

Encourage dissent and diversity: Use "ritual dissent." Define a problem clearly (e.g., how to gather accurate information from the country or how to have media report information that is verified or what to do with the shipment that is on the way or what to do with the future production). Form multiple teams to work on the defined problem (one problem at a time) in the large group meeting environment. Have each team appoint a representative who goes from its table to the table of another team and present it with the decision of the group from which the representative came. The host team listens in silence. After the presentation, the representative sits with his/her back towards the host team (as if he is not there) and the host team critically and honestly dissects the decision they heard. After the discussion, the representative of the host team goes to the table of another team and the process repeats until all ideas have been critically analyzed and refined.

Manage starting conditions and monitor for emergence: Build into your system the lessons learned from this scenario. If you find that the citizens of the African country were the greatest unexpected resource, then make it part of your procedures that when a country specific initiative is started, the locals from that country form an advisory council or are consulted.

*Prompt 4*: What factors can easily change the context to a different context (e.g., complicated or chaotic)? Give your reasons.

*Response:* This complex situation can become chaotic if factors such as these are present: one of your employees is taken hostage, or your story becomes the leading story in the media with verified reports of deaths resulting from your product. Participants might have other suggestions that would need consideration and discussion. The situation can move to the domain of complicated if the NGO has a road map for such a situation because they have a great deal of experience in similar situations or you have access to experts who know what to do in such a situation. There is no one right answer. The provided examples can facilitate discussion that can be managed.

*Prompt 5:* In your world, identify the issues that reside in complicated context. How are these issues handled and how they should be handled as per Cynefin Framework?

*Response*: Ask students to share their experiences about situations in which no one had any answers – not even the experts.

**Scenario IV**

You are the General Manager of an Agri-Input company belonging to one of biggest Indian Conglomerates. The company has a manufacturing facility in a densely populated industrial area. The land was sparsely populated until the development of the industrial area which gave birth to two slums – a cheap dwelling place for the unskilled and semi-skilled workers who migrated from villages and small towns. The company manufactures complex fertilizers and is dedicated to providing affordable and effective fertilizers to northern rural markets . One of the important fertilizers (urea), that the company makes requires Naphtha Gas as a raw material. Naphtha is a highly inflammable chemical. The supply of Naphtha Gas is

brought to the plant through thick PVC underground pipeline which runs from GAIL (Gas Authority of India), which is located in the outskirts of the town, approximately 15 miles from your plant.

A major fire broke out on Friday near the dwellings due to leakage in Naphtha pipeline. There were no casualties, but five persons sustained grievous burn injuries in the fire. The fire broke out at around 8 p.m. yesterday where underground work has been going on to construct the culvert for a four-lane highway. The machinery used in drilling to excavate a trench could have drilled a hole into the Naphtha pipeline. The fire broke out due to constant leakage in Naphtha, which caught up with overhead electricity high tension wires creating panic in the area. A major tragedy was averted due to the timely intervention of electricity department personnel who immediately cut off power supply to the localities. Although the local government is content with this measure to extinguish fire, but your Senior Manager (Fire and Emergency Services) has given you a cause for serious concern. He has informed you that the team of fire experts camping at the site reported that though the electricity cut had temporarily put the fire out, it is flaming back again. According to the expert, "the fire cannot be put out as it is emanating from Naphtha. One of the property of Naphtha is, it cannot be extinguished. But we can control it and we are doing that". You are very worried as the pipeline runs underground in a stretch of 15 miles through this highly populated slum areas; moreover there is a highly inflammable ammonia tank nearby.

