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THESIS

VOLATILITY MEASUREMENTS APPLIED TO INFORMATION SYSTEMS

by

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Inappropriate and/or duplicate IT systems results in a severe drain on resources. Identifying the development of low utility and duplicate systems allows for the redirection of resources with higher and unique returns. Volatility measurements allow systems to be compared to determine the gains over prior iterations along with aiding in determining which options to exercise for future systems. The decision maker of an organization must be able to monitor how IT systems are functioning and hold program managers and developers accountable for improving efficiency, timeliness, and accuracy of the information being gather and processed. Volatility measurements take consideration of all factors and give a baseline from which the IT manager can make decisions across systems. The additional capabilities provided by volatility measurements will go a long way in strengthening IT investments, the performance review of those systems, and provides the additional information needed to forecast and compare systems in order to make better decisions.

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VOLATILITY MEASUREMENTS APPLIED TO INFORMATION SYSTEMS

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Inappropriate and/or duplicate IT systems results in a severe drain on resources. Identifying the development of low utility and duplicate systems allows for the redirection of resources with higher and unique returns. Volatility measurements allow systems to be compared to determine the gains over prior iterations along with aiding in determining which options to exercise for future systems. The decision maker of an organization must be able to monitor how IT systems are functioning and hold program managers and developers accountable for improving efficiency, timeliness, and accuracy of the information being gather and processed. Volatility measurements take consideration of all factors and give a baseline from which the IT manager can make decisions across systems. The additional capabilities provided by volatility measurements will go a long way in strengthening IT investments, the performance review of those systems, and provides the additional information needed to forecast and compare systems in order to make better decisions.

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LIST OF ACRONYMS AND ABBREVIATIONS

CAPM	Capital Asset Pricing Model
CCOP	Cryptologic Carry-On Program
CFO	Chief Financial Officer
CIO	Chief Information Officer
DCF	Discounted Cash Flow
DoD	Department of Defense
EPM	Enterprise Performance Management
ERP	Enterprise Resource Planning
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
IEA	Information Enterprise Architecture
ISP	Information Support Plan
IT	Information Technology
KVA	Knowledge Value Added
LISI	Levels of Information Systems Integration
NPV	Net Present Value
OEP	Organizational Execution Plans
ROI	Return on Investment
SIGINT	Signals Intelligence
SMP	Strategic Management Plan
VIX	Volatility Index

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I. INTRODUCTION

Inappropriate and/or duplicate IT systems can result in a severe drain on resources. The development of low utility and duplicate systems needs to be identified so that system development resources may be redirected to areas with higher and unique returns (Valfer, Kirby, & Schwarzbart, 1981). Improving systems and system utilization can result in long-term benefits. The problem is there is not a measurement methodology to forecast and compare systems. The purpose of this research is to provide a methodology to forecast and compare IT investments, which can be used in IT investment decisions.

The decision maker of an organization must be able to monitor how IT systems are functioning and hold program managers and developers accountable for improving efficiency, timeliness, and accuracy of the information being gather and processed (Sniegowski, 2010). The Department of Defense (DoD) Chief Information Officer (CIO) distributed the ten point implementation plan to modernize information technology (IT) within the DoD. Included in those ten points were the strategic goals of strengthening IT investments and reviewing the performance of major investments (Tekai, 2012).

Identifying the benefits of a given system is an integral part of determining an IT system's value and the use of metrics allows for the measurement of that value. Return on Investment (ROI) is commonly used to measure the value of respective IT investments and as a comparative metrics. Benefits, costs, and the value of the IT over time as considered when measuring ROI, however many benefits associated with particular IT investments are difficult to translate into revenue and do not generalize to other IT investments making it difficult to calculate an ROI, which can be used to compare IT investments.

IT management is not purely a technical issue as evidence by competing IT value measurements that attempt to rank IT systems in their effectiveness, efficiency, and accountability (Yang & Melitski, 2007). The challenge for management is to have an IT strategy that improves innovation, flexibility, efficiency, and visibility of the underlying processes in order to have better data to make sound decisions (Housel & Bergin, 2013). Measuring and applying volatility to an IT investment serves this gap and can be used in determining IT strategic decisions.

A. RETURN ON INVESTMENT (ROI)

Measuring the ROI on information systems along with determining the factors and conditions that affect that ROI is not well understood (Roztocki & Weistroffer, 2009). While some authors point to financial ROI in the form of money, most literature is silent on measuring information system ROI (Fichenscher & Bakerman, 2011). In non-profit organizations such as the Department of Defense (DoD), ROI has mostly been used to measure the amount of savings generated against an alternative for each investment dollar. The greater the ROI, the greater the advantage is to the organization (NASA, 2006), however using that metric would leave a lot of information systems that increase productivity vice save costs with a negative ROI. How IT investments are measured, along with financial performance, determines the relationship between performance and those IT investments (Lim, Dehning, Richardson, & Smith, 2011).

Establishing the ROI on signals intelligence (SIGINT) systems through knowledge value added (KVA) was shown to be effective from the previous work of Rios, Lambeth, and Clapp. The next iteration of research is to configure the analysis to determine the volatility of a system and forecast the returns to determine if a system should be incrementally upgraded in the current version or completely moved to the next version so that resources are maximized. By applying volatility measurements to an information system, the relative effectiveness of future performance can be forecasted. Forecasting the benefits of SIGINT systems assists the program manager in determining whether to pursue an incremental or complete upgrade based on volatility. This approach is applicable to multiple IT systems upgrades or replacements.

B. FACTORS

Technology drives improvements in productivity across all sectors (Elias, 2000). However, IT investment success factors are still not fully understood (Roztocki & Weistroffer, 2009). One such factor is volatility. A survey of Chief Financial Officers

(CFOs) listed the increased volatility and risk along with changes in strategy as a top concern for the future business environment (Hosley, 2011). The volatility of a portfolio or asset is an important parameter used in option pricing, risk management, and asset allocation. As such, there are several approaches available to forecast the future volatility of a portfolio (Ganesan & Yadav, 2007). Risk factors are especially not well understood, but applying volatility measurements creates awareness of the risk within an information system (Roztocki & Weistroffer, 2009). The correlation between benefit and risk factors provides insight to the success of IT investment decisions (Zandi & Tavana, 2011). Cost is another factor with high cost in IT investments resulting in the need to efficiently and effectively evaluate IT investments for organizations (Zandi & Tavana, 2011). The balance between system stability and volatility is affected by many such factors and is a significant input in determining when to make system changes (Kang, 2007). Management and monitoring verify productivity gains and assist in determining the value of the underlying information system (Gholami, 2012).

The growing complexity of IT investments makes real-time adjustments a necessity to ensure a successful information system (Kang, 2007). Measuring actual improved capabilities against performance measures provides the support needed to adjust the mix of portfolio investments in order to maximize the returns to DoD (DoD, 2005). Having a measurement methodology that provides visibility and agility to respond to changes in the environment is critical (Hosley, 2011). In the financial sector, the Volatility Index (VIX) provides that mechanism (D’Anne, 2012), and a similar approach could be used toward information systems.

C. RESEARCH QUESTIONS

There are three research questions reviewed as it relates to volatility measurements.

1. Do volatility measurements provide a capability to forecast future performance of the system?

2. Do volatility measurements provide timing options for the implementation of incremental or new information systems?

3. Can beta be determined within a portfolio of systems based on volatility measurements?

The paper is organized as follows. Chapter II provides an overview of literature on the many factors that affect the perceived success of an IT system with specific focus on volatility. Chapter III provides the methodology of this research to answer the research questions. Chapter IV reviews the analysis of the data. Chapter V draws conclusion of the analysis in chapter IV and answers the research questions along with providing recommendations for implementation and future research.

II. LITERATURE REVIEW

Information is a strategic asset and transforming it to knowledge is essential (DoD CIO, 2012). Information systems provide that transformation from information to knowledge as well as obtaining efficiencies in delivering support (Olson & Wu, 2011). The DoD Information Enterprise Architecture (IEA) provides the strategic architecture from which to govern and integrate information systems (DoD CIO, 2012). It is desired that every information system project should execute within budget and on time and any risks are identified early (Al Kattan, Al Haddad, & Al Ali, 2011).

The DoD IEA provides the governance from which to operate the IT landscape. Decision makers prioritize the needed capabilities by determining the gaps between existing and required IT capabilities and plan the appropriate investment options and resources to those gaps. They then use those capabilities to establish the criteria and performance metrics for future investment decision making as well as grading of past investments decisions (DoD CIO, 2012). Volatility measurements are used frequently in the financial management sector and could be used to provide additional information to aid in the investment decision making process. The DoD IEA provides capability descriptions that allow the decision makers to identify, evaluate, and compare different investments to a baseline and also identify the investment risks (DoD CIO, 2012). Volatility measurements in the comparison of a baseline allows for the formulation of a beta. Beta is a common investment metric that can also be used to forecast future performance and identify the risks associated with a particular information system.

"In reality, IT project managers face considerable uncertainty in determining the likely extent of any risk factor identified as a potential threat, and therefore, uncertainty about possible solutions in terms of their cost and effectiveness" (Taylor, Artman, & Woelfer, 2012, p. 19).

This section reviews the governance of IT systems, the factors that affect performance, IT integration, metrics, volatility, risk, beta, and forecasting of IT performance. Within each subsection, the benefits for use of volatility measurements are discussed as it pertains to the different factors.

A. GOVERNANCE OF IT SYSTEMS

The proper governance of an IT system is essential to determine if a system is providing a positive return on investment. Two broad categories that factor in governance are the strategy and the measurements. Prior to measuring volatility of any measurement, it is imperative to determine the strategy that precipitated the IT investment. The Department of Defense organizational execution plans (OEPs) provide the mission that the IT investments are to effect (DCMO, 2013). Once the business area is determined, an appropriate metric is used to measure the performance of the IT system along with managerial performance (Merikas, Merikas, & Sorros, 2005). The metrics, in agreement with the overall strategy, then determine the options in the continuation of IT services and infrastructure in other functional areas (DCMO, 2013).

Strategy guides the governance model to organize and control IT projects (Gholami, 2012). The governance model can also be referred to as investment management where the functional strategies are aligned with the overall Strategic Management Plan (SMP) and along with the OEPs determine the factors that drive value in the IT investment portfolio (DCMO, 2013). It is only when the business processes and IT strategy are closely coupled that performance improves (Kang, 2007). Capturing the metrics to determine the maturity and changes in strategy is crucial in ensuring that decision makers are able to respond to those changes. The directive to manage IT systems as a portfolio through IT portfolio management (DoD, 2005) further increases the need to mitigate negative reactions to fluctuations in the IT systems along with determining the risk tolerance for a system (Gilliam, Chatterjee, & Grable, 2010).