The company is already trying to emerge out from the losses this year when 39 vehicles and a digger were gutted in a massive fire which broke out at a product handling gate of your plant. The digger was engaged in work for the GAIL and unknowingly drilled into the underground Naphtha pipeline. A repeat fire broke within four months and that too near the local dwellings resulting in financial as well as reputation losses. The local government has issued a

show-cause notice to the company. The media has blown the entire incident out of proportion-highlighting the pipeline passage through the slums and the repeat of leakages within four months. Panic stricken slum dwellers are demanding the closing of the entire plant; there are rumors of all kinds spreading amongst the local people about fresh outbreaks of fire, fresh causalities, possibilities of leakage effecting the entire town, etc. They are exchanging text messages like, "praying for the residents." Though everybody including your fire fighting team believes that the Naphtha leakage has been caused by drilling, but you are not convinced. The PVC pipeline was purchased after several tests. One of the tests examined if the pipe could sustain predictable damage in case a drilling machine accidentally ran through it. This PVC pipeline had passed the test.

You know that this leakage is going to cause significant financial losses. A series of questions are running in your head: What is the possible magnitude of the problem? How to control the fire whose flames are rising up to 20 meters high? Should the plant be closed down permanently or should the route for the pipeline be changed? How to address the government, media, residents of slums and the public at large? You definitely do not want to repeat the Bhopal Gas Tragedy. Even several decades later, your competitor company and the town of Bhopal are still reeling from the after-effects of that leak.

The following alternatives are running through your mind:

Alternative 1: This is a chaotic situation. It requires immediate action. First, you get the Naphtha gas line shut from the supply side immediately. Then you ensure appropriate medical attention for the injured individuals. You stop all the digging in and around the pipe. Also, you set a schedule of frequent dissemination of factual information to the media. Then you do the probes to investigate the leakages using multiple approaches including participative and expert opinions.

Alternative 2: In your mind this is a complex context. You need to conduct probes to understand the patterns causing the repeat problems before taking any action. You believe that no one has enough information to give all the facts of the situation. You would immediately call for a meeting of all the heads of the departments, some employee representatives and consultants. Together you discuss the possible reasons for the frequent leakage and then based on the discussion, you try to identify a pattern of events that lead to leakage and then decide your action plan.

Alternative 3: In your mind it is a complicated context. You ask your engineering consultants to do a site view of the leakage and collect information on the reasons for leakage. Once you have all the required information, you will be able to analyze it and take suitable action.

Alternate 4: In your mind it is a simple context. You consider the leakage issue as a typical maintenance problem. You trust the ability of your maintenance manager and consider this time as an opportunity to show your trust in him. You delegate the task to him for handling the leakage on his own. Since the crisis was well addressed in the previous leakage in April, you would ask him to reflect how the crisis was dealt with at that time and draw cues for handling it now. You keep a constant touch with him to understand the developments in this regard.

**Analysis of Scenario IV**

*Prompt 1*. Identify the context of the given situation based on Cynefin Framework. Give reasons for your answers.

*Response*: This is a realm of unknowns. You are not sure what caused the leak and if more leaks can happen unexpectedly. The leaks have the potential to be deadly at a large scale. The flow of information is chaotic. Inaccurate information and rumors, all negative about your company, are rampant and spreading. The flow of such information or its impact on the masses

or their reactions could not be predicted. The environment is very turbulent and volatile. There are many decisions to make and no time to think. In this scenario the manager is to consider multiple emergency conditions: outbreak of fire, injuries, panic, rumors, running of Naphtha across a populated region. Hence the context is chaotic.

*Prompt and response 2*: The same as scenario I.

*Prompt 3*: In light of the analysis using Cynefin Framework, what solution would be best and why?

*Response*: In a chaotic domain, a leader's immediate job is not to discover patterns but to stop the bleeding. Leader must first act to establish order. Communication of the most direct top-down is imperative and needs to be very clear; there is simply no time to ask for input. So the first act is to diffuse the crises. Once that is done, the next step is to use this period to set up mechanisms to take advantage of opportunities afforded by crises. Encourage employees to challenge your view point once the crises have been abated. Then sense where stability is present and from where it is absent, and then respond by working to transform the situation from chaos to complexity, where identification of patterns can both prevent future crises and discern new opportunities. Hence the most suitable alternative would be 1. As the manager first take immediate actions to abate crises and then call for meetings to identify where stability and patterns are present in the leakages and where they are absent. Further, the manager would also need to create forums to take inputs from employees and the experts.