The use of measurements is essential in governance. Unforeseen external circumstances generally demand system changes. Data analysis identifies those demands of change by measuring several objectives and provides an opportunity for decision makers to weigh the chaos of disruption versus that of the benefits of change in the system (Kang, 2007). Historical data, especially of the standard deviation, assists in the governance of the IT systems and provide metrics from which to compare risks and opportunity (Merikas et al., 2005). The volatility measurements manage expectations of the IT portfolio along with financial risk tolerance (Gilliam et al., 2010). The governance of the IT systems has to be effective and the IT strategy aligned with the overall strategy and appropriate measurement of factors in order for the IT systems to be measured for effectiveness and efficiency.

IT changes are a balancing act between system volatility and system stability (Kang, 2007). As the environment changes and strategies mature, governance needs to be refined (DCMO, 2013). The decision in making changes in policy and/or IT systems needs to have as a factor the moderation of output volatility (Chichilnisky & Gorbachev, 2004). Investment portfolios are measured adequately through statistics, specifically the mean and standard deviation, which is commonly used to describe the volatility of a portfolio (Merikas et al., 2005).

Every IT system needs to be evaluated with all available measures. However, program managers should be wary of operational concerns for the IT system overriding the prevailing IT strategy (Housel & Bergin, 2013). The primary intent is a strategy and management approach that encompasses the enterprise and provides for common integrated technical infrastructure and services (Yang & Melitski, 2007). Managers need to ensure that IT strategy fits the overall business objective, that they have a thorough understanding of the business needs that the IT system addresses, and apply the IT to implement new ways of doing business (Stikeleather, 2013). An IT strategy is a comprehensive plan that gives a roadmap on how IT will accomplish the objectives and principles of a particular organization (Housel & Bergin, 2013). Strategic values such as efficiency and accountability should be addressed in the IT strategy, especially for government (Yang & Melitski, 2007). Metrics need to track and record the effect of IT on productivity along with the benefits to the operators (Housel & Mun, 2013). Accomplishing the strategic goals of the DoD CIO for strengthening IT investments and review performance of IT investments (Tekai, 2012), can be accomplished with a volatility measurement of any appropriate metric. Measuring the volatility of metrics over time will provide options for the IT managers along with real-time tracking of the value of that particular IT system.

Analysis of the metrics over time can categorize the returns in terms of volatility with the greater standard deviation resulting in higher volatility. Once the volatility is determined, the returns of a new system can be forecasted and tracked against that forecast to determine the increase (or decrease) in benefits for that system. For example, evaluating the Cryptologic Carry-on Program (CCOP) would start with assigning a surrogate for revenue such as unit cost ($/signal). A forecast for the system is then generated based on the historic volatility as well as the volatility of a previous system. The operating costs for both the present and previous system are applied to the metric. The metric can then be tracked against the forecast to determine the gain or loss. Adjustments can be made for unique risks between the systems and then the resulting forecasts can be compared to alternative systems. To ensure the greatest return any methodology should capture the changes in benefits as well as costs while capturing the operational benefits, unit cost, and variance (Ford, Housel, & Mun, 2009). Measuring the volatility of the metrics in a given IT system provides an additional tool and methodology in making strategic decisions.

Lack of information in a valuation model makes it more difficult for managers to make informed decisions on an IT system and properly identify options (Copeland & Tufano, 2004). The ultimate goal is to maximize the benefits of an IT system while limiting cost and risk, especially in a cost-constrained environment (Ford et. al., 2009). Providing volatility measurements increases the information that a manager has to properly value options. The value assigned to IT systems with certain assumptions can then be mapped out on a decision tree visibly showing the value of a system at a particular time (Copeland & Tufano, 2004).

The custom-built decision tree based on forecasts provides the options from which the manager can monitor and make decisions for the IT system (Copeland & Tufano, 2004). The decision tree provides the foundation from which a real-time system can compare the relative volatility measurements and provide the strategic goals of agility and interoperability. With a more accurate model, managers are more likely to make decisions in a rational and timely manner (Copeland & Tufano, 2004). Volatility measurements should decrease as technology is adopted and matures which can then be compared to previous systems to determine the real impact that the particular system is providing. Aligning the budgeting and planning systems to the overall IT strategy along with the individual decision trees should also improve the timeliness of decisions regarding IT systems (Copeland & Tufano, 2004).

IT systems go through four phases: research and development, ascent, maturity, and decline (Housel & Bergin, 2013). The volatility measurement for a given metric should be high during the research and development phases, decreasing as it is in the ascent phase, minimize at maturity and then start increasing as it enters the decline phase. Changes in the volatility measurement allows for the explicit review of nodes in a decision tree and its alignment with the forecasting as well as options (Copeland & Tufano, 2004). Organized appropriately, the IT systems will develop new and more effective roles within the enterprise ecosystem (Stikeleather, 2013). As an IT system matures, it will progress through five stages: bleeding edge, leading edge, state of the art, dated, and obsolete (Housel & Bergin, 2013). The maturity stages can be aligned with the growth phases that a volatility measurement could identify. In the maturity model, the volatility would start high, minimize at state of the art, and then increase until high again at the obsolete stage. Providing a volatility measurement allows for a more accurate forecasting of an IT system and provides additional information from which to decide on options, and the framework for a real-time monitoring system. Better decisions on options along with the ability to track performance will strengthen IT investments and the performance of those systems.

B. FACTORS AFFECTING IT EFFECTIVENESS AND EFFICIENCY

Governance provides the management and overall environment from which the information system operates and is a primary factor in determining the success of that information system. There are many other factors that affect IT investment performance including organizational size, fit, and system characteristics (Roztocki & Weistroffer, 2009). The resources allocated to the information system along with the technical feasibility are also of great importance (Kang, 2007). These factors are reviewed and assessed into broad categories of costs, dynamics, performance criteria and integration.

Cost appears to be a constant factor in all systems, IT or otherwise, as it is a constraining resource. Cost has the benefit of having a large amount of data and systems in place that can monitor and trace cost to specific services and products. However, undependable cost estimates can lead to flawed strategic and operational decisions (Roztocki & Weistroffer, 2009), which discussed earlier would significantly hamper the effectiveness of the information system. Government appears to focus on reducing costs, implementing Enterprise Resource Planning (ERP) to standardize systems while also outsourcing IT staffs in order to avoid recruiting, developing, and retaining such personnel (Olson & Wu, 2011). Effective cost management systems provide management a factor that they can control which even further highlights the focus on costs. The logical conclusion is that an effective cost management system would lead to fewer mistakes in IT investments (Roztocki & Weistroffer, 2009). However, information system risk is not only costs, but disruptions, hidden costs, future upgrades, etc. (Olson & Wu, 2011). Although cost is a primary factor in the efficiency of an information system, the focus on costs appears to result in little to no attention on factors that are just as important to a system such success such as system dynamics, performance criteria and integration.

An incomplete understanding of the system dynamics with the information system and the structural relationships that it operates within, leads to volatility in forecast which affects future costs (Scher & Koomey, 2011). The standardization of systems and measurements has increased the risk of missing the dynamics of the structural relationship and thereby increases the overall risk of the information system and forecasts made (Long, 2010). Working through the dynamics of the environment is essential to capture best practices, pace of change, and allows for a larger source of data. Institutions and the people within adapt to new structural relationship and increase productivity should the relationship be fully understood (Scher & Koomey, 2011). Forecasting is not new to business or the DoD and with the additional data; those forecasts become more accurate and allow decision makers to make more informed decisions with empirical data (Hosley, 2011). Volatility measurements of performance metrics provide a visible indicator of when adaptation of system dynamics for the information system has occurred and can also indicate the lack of adaptation.

There are many different performance criteria relevant to decisions and outcomes for information systems (Roztocki & Weistroffer, 2009). The DoD IEA determines compliance in achieving effectiveness and efficiency goals (DoD CIO, 2012). The performance criteria selected is highly significant to the information system's perceived performance (Kang, 2007). For example, the unit cost for a production criteria should decrease as production increases, becoming more efficient in the utilization of resources (Chichilnisky & Gorbachev, 2004). However, a performance criterion for perceived usefulness and user satisfaction is critical as those two factors are indicative of the continual use of a given information system. A misalignment of performance criteria with the overall strategy and goals could result in a constantly changing network environment and a disruption to the overall system (Kang, 2007). A lot of focus is on the performance criteria of efficiency, but operating at peak effectiveness is just as important if not more so (Hosley, 2011). Whatever the performance criteria, volatility measurements of those criteria are taken leading to insights to the outcomes and decisions of the information system being measured.

There are many factors that affect performance such as security, reliability, scalability, availability, monitoring and management, and all of these factors need to be integrated (Olson & Wu, 2011). The many factors make for an extremely complex system that supports the business processes (Kang, 2007). Integration has to be focal point in the implementation of any information system and has led to technologies such as enterprise application integration (EAI) (Roztocki & Weistroffer, 2009). Another source of complexity is the network connections that information system makes to other systems (Kang, 2007). This complexity leads to a lack of structural constancy in the early phases of a system as changes are constantly made to integrate systems. Physical systems such as production lines are an example of structural constancy but information systems generally do not exhibit the constancy needed to accurately forecast. Structural constancy is necessary for forecasting performance accurately (Scher & Koomey, 2011). Once the information system is integrated it is reasonable to expect that existing resources are used more efficiently as data allows for more informed and better decisions (Roztocki & Weistroffer, 2009). The goal then becomes to be more responsive and proactive, and that requires increased certainty in volatile times which comes from an integrated system (Hosley, 2011). Volatility measurements would give additional data that could indicate the effectiveness of the integration of the information system along with determining the volatility environment.

Costs, system dynamics, performance criteria and integration are the critical few of the many factors that influence IT investment decisions. Volatility measurements allow for further investigations into the influence those factors have on the performance of information systems (Zandi & Tavana, 2011). In order to fully benefit from performance measurements, the systems need to be observable, structurally consistent, constant across variations, and permit collection of large depth of data (Scher & Koomey, 2011). And as experience is gained with the information system, the application use and therefore benefit should increase (Kang, 2007). Volatility measurements in information systems may determine the drivers that should influence decisions along with the timing of those decisions.

C. INTEGRATION

Assumptions and risks can undermine the most adroit implementation of an IT system. Volatility measurements provide a tool from which assumptions and risks are lessened. Interoperability allows for the sharing of data and should be built into the strategy in order to get the benefits desired from an IT investment. Demands of the external environment require the ability to adjust practices quickly, which would be an agility component (Guertin et. al., 2012). An interoperable and agile system along with volatility measurements can positively affect the assumptions and risks made within an IT system.

The current IT environment relies on integrated rather than stand-alone systems that interact with multiple software and hardware components (Kang, 2007). Interoperability allows for the sharing of data and should be built into the strategy in order to get the benefits desired from an IT investment. There is an ideal balance between innovative ideas and efficient focused management (Guertin et. al., 2012) and with an interoperable environment with substantial data collection that balance can quickly be located. First, the proper enterprise architecture for a system has to be determined. For example, a distributed system where information is analyzed centrally appears to be best served with a client-server architecture where one computer acts as a server and others as clients (Chang & West, 2006). Interoperability is a challenge in inherently distributed and horizontal systems and in order to acquire fast and effective responses, interoperability has to be built into the structure (Kasunic, 2002). Second, boundaries between entities is disappearing both horizontally and vertically, which demands interoperability in the enterprise IT system (Stikeleather, 2013). The interoperability performance can be measured with the Levels of Information Systems Interoperability (LISI), which proposes four sets of interoperability measures: technical compliance, system interoperability, operational interoperability, and organizational and cultural (Kasunic, 2002). The horizontal integration and interoperability in order to share information is especially a daunting challenge which if solved could unleash substantial returns in an IT system (Yang & Melitski, 2007).

The digital ecosystem is a demand-driven environment where systems need to be proactive and responsive (Chang & West, 2006). Network performance and integration are challenges in developing an agile system (Kang, 2007). The digital ecosystem is ever changing with bandwidth growing at least three times faster than computer power (Gilder's law) and magnetic storage costs reducing by half every 18 months (Shugart's law), which when combined with the value of a network being the square of the number of users of that system (Metcalfe's law) (Housel & Bergin, 2013), the agility within a system and organization becomes crucial. Education and training can increase organizational agility (Guertin et. al., 2012); however, if it is not inherent in the IT system, then the organization may still fail to meet its objectives. There are often conflicting preferences and values regarding IT investments and all are legitimate and important, which requires an agile system to respond to the fluid environment (Yang & Melitski, 2007). An agile system would adjust to the demands of the external environment (Guertin et. al., 2012).

Assumptions are made throughout the technology life cycle as models are used that give a simplified representations of the environment, usage, learning curves, etc. (Copeland & Tufano, 2004). The assumptions are then used to balance the value as it relates to efficiency and agility in order to provide IT systems with interoperability and agility (Stikeleather, 2013). The value of the underlying system may not be clear; therefore, past performance sets an estimated value (Copeland & Tufano, 2004). Assumptions could affect the answer to questions such as should investments be made toward personnel or new technology and what sub-processes should receive further investments. Measuring the volatility for metrics that measure critical objectives would give insight as to which IT system or sub-process is truly having the desired effect and thereby reducing the assumptions made.

Integrated risk management is multiple step process that identifies, predicts, models, analyzes, mitigates, hedges, diversifies, and manages risk (Ford et. al., 2009). Risk identification is closely tied to assumptions made in assessing, selecting, and implementing an IT system. One such risk would be a lacking a strategic perspective, focusing instead on budgetary and operational efficiencies (Yang & Melitski, 2007). Other factors may include organizational design or socio-technical work design where a mismatch could produce a potential for risk. Risk prediction is the projection of an IT project, forecasting the effect of the project over time. The risk model gives the financials on a given project under certain circumstances. Risk analysis is the methodology of running simulations to determine the actual risk involved. Risk mitigation is the comparison of alternatives and the framing of options. Risk hedging is the building of options within the system. Another risk is the data, as incomplete adoption and non-adoption of IT systems may not be available to make the comparison with the adopted IT systems in order to determine the differences in metrics (Sahin, 2006). Risk diversification is optimization across several systems and finally, risk management deals with the tracking and updates as the system progresses as it pertains to risk. Risk management may presume a stable, predictable, controllable environment, which may not be the case especially in the digital ecosystem; therefore agility should be identified and measured (Guertin et. al., 2012). In each case, measuring volatility lessens the risk by providing additional information and identifying key points in the system's life cycle.

Although assumptions and risks will continue to be part of the IT investment environment, volatility measurements provide a tool to lessen those assumptions and risks leading to a more accurate forecast of performance. Measuring the volatility can also assist in determining the adoption of the technology. Technology adoption from the user prospective is broken up into five groups, the innovators, early adopters, early majority, late majority, and laggards (Housel & Bergin, 2013). The volatility measurement will be high in the early adoption and will start to decrease noticeably as the early majority begins to adopt the technology with the volatility smoothing out near a low as the laggards begins to finally adopt the technology. Integration and agility are critical success factors for an IT system, increasing communication between stakeholders and quickly aligning with any changes in objectives (Yang & Melitski, 2007). An IT system with integration and agility along with an accurate forecast, with the help of a volatility measurement, will strengthen IT investments and the performance review.

D. METRICS

There is a move to quantify data drivers and include them into an Enterprise Performance Management (EPM) program (Hosley, 2011). Those data drivers are the many different metrics that are used to assist decision-making. This section reviews the decision-making metric needs, some of the different metrics available, and the challenges in using those metrics to measure the performance of an information system.

Quantifiable performance measures are used to manage and monitor IT investments. Those measures allow for the grading and tracking of investment decisions and allow for an evaluation to modify, continue, or terminate investments based on those outcome-based measures. The performance measures also allow for a determination of the investment risk for an information system (DoD CIO, 2012). Understanding the performance measures and the information that it presents is crucial in order to be more proactive and make better decisions (Hosley, 2011). Fully understanding the information allows for an analysis to determine the progress made in filling a capability and assists in identifying gaps as described in an Information Support Plan (ISP). Once the gaps are identified then it is determined how available funds are spent to close those gaps. An integrated information system provides the information needed to decision-makers that allow them to take action on issues and make better informed decisions (DoD CIO, 2012). Volatility measurements provide an additional data point for decision-makers to take action potentially providing the critical information of when to take action.

Portfolio managers evaluate the IT investment periodically to ensure that the system is providing actual support (DoD CIO, 2012). There are several IT evaluation methods including net present value (NPV), ROI, information economics, cost benefit analysis, and return on management that provides the framework to quantify the benefits and risks (Zandi & Tavana, 2011). The evaluation contains measureable outcomes and targets as determined by the functional strategies of the information system (DCMO, 2013). The ISPs are used to determine the progress in achieving the stated capabilities within the ISP (DoD CIO, 2012). The evaluation frameworks that quantify the goals should be part of the functional strategy and aligned with the overall objectives.

The desired end state of an information system should able to be determined by looking at the measurable and observable goals (DCMO, 2013). Reduction of costs will generally be a primary goal which is accomplished through the reduction of IT staff, better inventory control, or duplicate system elimination (Olson & Wu, 2011). Other metrics could include benefits such as better output and increased skills or could include indirect costs such as decreased status, unpleasant routines, or lost time. The consistency of the benefit/cost ratio is desirable so that the ratio does not vary among different managers or over time (Kang, 2007). Cost is an important metric and is essential to determine ROI, but there are other metrics as important but may be difficult to fit into an evaluation framework such as product functionality and quality, implementation and interface speed, price, reliability, scalability, availability, customer service, security, service level monitoring and management (Olson & Wu, 2011). With all the different metrics available it is essential for the managers to ensure that the performance measures are directly tied to the strategy (DCMO, 2013). Volatility measurements work across the entire spectrum of quantifiable performance measures and provide the decision maker with another metric from which to make decisions.

The breadth of metrics should make measuring performance of an information system relatively simple, unfortunately that is not the case and there remain several challenges. Although capabilities are identified, the performance measures establishing capability achievement have not been fully identified or aligned for all capabilities (DoD CIO, 2012). As such, accurate and meaningful cost/benefit ratios are difficult to implement (Olson & Wu, 2011). Goal value computation is still a work in progress with a needed shift in focus from objective function optimization to realistic target values and goals for those functions (Zandi & Tavana, 2011). The goal appears to have a single measure from which to make decisions, but no manager should trust a single measure in its entirety, rather take a look at multiple measures to determine efficiency and effectiveness (Merikas et al., 2005). Maintaining flexibility is crucial with new information, policy, technology, or other environment changes that could signal a change in a system dynamic relationship. Measurements and forecasts respond to these insights in order to provide the decision makers with the needed information (Scher & Koomey, 2011). Volatility measurements can provide the insight needed to monitor multiple metrics, with changes in volatility signaling the change of a relationship and thereby focusing the decision maker.

E. VOLATILITY

Measuring and forecasting volatility through historical volatility and a normal distribution provides a volatility expectation from which managers can make decisions (Ederington & Guan, 2006). Volatility measurements are used to represent future volatility and are used throughout the financial services industry to forecast stock index volatility (Arak & Mijid, 2006). Those decisions in conjunction with a thorough risk assessment should reduce the complexity and uncertainty in the implementation of an information system (Taylor, Artman, & Woelfer, 2012). The volatility measurements can provide options from which to reduce uncertainty by reassessing the business metrics as information changes or becomes available (Zandi & Tavana, 2011). The reassessment should include quantifiable measures that hedge the risk of the system and reduce the overall volatility of the investment portfolio (Damodaran, 2005). In this section, volatility is reviewed with its uses in the financial services, how it is measured and forecasted, and its relationship with risk.

Within the financial services sector, volatility is measured in the S&P 500 through the VIX. The volatility is estimated through the standard deviation of the closing price of an asset (Ganesan & Yadav, 2007). The VIX provides investors a forecast on the expected future volatility of the stock market with future contracts that give a 30-day expected volatility (D'Anne, 2012). The VIX is also seen as an indicator for sentiment on the direction of stock prices, especially declines (Arak & Mijid, 2006).

Measuring volatility provides not only sentiment of market decline in its associated market, but also the actual imminent volatility (Arak & Mijid, 2006). Defining volatility is simple as equating it to the standard deviation of the measured return over a specified period of time (Wang, Wang, & Yourougou, 2012). This is in alignment with the treatment of uncertainty within probability theory (Zandi & Tavana, 2011). Measuring the volatility can then provide the value of options as the square root of the forward volatility (D'Anne, 2012). There are other approaches to measuring volatility such as the mean absolute return deviation which has been argued as more accurate alternative to historical volatility (Ederington & Guan, 2006). Other alternatives include the daily squared returns, serial correlation adjusted, mean adjusted daily squared returns, and absolute change in returns (Iltuzer & Tas, 2013).

The general consensus is the use of historical standard deviation to determine the volatility (Ederington & Guan, 2006). There are arguments against using historical data on the premise that the past in not a quality predictor of the future (Hosley, 2011). The other concern in measuring volatility is the subjective choice of the number of observations to determine the standard deviation sample size, the forecast horizon, and the moving average (Iltuzer & Tas, 2013). However, measuring volatility is a worthwhile endeavor as it allows forecasting and the comparison of those forecasts. Information systems are generally found to increase efficiency and reduce volatility (Long, 2010), measuring the volatility of the appropriate metrics would allow for a visual monitoring of the efficiency and volatility for a given IT system.