*Prompt 4*: What factors can easily change the context to a different context (e.g., simple or complex)? Give your reasons.

*Response*: In this scenario, the need and ways to convert a chaotic context into a complex context would need to be addressed. It would not be feasible to continuously operate under chaotic conditions.

*Prompt 5:* In your world, identify the issues that reside in chaotic contexts. How are these issues handled and how should they be handled as per Cynefin Framework?

*Response:* Questions could be asked about issues that have caused crises level conditions.

## Conclusion

Through the use of these scenarios, management students can be sensitized to the various contexts in which they may have to lead. In addition, they can learn to use appropriate approaches for addressing problems in these contexts. Business education tends to prepare managers for an orderly and static world that can be rationally analyzed to make optimal decisions. In the new complex world, not all domains in which managers work lend themselves to such an analysis. It is necessary for the modern manager and leader to have skills to understand complex and chaotic contexts and to respond effectively. The scenarios and the matching analysis can be used to develop such skills. The instructors should scramble the scenarios before presenting them to the participants and have them respond to all the scenarios prior to the start of the discussion. It would be valuable to have students work in small groups and discuss their individual responses and arrive at a consensus for an appropriate response.

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# Towards a Theory of Process Improvement leading to a Successful CPFR Implementation: A Case Study

Robert G. Stoll

Assistant Professor
Ashland University
Department of Business and Economics
Dauch College of Business & Economics
401 College Ave
Ashland, OH 44805
419.289.5905
rstoll2@ashland.edu

Joseph R. Muscatello

Associate Professor
Kent State University
Department of Business Management and Technology
14111 Claridon Troy
Burton, OH 44021
440 834-3733
jmuscate@kent.edu

## Abstract

Collaborative Planning and Forecast Replenishment (CPFR) techniques and systems have been advertised as a way to improve a firm's supply chain management through optimization of demand and supply data. Although technology is required to support CPFR, it requires process and procedural improvement to generate positive results. This paper is a case study of a successful retail CPFR implementation.

## Introduction

Today's competitive pressures compel organizations to improve supply chain performance as a means to achieve competitive advantage. These efforts at supply chain improvement initially started with the areas that the firm could control internally such as inventory management, process improvement and quality. These improvement initiatives naturally progressed externally to include collaboration between the firm and its suppliers as well as between the firm and its customers (Kubde and Bansod, 2010). This paper investigates a retail company's successful implementation of Collaborative Planning and Forecast

Replenishment (CPFR).

Forecasting demand (and subsequently setting inventory levels) is difficult owing to the influence of promotions, changing demand patterns, and competitive pressures. The traditional answer to inventory problems has been to simply hold increased inventories. Holding high levels of anticipatory inventory may offer a way to avoid out-of-stocks, but it is a very expensive method of avoidance. As an alternative, many value-chain participants have determined that a better approach is to aggressively work together to manage inventory. Co-operative planning between trading partners facilitates better matching of supply and demand. Rather than trying to independently project demand patterns, buyers and sellers share information in advance and work together to develop realistic, informed, and detailed estimates that can be used to guide business operations.

It should be noted that in practice CPFR agreements are very specific in nature. A great deal of time and effort is needed up-front to negotiate specific items such as goals and objectives, frequency of up-dates to the plan, exception criteria, and key measures. The result is a published document defining relevant issues that has been jointly developed and agreed to. A nine-step business model for CPFR (VICS, 2014) has been developed which provides an indication of the scope of effort involved:

1. Develop front-end agreement.
2. Create joint business plan.
3. Create sales forecast.
4. Identify exceptions for sales forecast.
5. Resolve/collaborate on exception items.
6. Create order forecast.
7. Identify exceptions for order forecast.