Forecasting volatility allows for the forecasting of other metrics and provides a mechanism by which to compare and evaluate results of a system (Iltuzer & Tas, 2013). The comparison and evaluation of results are especially relevant in a volatile environment and those periods of volatility are expected to continue (Elias, 2000). Volatility measurements, both the actual and forecasted volatility, provide information on the future volatility of a system (Wang et al., 2012). Although there are several forecasting methodology and volatility models, the best volatility forecast includes the current volatility (Iltuzer & Tas, 2013).

Future volatility is forecasted across a wide variety of forecast horizons using historical standard deviation (Ederington & Guan, 2006). For example, the VIX has been shown to have a short forecast horizon with most viewing it as a forecast of imminent volatility (Arak & Mijid, 2006). Other volatility measurements use other metrics such as the information ratio which measures the volatility in excess return per unit (Merikas et al., 2005). The relationship between volatility and returns appears to be skewed to the negative side with negative returns having a greater impact on the increase of volatility as compared to the decrease in volatility with a positive return (Lee & Rye, 2013). Given that relationship, a forecast of increased volatility is a good option point to ensure that the value of a system increases (D'Anne, 2012).

Developing a forecast for future volatility provides a tool by which to compare actual volatility against a forecast which can then help determine if there has been an increase or decrease in risk (Arak & Mijid, 2006). It appears that there is a positive relationship between results and volatility with high beta portfolios performing extremely well in low volatility environments; however a high volatility environment is detrimental to those returns (Trainor, 2012). This would indicate that high volatility environments are riskier and decision-makers should act appropriately. New information systems that are planned tend to resemble longer established systems in their results, however emergent systems seem to be the product of high volatility environments and are at the risk of unbalancing the benefits of stability with the disruption of volatility especially in its initial use (Kang, 2007). Knowing the different volatility fluctuation points would provide the decision-maker with the capability to hedge risk and provide for greater returns to the organization (Damodaran, 2005).

Volatility is affected by several different factors, normally in the form of shocks through changes in capital, labor, preferences, demand, or technologies (Chichilnisky & Gorbachev, 2004). The uncertainty that these factors produce provides an opportunity for exploitation of those factors through risk management (Damodaran, 2005). The shocks to the system generally increase volatility; however negative shocks have demonstrated stronger increases in volatility (Lee & Rye, 2013). This provides decision-makers an opportunity to identify the possible negative shocks and place options on those factors in order to take advantage of the uncertainty. However, once in a high volatility environment the return on the systems does not correlate to a respective beta level, which means that a high beta portfolio would have higher risk without a corresponding likelihood of higher returns (Trainor, 2012). Therefore, the hedging of risks, through options, is crucial to protect against negative risks while the environment is of low volatility resulting in increasing value to the options as volatility increases (Damodaran, 2005).

F. RISK

IT investments are inherently risky especially in a volatile environment (Zandi & Tavana, 2011). Measuring risk is seen as the product of two factors, the intensity of the disruption to the system and the likelihood of the risk to happen (Al Kattan et al., 2011). In financial analysis, risk is viewed as the nondiversifiable or systematic risk of a particular market with its value affected by the discount rate. Similarly to the information system environment, risk management is the primary defense against risk with risk-hedging options available (Damodaran, 2005). The high cost of many information systems is a major risk in of itself (Olson & Wu, 2011). Volatility measurements and forecasting is crucial in order to conduct proper risk management (Brownlees, Engle, & Kelly, 2012). This section reviews the risk factors, operational risk, challenges of risk, measuring risk, and the relationship of risk to beta as they pertain to information systems.

Many organizations appear to have a low awareness of risk factors and risk management activities, especially as it relates to IT critical risk factors (Gholami, 2012). The DoD uses portfolio risk, a combination of utility and cost, to review information systems and ensure that they meet the capabilities required and assessing the costs in terms of cost savings and improvements to the process. The process of identifying the portfolio risk encompasses the entire life cycle for the system and provides for an estimated ROI (DCMO, 2013). There are many risk factors, including outsource risks and changes to requirements, and conducting an analysis on those factors can quantify the risk and provide the managers the information needed to make decisions (Olson & Wu, 2011).

The evaluation of risk is quantified through an assessment of the value of the asset, the vulnerability of that asset and the threat to that asset (Gholami, 2012). The threat to an asset is identified in risk management of IT by assessing many factors including the budget, staff, expectations, planning, requirements, management support and user involvement (Al Kattan et al., 2011). Other risk factors include physical threats, such as fires or break-ins, system intrusions which would be hackers or malicious software, and functional threats that includes improper use or inaccurate data (Olson & Wu, 2011). The risks are categorized into financial risks, technical risks, managerial risks, behavior risks, and political and legal risks (Gholami, 2012). The political and financial risks are especially important as they pertain to the DoD environment. On the governance side, the most important factors in implementing an information system are clear requirements and a competent staff (Al Kattan et al., 2011). Due diligence in identifying the risk factors and employing a risk management plan should reduce volatility. The volatility measurements assist in tracking the identified risk factors and determining if the risk management plans are effective.

Organizations invest in information systems to increase their value by becoming more efficient at generating cash flow and/or by lowering the cost to do business. Effective risk management assists in those endeavors through identification of the factors that hinder the value increase (Damodaran, 2005). One definition of risk is the probability of failing to meet an objective (DCMO, 2013). Increasing value is such an objective and identifying risk factors and putting in place mitigation plans to combat factors, such as loss of operational data and downtime, is critical to ensure that objectives are met (Olson & Wu, 2011). Measuring risks quantitatively continues to be a challenge as is the measurement of IT performance as it relates to increasing value (DoD CIO, 2012). Measuring the value in the decrease of operational risk is a step in the right direction.

Risk assessment techniques have grown in importance, the ability to identify and avoid unnecessary risk is valuable (Gilliam et al., 2010). The IT budget is such a risk that continues to be one of the most significant factors to the success of an information system (Al Kattan et al., 2011). Having identified the risk, the budget can be increased to avoid the risk altogether or other mitigation steps can be taken to control costs and reduce the risk. Unfortunately, in a high technological environment, it is difficult to identify the exact source of a risk such as escalating costs (Long, 2010). However, one operational risk factor that can be mitigated directly and reduce other risks indirectly is to ensure a competent staff is in place. A competent staff is more likely to implement an information system successfully as well as conduct proper risk management to reduce the overall operational risk of a system (Al Kattan et al., 2011).

There are several risk challenges especially as it relates to information systems. Even with all of the different risk assessment techniques, methods, and tools available to identify and measure risk, there remains the challenge of low awareness for risk management (Gholami, 2012). Those organizations that practice good risk management are still faced with the challenge that not all risk can be eliminated. Since not all risk can be eliminated, decision-makers prioritize the IT strategies with risk considerations or at least should (Zandi & Tavana, 2011). Long-term projects have the advantage of time but the decision-makers for those projects need to be wary that they do not take extreme risks and counter the time advantage (Elias, 2000). Possibly the biggest risk challenge is to have the entire organization, not only the decision-makers, to look for the opportunities that arise from proper risk management (Damodaran, 2005).

Risk has both a danger and an opportunity element (Damodaran, 2005). Risk management is a positive process with a feedback element to generate control leverage and get realistic expectations (Al Kattan et al., 2011). The asymmetric relationship of an asset value and volatility is displayed through leverage hypothesis and the risk factor volatilities display a similar relationship with control leverage (Lee & Rye, 2013). In portfolios, decision making models quantify risk through probability and utility (Taylor et. al., 2012). Once the risk is quantified, it can then be correlated to the overall portfolio which allows for the opportunity to include negatively correlated assets to reduce the overall risk of the portfolio (D'Anne, 2012).

Risk is the uncertainty and unexpected results in an information system which is displayed in volatility. Volatility measurements of the metrics provide a method to quantify that risk. That quantification provides the decision makers the information needed to either hedge that risk in order to protect against it or to place an option on that risk in order to take advantage of it (Damodaran, 2005). Either way, whether to hedge or option the risk, regular volatility measurements reviews and evaluations ensure proper governance of the system (Gilliam et al., 2010). A risk monitoring element integration into the information system provides the progress feedback, analysis, and corrective action points (Taylor et. al., 2012). The volatility of the metrics to be measured and monitored is identified through evaluation of the criteria and objectives of the information system (Zandi & Tavana, 2011). The measurement of risk provides the mechanism to generate risk profiles for the information system which leads to a decision on the proper level of governance and controls for the system (Taylor et. al., 2012). In a portfolio of investments, the volatility feedback takes advantage of the positive relationship between the volatility and the expected return (Lee & Rye, 2013). In the financial sector, the VIX provides the volatility measurements and when measuring a high level signals significant risk of sharp market moves (D'Anne, 2012).

IT investment managed as portfolios along with incorporation of performance measurements and risk management was mandated by DoD in 2005 (DoD, 2005). With a portfolio of investments, the beta of the investment can represent the risk. Beta is the ratio of the individual system covariance and the overall portfolios returns (Roztocki & Weistroffer, 2009). Once beta is determined, investment portfolio management can leverage the relationship between performance and the volatility environment where high beta portfolios perform better in low volatility environments vice high volatility (Trainor, 2012). Determining the volatility environment then becomes the challenge.

G. BETA

In the financial sector, beta measures the systematic risk of an asset or portfolio and is measured by the volatility of that asset or portfolio (Ganesan & Yadav, 2007). Beta is a good indicator of deviation in a portfolio, accounting for 70% of the correlation (Trainor, 2012). This section reviews beta in the financial markets and the measurement of beta and its relation to volatility.

The Capital Asset Pricing Model (CAPM) describes the risk and return relationship between an asset and its market, with beta representing the risk (Damodaran, 2005). The volatility environment has an effect on the returns with high volatility environments producing negative returns for high beta portfolios. The time horizon also has an effect with short term investments having a higher risk factor for beta than long term investments (Trainor, 2012). With a changing environment, the beta will also change through time (Siegel, 1995). Compounding of returns only amplifies the negative relationship between higher beta assets and high volatility environments as well as the positive relationship of higher beta assets in low volatility environments.

Regression analysis of historical data is presently the best method to measure beta (Siegel, 1995). The regression analysis determines if the beta is related to the any excess return in the present time period based on the returns from prior time periods for a specific asset. The volatility over the specified time period is a beta multiple of the portfolio (Trainor, 2012).

Beta and return relationships turn negative with substantial increases in volatility levels (Trainor, 2012). Increasing returns to scale industries, those that industries where efficiency increases with greater production, are generally more volatile (Chichilnisky & Gorbachev, 2004). Low beta assets in low volatility environments outperform high beta, high volatility assets. Furthermore, asset returns decrease as volatility increases (Trainor, 2012). Therefore, forecasting volatility allows the decision maker to adjust the portfolios in accordance with the prevailing volatility environment.

H. FORECAST

In a 2011 survey, all companies planned to invest in information systems, especially process and data analytics, with the hopes to improve forecasting and budgeting (Hosley, 2011). The forecasting of volatility is especially important in high volatility environments, which is seen in many asset classes (Brownlees et. al., 2012). This sections reviews the data for forecasting, forecasting of value, and the models used to forecast and their relationship with volatility.

Volatility measurements forecast future volatility of the underlying asset (Arak & Mijid, 2006). The ability to capture that future volatility and the change in systematic risk gives the decision maker more agility in governance of that portfolio (Siegel, 1995). However, there are requirements for the system in order to benefit from the measurements. Those requirements include being observable, constancy across variations, constancy of structure, and collection of accurate and large amounts of data (Scher & Koomey, 2011). There should also be a risk monitoring mechanism integrated into the system that allows for progress feedback, analysis, and corrective action (Taylor et. al., 2012). The measurements and risk monitoring are part of the overall risk management plan which establishes the policies and response to uncertain events (Al Kattan et al., 2011).

In a high volatility environment, high beta portfolio values decline (Trainor, 2012), which makes knowing when a portfolio has entered a high volatility environment critical to the management of a portfolio. Uncertainty is part of any investment and knowing how to respond to shocks in the system is good governance. A positive shock generally results in a volatility decrease, whereas a negative shock results in a much stronger increase in volatility (Lee & Rye, 2013). Knowing the volatility environment is important in that a high beta portfolio performs well in a low volatility environment yet underperforms greatly in high volatility environments (Trainor, 2012).

Rolling forecasts generate more accurate results in the value of an asset (Hosley, 2011). The value of an asset is the value of key inputs such as cash flows already made, growth rate, time, and discount rate that reflects the risk for that asset. The discounted cash flow (DCF) model measure the value of a firm in such a way. However, risk adjustments to that valuation model narrowly focuses on discount rate which results in adjustments that are either nonexistent or haphazard (Damodaran, 2005). Using large forecast time periods along with frequent reestimation of those forecasts improves the accuracy of value forecasts and reduces the need for risk adjustments (Brownlees et. al., 2012). The DCF model uses expected value as its metric of choice to represent the probabilities of multiple forecasts to revenues, future cash flows, and growth and margins (Damodaran, 2005). However, in knowledge sectors, which information systems would belong, growing productivity could result in more volatility resulting in the need for more forecasts (Chichilnisky & Gorbachev, 2004). A similarity among organizations is the desire to have an EPM program that provides visibility to the forecasts over time (Hosley, 2011).

The accurate forecasting of volatility with a given asset is of growing importance (Ganesan & Yadav, 2007). In the financial management sector, this importance is seen with the VIX and its volatility forecast model (D'Anne, 2012). The simple premise in financial managements is that over time greater risk should come with greater returns (Trainor, 2012). The goal is to identify the factors, time horizons, and reestimation frequency to develop a successful forecasting and risk assessment model (Brownlees et. al., 2012). Unfortunately, forecasting is hindered due to the lack of structural constancy and constancy across different conditions as systems are constantly changing (Scher & Koomey, 2011). However, identifying relationships such as continued low volatility levels with high beta portfolios results in higher returns (Trainor, 2012) and result shocks increase volatility in both directions with negative shocks producing the greatest change in volatility are valuable (Lee & Rye, 2013). These relationships provide the decision-maker with an opportunity to exploit these relations and adjust portfolios based on the volatility measurements (Trainor, 2012). Capturing and understanding the volatility changes provides the foundation for better models and forecasts (Brownlees et. al., 2012).

There are many factors that affect the success of an information system, its governance, integration with other systems and/or sensors, the metrics used to gauge performance, and the risk in the environment and with the system. Volatility measurements appear to encompass all of those factors and provide relationships and correlations that provide an opportunity for exploitation. In the financial sector this is seen with the trading of VIX contracts that are of negative correlation with the market which reduces portfolio risk significantly (D’Anne, 2012). Applying volatility measurements to information systems seems to provide the potential for exceptional returns.

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III. METHODOLOGY

How quickly a system is adopted will be affected by the fluidness and completeness of the implementation plan. An IT system is a strategic tool to accomplish an organization's mission and should link to the overall strategic plan as well as the budget process (Yang & Melitski, 2007). If the system does not meet that basic requirement of being linked to a higher strategy then the implementation is likely doomed. The ability to review the performance of major IT investments and strengthen IT investments is critical in accomplishing the overall IT strategy (Tekai, 2012). The data collection should be integrated and streamlined, focusing on benefits, including the intangibles, and capable of allowing the comparison of alternatives and the development of options. Pilot programs should be implemented to get credible numbers especially if a previous system is not available. The IT systems should have a clearly designated person responsible for the tracking and performance of those IT systems along with the responsibility for exercising options in order to make more sound decisions (Copeland & Tufano, 2004). The metrics being collected need to be relevant to the objectives desiring change including any cultural change that is desired which will require an organizational measure of performance (Kasunic, 2002). Metrics provide the input from which management can review performance. Understanding of the technology life cycle provides managers with the knowledge to strengthen IT investments. The volatility measurement is reliant upon data collection and the implementation of the IT system and enhances the metrics and technology life cycle of the IT system.

A. DATA COLLECTION

The data collection should allow the IT system to deliver business value and becomes a source of innovation (Stikeleather, 2013). An important feature of data collection should be that it is operational in nature, while still being linked to strategic objectives (Yang & Melitski, 2007). Calculating true cost and benefits of IT is a challenge for both revenue and cost elements and an integrated data collection process would ease that burden. Data collection should be credible with clear, concise, understandable, and believable metrics without being a burden to the operator. The data becomes of central importance to the IT manager as data collection, data reduction, data analysis, and data display is managed by the IT system allowing the manager to make decisions quickly (Yang & Melitski, 2007). The data collected can then be measured for volatility, adding another layer of information for the IT manager to make strategic decisions as it relates to the IT system and the options presented for the system.

Data Gathering Procedures:

The database provides an approach from which a rigorous cost/benefit study is implemented to evaluate the information system (Olson & Wu, 2011). The SIGINT database comprises 5 signals intelligence systems that store reports. The number of reports provides the inputs for a surrogate revenue over a specified time frame. Computer networks are becoming more predominant in the performance of an information system along with the integration of those systems. The complexity of the system is likely to produce issues during actual use (Kang, 2007). Because of this complexity the generated number of reports is scrubbed to ensure that the analysis does not include time frames of what appears to be initial testing. The data gathering provides over two years of data from which to conduct analysis. The actual names of the systems as well as the dates have been substituted in order to maintain the research as unclassified. The time periods do align, i.e., n (period) 102 of system 1 = n 102 of system 3. Systems 2, 3, and 5 contain incremental systems and are annotated as 2.0, 2.1, etc. The data is collated onto a spreadsheet from which the analysis is conducted.

B. ANALYSIS

The purpose of metrics is to compare other systems to one another, however with many systems lacking a common output or environment, metrics by themselves can be misleading. It is the relativity of the metrics of one system to the same metric in another system, such as a previous system, where the benefits can be measured. A previous system or historic data can provide a baseline from which a new system can be compared. It is critical that the metric chosen effects the objective desired and is consistent in its measurement. There are many metrics that can be chosen such as ROI, efficiency ratios, cost constraints, KVA, payback period, unit cost, etc. In an IT system, the benefits are rarely revenue and therefore a surrogate is used, which only adds to the measurement ambiguity. Using metrics over a short time period could lead to a lot of volatility and those short-term fluctuations could lead to an overreaction by managers. Using a longer timeframe and cyclically adjusting the metric over that timeframe should give a better measure of the true volatility and value of the system. However, metrics themselves could be shortcomings as there are other factors such as interoperability and agility that may not directly influence cost or benefits and are even more difficult to measure in nominal terms. Volatility measurements over a long period, with any appropriate metric, provide additional information for the manager from which to review performance and strengthen the IT investments.

Rios conducted research on SIGINT systems to determine its ROI. Analyzing the outputs of the U.S. Navy CCOP in common units, a price per unit of output can be generated to account for both cost and revenue at the subprocess as well as asset level. This can then be used to determine ROI for each asset and allow for effective valuation and comparison of different IT systems. Further, this can provide for a common framework from which to understand, evaluate, and justify the impact of government investments in IT systems. This common framework is the KVA methodology which allows program managers to build meaningful metrics and perform financial analysis on the SIGINT systems (Rios, 2005).

Lambeth and Clapp built upon Rios' research and applied the KVA methodology to the deployment of the CCOP system on board the USS GONZALEZ (DDG-66). Military acquisition requires investments to be productive, efficient, and support joint operational capabilities. Defining a ROI methodology by which systems can be measured is crucial in establishing a more efficient acquisition process. Furthermore, using a near real-time method allows the decision-maker to get the latest metrics on a system to determine its present effectiveness and provide valuable information for a more effective revenue allocation. The KVA methodology would allow program managers to allocate future resources based on the collected metrics and therefore make more efficient IT investment decisions (Lambeth, III & Clapp, 2007).

Marco Nelson captured volatility of ROI to generate a beta derivation in IT investment portfolios. DoD CIO instructs that "a portfolio baseline shall be established and maintained for each portfolio" (Instruction, 2006, p. 15). Since the DoD does not generate revenue, similar to the corporate market, a surrogate for revenue and cost streams such as the KVA methodology should be used. The KVA methodology can also be used to provide the ROI estimates of volatility in order to produce the notional IT beta. Key decision makers can then use the beta derivation steps to develop the baseline of a family of systems and then evaluate new or existing assets within an investment portfolio (Nelson, 2010).

This research expands on the previous work adding volatility measurements as well as analyzing actual returns that the SIGINT database has gathered. Unit cost will be used as the surrogate for revenue as it can quickly be calculated for each system with the data in the database.

Analysis Procedures:

The number of reports is compared on a daily, weekly, and monthly time frame against the rolling average, the average number of reports over the life of the system, and the moving average, the average number of reports over the last 60-days (8 weeks and 2 months). This gives a visual representation of the benefits of the system over its life cycle.

The next step is to calculate the unit cost. Based on annual budget estimations, the systems cost $2,000,000 annually to operate (DoD, 2013). The exact amount for each system is classified therefore an estimation is used. The amount along with the number of reports is used to calculate a unit cost ($/report). The unit cost is used as the surrogate for revenue as well as the volatility data.

One challenge is to "smooth" the data as it goes through the business cycle (Chichilnisky & Gorbachev, 2004). In order to smooth the calculated data, the number of reports is based on a moving time-frame of one year. The initial unit cost is determined by the first 365 data points gathered from the database. The unit cost metric becomes the input into the volatility measurements.