8. Resolve/collaborate on exception items.
9. Order generation.

CPFR may be a simple concept, however turning it into practice is a difficult task. Since it involves collaboration with several trading partners, cultural challenges with each organization are realized and requires an across the board buy-in. A change in business processes is required, along with an inward focus to develop a broad multi-enterprise view.

**Case Study Discussion**
**Company A: Successful CPFR**

This case contributed to establishing a standardized start-up process for implementing CPFR. The partnerships provided input into the creation of a baseline evaluation of the partnership's four core CPFR processes. This allowed a quick understanding of the strengths and weaknesses of the partnership and actions needed to improve the process.

The case demonstrated that CPFR is not simply another form of category management. Deployed as described in this case, CPFR becomes the key essential process to begin optimizing the supply chain. The focus of this case is not simply to sell more product to the retailer's distribution center or depot; it was on selling more product to the consumer by concentrating on delivering product efficiently and reliably to the retail shelf using retail point-of-sale data.

**CPFR Processes Addressed**

- Collaborative Processes
- Integrated Planning and Forecasting Processes
- Replenishment Processes
- Supply Chain Management Processes

**Objectives**

Conservative estimates show 8% to 10% out-of-stocks still exist in retail stores, along

with excessive inventory costs throughout the supply chain. These all become additional costs to the consumer.

Company A is deploying CPFR to enable creation and integration of consumer demand data. This will trigger product flow from its manufacturing plants to the customer distribution center, and to the retail store shelves, and ultimately from the store shelves into consumer homes.

The primary objective is 100% product availability on the store shelf, while simultaneously reducing inventory requirements in the retail stores, customer distribution centers, and the manufacturing plants. Eventually, Company A expects to produce and ship in response to a consumer demand signal. This case will test and validate methods that can help achieve this. The primary CPFR output concentrates on improving inventory and reducing out-of-stocks. Company A recognizes that the main causes that prevent successful implementation of CPFR are:

1. Ineffective trust-based collaboration.
2. Ineffective planning using visibility of POS consumer demand.
3. Ineffective forecasting.
4. Ineffective product replenishment in response to demand fluctuations.

**Methodology**

The objective of CPFR is to test and validate the design requirements and the changes needed to create a responsive, reliable, and cost-efficient system that links manufacturing plants to customer distribution centers to retail store shelves using Point of Sale information.

The key is understanding that CPFR is not a technology, but a process. To test and deploy new processes, the CPFR partners agreed to three core activities:

1. Document and map the current supply chain processes for product and data flow.

2. Assess the current CPFR capability.

3. Create a joint action plan to address improvement opportunities.

Failure to follow the three-step process in order could lead the project down a path toward unsatisfactory results. It was critical to include this process in the Front-End Agreement, obtaining top-level consensus for the case's strategies, measures, and processes.

**Supply Chain Lead-Time Mapping of Product and Data Flow**

Together, team members from both companies traced product movement and the signals that triggered it. All of the processes were mapped, and the time lag between processes and triggers was measured from the point that a package was scanned at retail to the point new product was replenished on the shelf.

**CPFR Assessment**

Once the partners understood the supply chain process, there was no easy way to translate the supply chain improvement opportunity into CPFR action. CPFR assessment was developed to identify each of the CPFR key processes. This helped to verify the understanding from the supply chain mapping, and directed the creation of a CPFR process improvement plan.

**Joint Action Plans and Testing**

This step combined the first two steps into a test plan. It was documented and approved by the team sponsors, and the process improvement testing and documenting began. Historical POS data was collected on the test category (limited number of SKUs) and the POS data was continuously analyzed using actual orders and shipments.