The volatility measurements are determined from the unit cost of the respective time frames. First, the natural log of the change between the unit costs is determined. Then the standard deviation of those natural logs is determined to provide the volatility of the system.

Statistical analysis provides the relationship between volatility and benefits over time (Scher & Koomey, 2011). The historical standard deviation provides the volatility measurements that are then used to forecast the future volatility. Future volatility is forecasted through historical standard deviation (Ederington & Guan, 2006). This is a time series approach for forecasting volatility, which relies on past volatility to predict future results (Wang et al., 2012). The model used to determine the forecast is the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model. The forecasts generated in this research are for a year out in order to provide decision makers an opportunity to plan and take actions based on the data. The forecasts are estimated using the data from the daily, weekly, and monthly computations providing a range of forecasts from which to make decisions.

The final analysis is to determine beta between all of the systems. The percentage of change for the unit cost is determined for each system. The market comprises the unit cost calculated using all reports generated and the total cost of all of the systems added together. The change percentage is calculated for the market as well. The two sets of change percentages, market and system, are then brought through a regression analysis to determine the beta coefficient. Each system is compared to the market to determine the beta.

C. TECHNOLOGY LIFE CYCLE

The technology life cycle is the timeline for developing technology and recovering the costs for that development (Housel & Bergin, 2013). The digital environment will be proactive and demand responsiveness from IT investments (Chang & West, 2006) and managers need to invest in the technology life cycle to meet those challenges. There are several technology life cycle models, but they generally start with an assessment or investigation, then move to a design or selection phase, followed by implementation or production, and finally, move into an evaluation and analysis phase before starting the cycle over (Housel & Bergin, 2013). Volatility measurements are concerned operationally with the management, evaluation, analysis phase but can be used in the other phases of the technology life cycle by determining how the volatility from previous systems is being addressed.

While implementing a system, the value of IT is not only about efficiency but also the integration of organizations and users (Yang & Melitski, 2007). The systems should reach the most customers based on hardware that users have available (Smith, 2007). The system should link computers and users via networks and allow the interaction with one another to produce benefits and achieve objectives (Chang & West, 2006). The interaction and growth of users could allow an IT system to provide significant software and computer power at lower price points while providing better performance at lower prices (Smith, 2007). The challenge for an organization is to produce one-stop service for IT systems that provide cost efficiencies and standardization while still providing security, privacy, and innovation (Yang & Melitski, 2007).

If performance of an IT system is normally distributed then the volatility of the system can be represented by the standard deviation, with one standard deviation representing two-thirds of the possible outcomes and two standard deviations representing 95% of the outcomes (Copeland & Tufano, 2004). The performance of the IT system through the use of metrics provides a nominal input by which to calculate the volatility. The volatility then becomes a metric by which to compare systems to one another and determine how risk is reduced and the system becomes more predictable. The volatility may also assist in determining as which stage of the technology life cycle the system resides providing managers an indication of what IT investments to make and possibly answer which IT systems provide the best return and how to deploy the systems (Housel and Mun, 2013). The decisions still need to be linked to the IT strategy and budgets while balancing stakeholders competing interests and demands (Housel & Bergin, 2013). The time value of money needs to be considered, as benefits may not appear for some time, even though the expenditure may be required today. The niche area is the first area of technology adoption followed by the unregulated spaces, certified applications, recommended practice, and finally mandatory practice (Smith, 2007). The volatility measurement will have a similar adoption pattern, by first proving its usefulness in increasing the accuracy of forecast in a niche area.

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IV. DATA

A. AVERAGE RETURNS

1. System 1

The rolling daily averages for System 1 (Figure 1) shows a positive trend to period 310, which is just short of one year, then stabilizing in the number of reports generated through the remainder of the observed time periods. The 60-day moving average is not a stable with a significant increase at period 180 and volatile returns through period 741 until a significant drop.

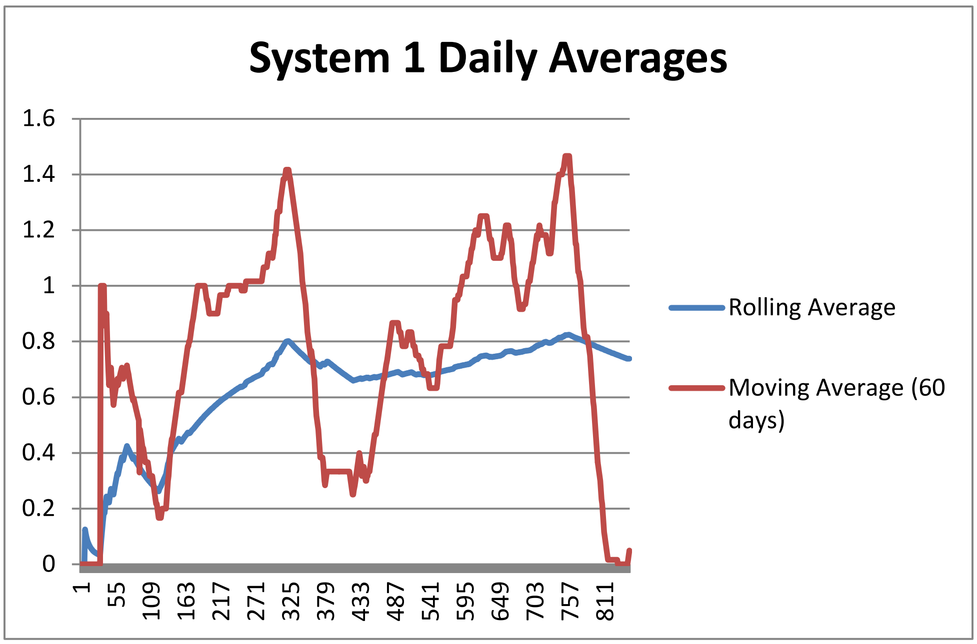


Figure 1. System 1 Daily Averages

There are two conclusions observed through the data. The first is the significant increase in reports to period 180, approximately 6 months, which is indicative of the conquering of the learning curve. The second conclusion is that the system may have reached the end of its usefulness with the drop to almost zero in the 60-day moving average. The weekly and monthly (Figures 2 and 3) averages also support those conclusions.

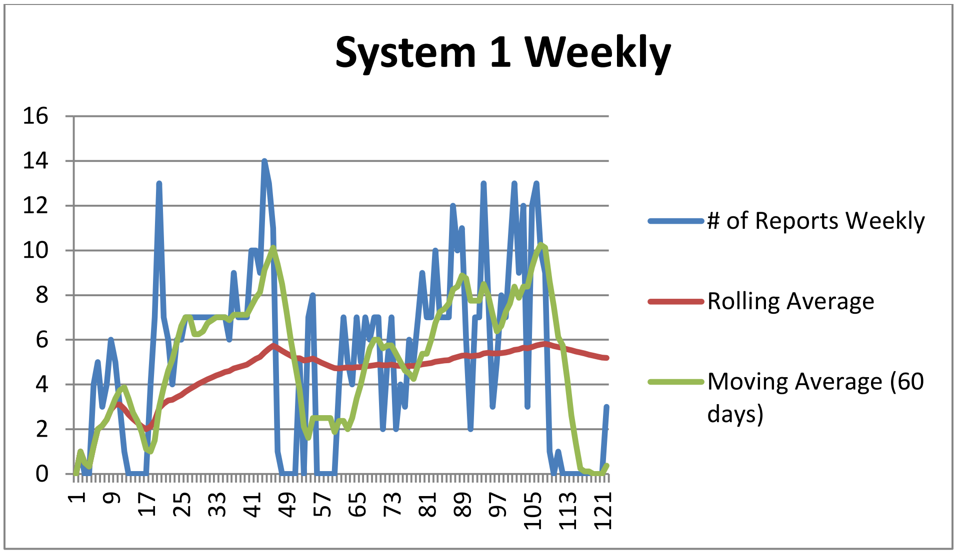


Figure 2. System 1 Weekly Averages

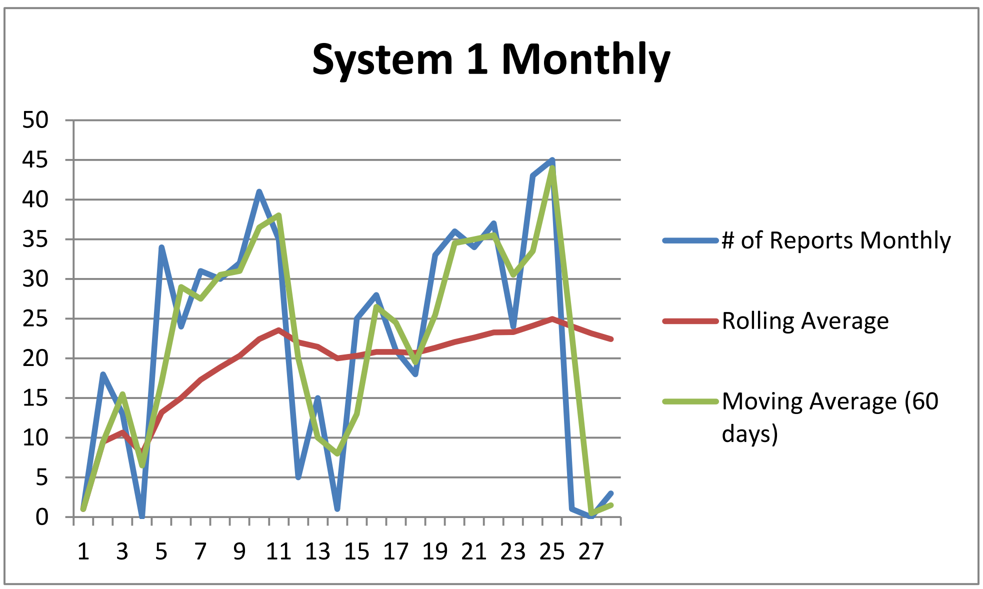


Figure 3. System 1 Monthly Averages

2. System 2

For system 2 (Figure 4), the rolling average shows a continued positive trend with the greatest rate of change occurring to the month 8 point. The 60-day moving average is showing a stabilization of approximately 200 reports per month.

As with System 1, the large increase in month 5 appears to indicate a learning curve with increased readings over the next 4 months. The stabilization of high readings indicates a system that is of continued benefit.

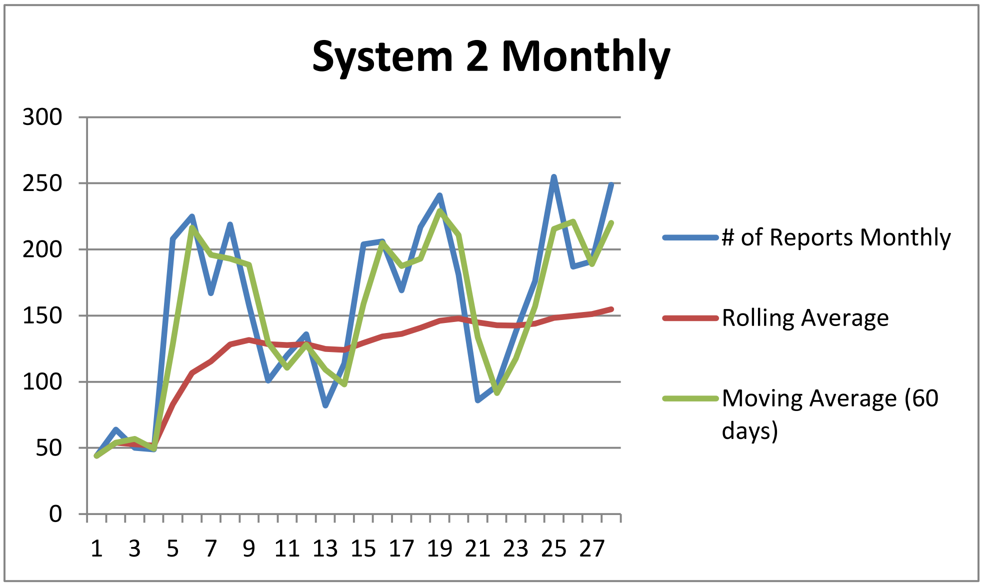


Figure 4. System 2 Monthly Average

System 2 is one of two systems observed that have identifiable increments (Figures 5–8). As expected, the latest increment (Figure 8) produces the greatest number of reports, out-producing all of the other increments combined. With the exception of a recent sharp increase in System 2.0 (Figure 5), the previous increments appear to be at the end of their life cycle. Systems 2.1 and 2.2 (Figures 5 and 6) appear to have been mature when the database started collecting data which would account for the higher starting averages and the negative trends since reporting supports the end of life cycle observation. System 2.3 (Figure 8) continues to show positive trends in both its rolling average and the 60-day moving average.

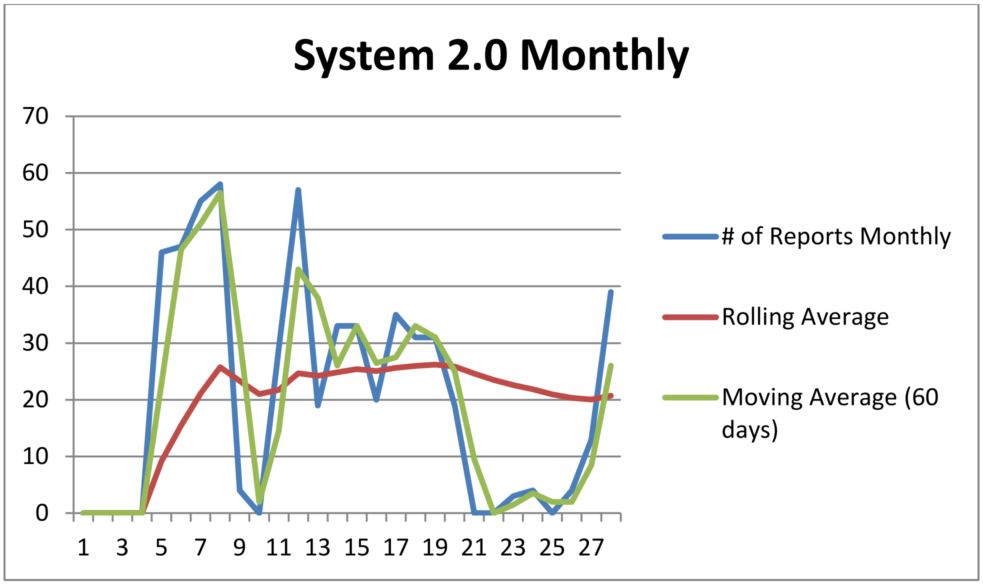


Figure 5. System 2.0 Monthly Averages

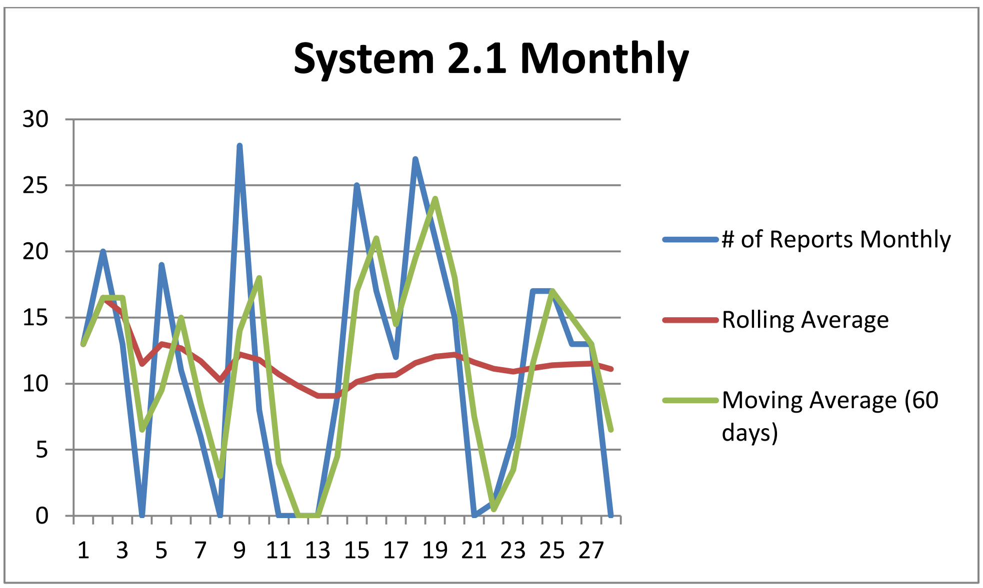


Figure 6. System 2.1 Monthly Averages

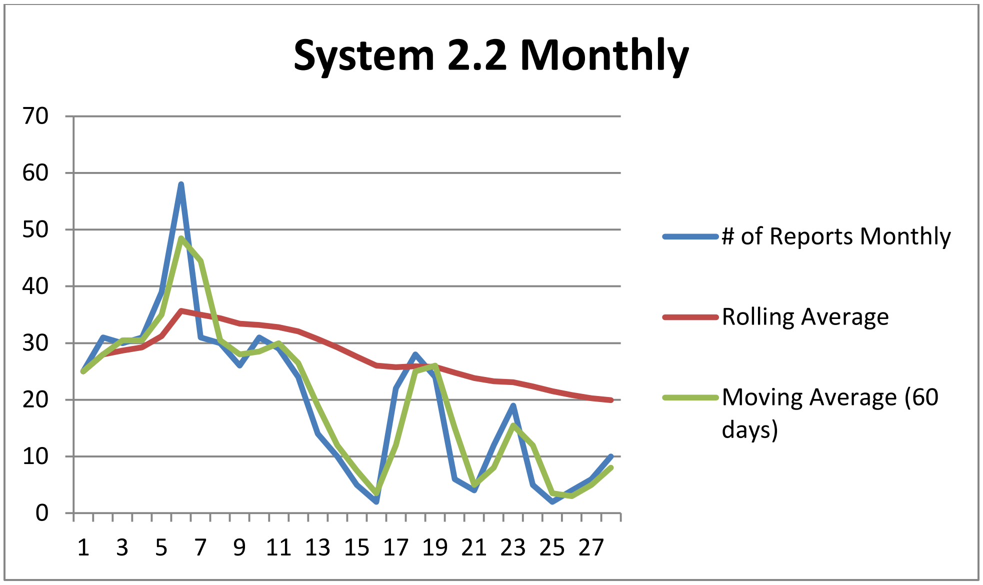


Figure 7. System 2.2 Monthly Averages

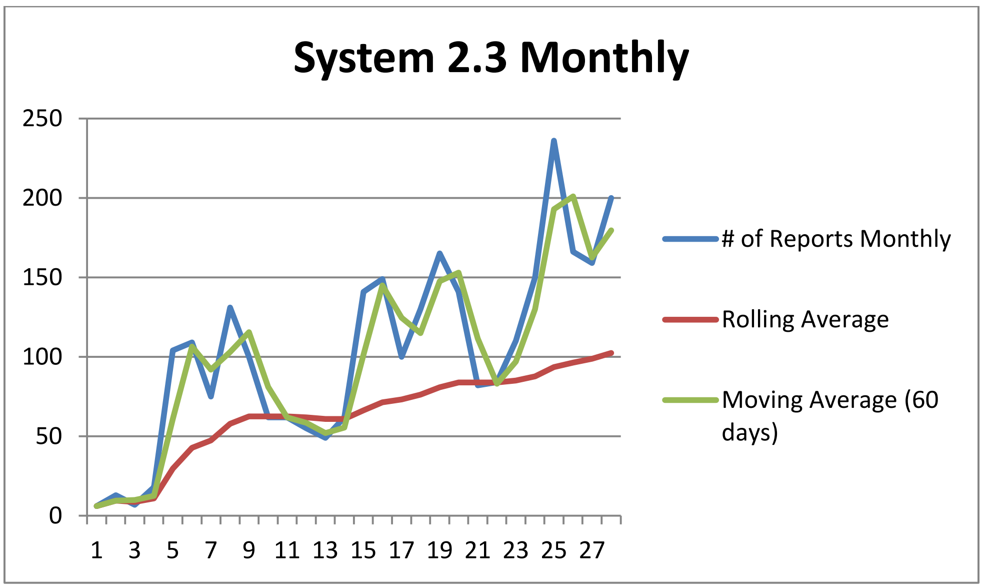


Figure 8. System 2.3 Monthly Averages

3. System 3

Similar to System 2 (Figure 4), System 3 (Figure 9) shows positive trends for both the rolling average 60-day moving average. Unlike System 2, the learning curve for System 3 appears to occur at a later timeframe of 16 months. The continued increase of readings indicates a system that is of continued benefit.