**Metrics**

The cases measure aspects of nine elements:

1. Forecast Accuracy vs. Actual Orders

2. Distribution Center Service Level and Inventory

3. Retail In-Stock Service Level and Inventory

4. Manufacturer Order Fill Rate vs. Original Order

5. Manufacturer Order Fill Rate vs. Advanced Shipping Notice (ASN)

6. Delivery Punctuality

7. Transportation Efficiency (Utilization)

8. Shipment Variability by SKU

9. Profitability / Cost Reduction

**Summary**

CPFR must be recognized as a process, not a technical solution. To be successful, the existing process must become either simplified, streamlined, or standardized. Once this is accomplished, the process needs to become repeatable and scalable so technology can deliver broad-scale capability. If an existing process is delivering average results, technology will enable broad-scale mediocrity.

Company A agreed on the need to reduce retail out-of-stocks, while simultaneously managing the inventory levels required to remain in stock. Lead-time process mapping offered the fastest understanding of the supply chain processes and their results. The value of this analysis was directly proportional to the detail of the documentation, which highlighted where product movement was delayed and pinpointed its causes. Non-value-added activity is anything the consumer would be unwilling to pay for, and the process provided insight into the non-value-added activity in their customer and manufacturer systems and processes.

The detailed analysis included the lead times for order preparation, material acquisition, raw material queues, set ups, run time, WIP queues, move time, quality inspection, put away, pick/pack, shipping queues, transportation delays, retail receiving queues, stocking queues, and

shelf space issues. The activity was charted; before/after time analysis identified the loss for each delay. At this level of detail company A was able to apply comprehensive improvement tactics such as Lean Methods, Kaizen events, DMAIC, as well as simple control sheets. The other obvious issue was the need for training and educating the work force about the price of delays and the need to treat downtime as the enemy of efficiency.

Any case study has limits, and this one is no exception. The contribution is the understanding of the extreme level of detail that must be provided and improved upon to understand, justify and reduce/eliminate, non-value added activities. Also, the methodology used to root out the detail can be of use to other CPFR implementers.

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**The Analysis of Risks and Value in Information Systems**

David C. Chou
Department of Computer Information Systems
Eastern Michigan University
Ypsilanti, MI 48197
E-mail: dchou@emich.edu

Information systems frequently encountered risks in their operations. Risks, based on Oxford English Dictionary, is defined as "the possibility of loss, injury, or other adverse or unwelcome circumstance; a chance or situation involving such a possibility". Risks has been defined in different applications with different implications. For example, the finance discipline risk was to describe the possibility that an actual return on an investment will be lower than the expected return. In insurance discipline, risk is a situation where the probability of a variable is known but when a mode of occurrence or the actual value of the occurrence is not (Wikipedia, 2015). Risk can also be treated as the correspondence to uncertainty. Uncertainty is a potential, unpredictable, unmeasurable and uncontrollable outcome, risk is a consequence of action taken in spite of uncertainty (Antunes, et al., 2015).

Risks have been introduced to information systems and information technology (IS/IT) discipline for a long time. The main focus of IS/IT risks was on security and privacy issues in related literature. Cloud computing, for example, contained the following risk factors: authentication, data security and privacy, interfacing with internal systems, system availability, business continuity, and ownership of content and other legal requirements (Raval, 2010). Among these risk factors, security and privacy are the most concerned area. ISO (2008) defined IT risk as "the potential that a given threat will exploit vulnerabilities of an asset or group of assets and thereby cause harm to the organization. It is measured in terms of a combination of the probability of occurrence of an event and its consequence."

A simple explanation of risk can be "the potential of losing something of value." For this reason, the risk and be clearly linked to the value of subject. As long as we can identify potential risks of subject, say IS/IT, we can reach to the value we expected. Chou (2015) proposed a value creation model for cloud computing, in which four components have been created, including awareness, translation, comprehension, and cloud computing value creation. The combined framework can be fulfilled to the status of cloud computing sustainability. Chou and Chou (2012) also proposed a value realization process model in Green IT. Similar to Chou's (2015) cloud computing realization model, there are four components to reach to the value of Green IT.

It is interesting to discover the true linkage of risk and value. This paper intended to conduct a deep analysis to both areas of risk and value and then investigate their potential relationship. The main focus of this study is on the risk and value connection in IS/IT applications.

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