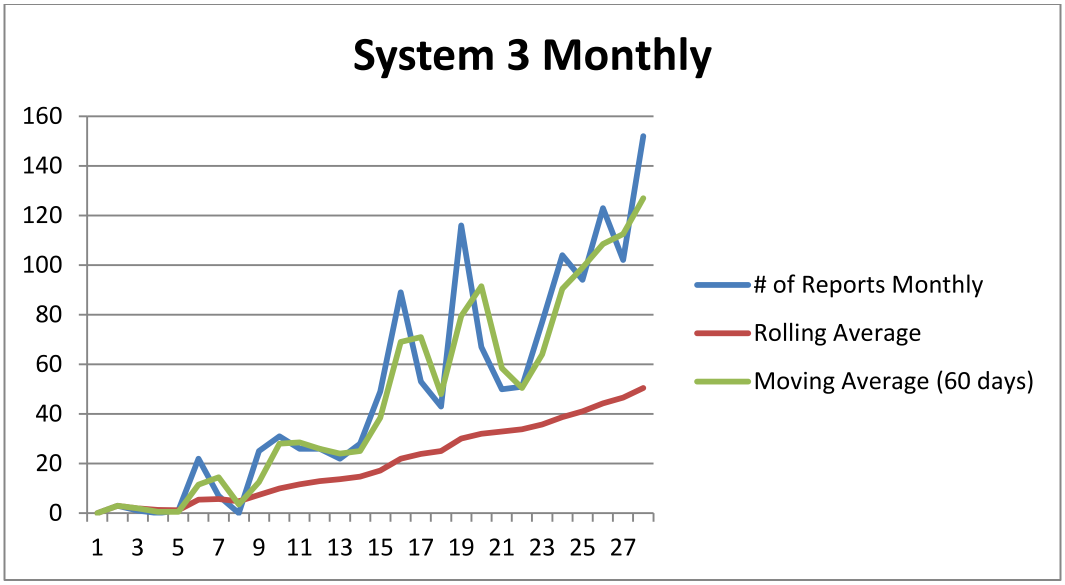


Figure 9. System 3 Monthly Averages

System 3 is the other system observed that has identifiable increments. As with System 2, the latest increment produces the greatest number of reports. Interestingly, there was also a recent sharp increase in System 3.0 (Figure 10); otherwise it also appeared to be at the end of their life cycle. System 3.1 (Figure 11) continues to show positive trends in both its rolling average and the 60-day moving average.

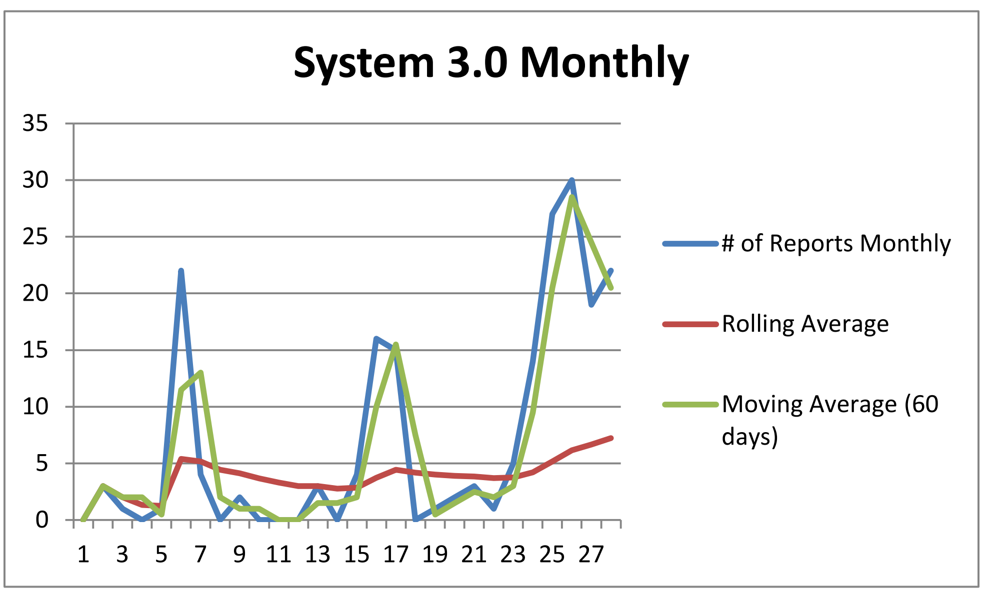


Figure 10. System 3.0 Monthly Averages

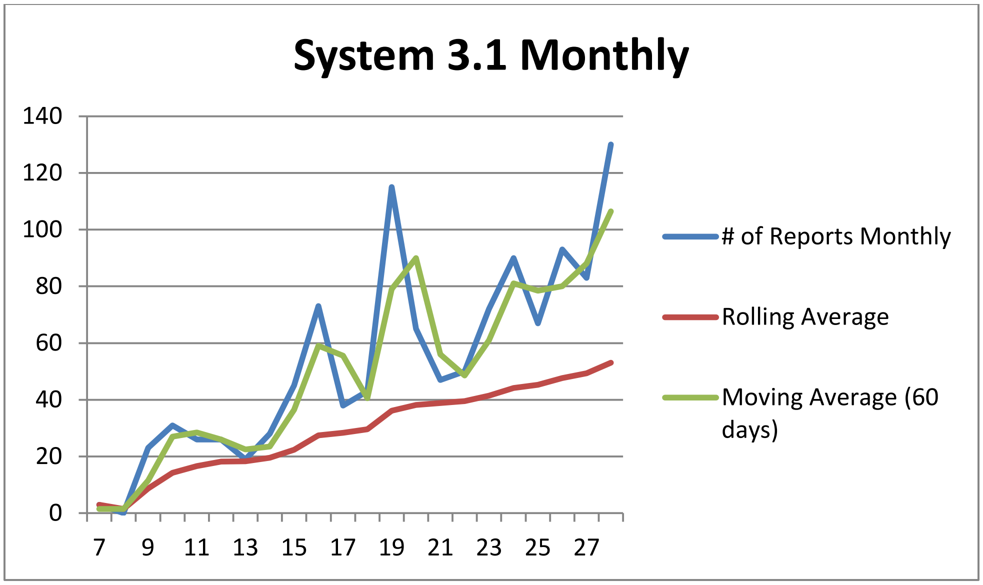


Figure 11. System 3.1 Monthly Averages

4. System 4

For System 4 (Figure 12), the rolling average shows a positive trend with the greatest rate of change occurring up to 8-month point, which is similar to System 2 (Figure 4). However, after month 10, the trend becomes slightly negative. The 60-day moving average is volatile, showing a sharp increase at month 6, peak at month 7 and then decreases to month 13 until another sharp increase at month 26. As with System 2, the increases in rolling average to month 8 appears to indicate a learning curve. The stabilization of high readings indicates a system that is of continued benefit.

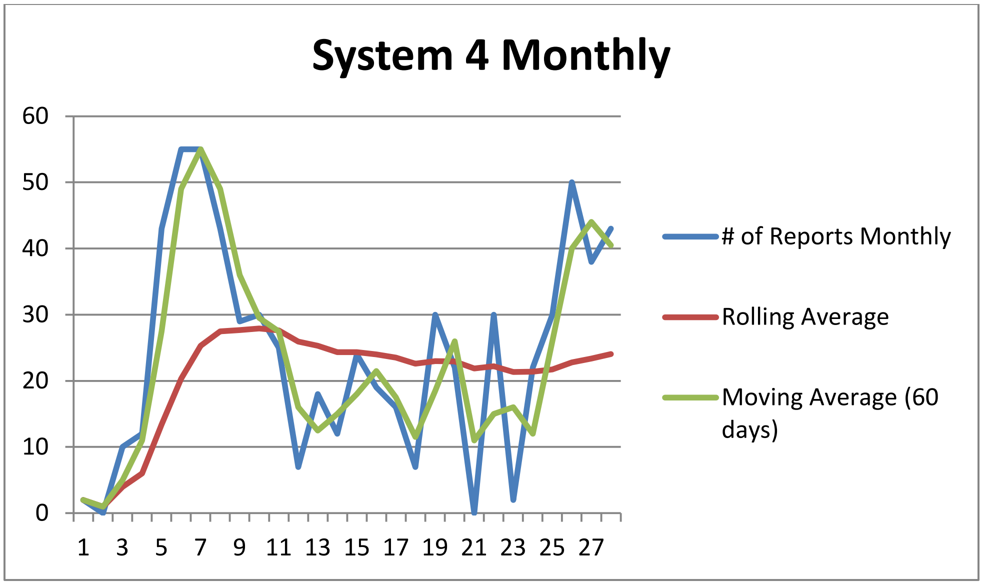


Figure 12. System 4 Monthly Averages

5. System 5

For System 5 (Figure 13), the rolling average shows a positive trend with the greatest rate of change occurring up to the 9 month point, which is similar to System 2 (Figure 4) and 4 (Figure 12). The 60-day moving average is volatile with large peaks up to month 21 then substantial decreases with a post month 9 low at month 25. The increases in rolling average to month 9 appear to indicate a learning curve. The volatility of readings indicates other factors in play than just the information system.

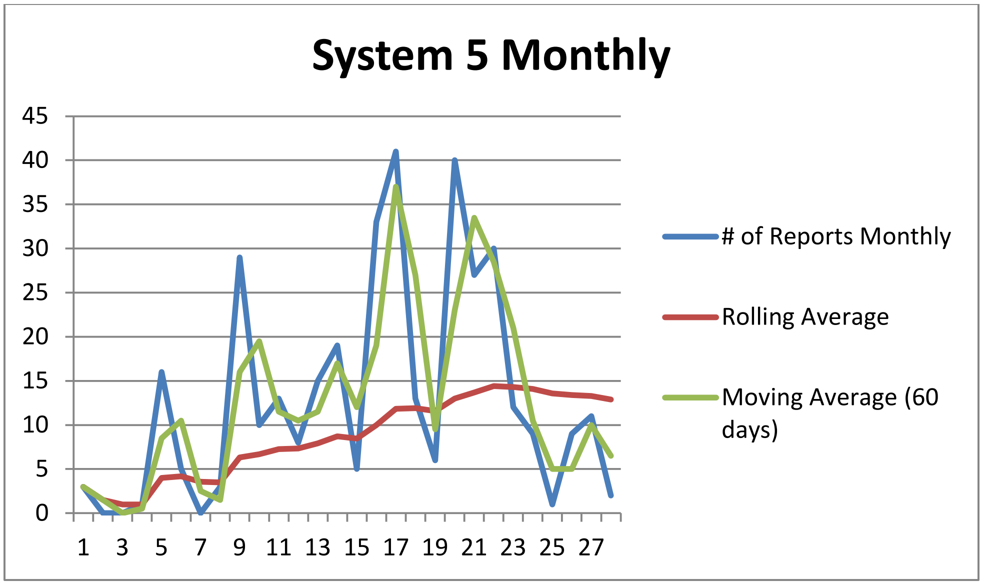


Figure 13. System 5 Monthly Averages

B. UNIT COST

1. System 1

The unit cost for System 1 (Figure 14) over the observed timeframe shows a positive trend (unit cost going down) until daily point 774 which is over two years but then increases (negative trend) for the remainder of the observed period. The low unit cost calculation for System 1of $5797 means nothing until it is compared with other systems or the overall signal reports market. Unfortunately, the unit cost for System 1 is well above the market unit cost which was below $5000 for the entirety of the observed period.

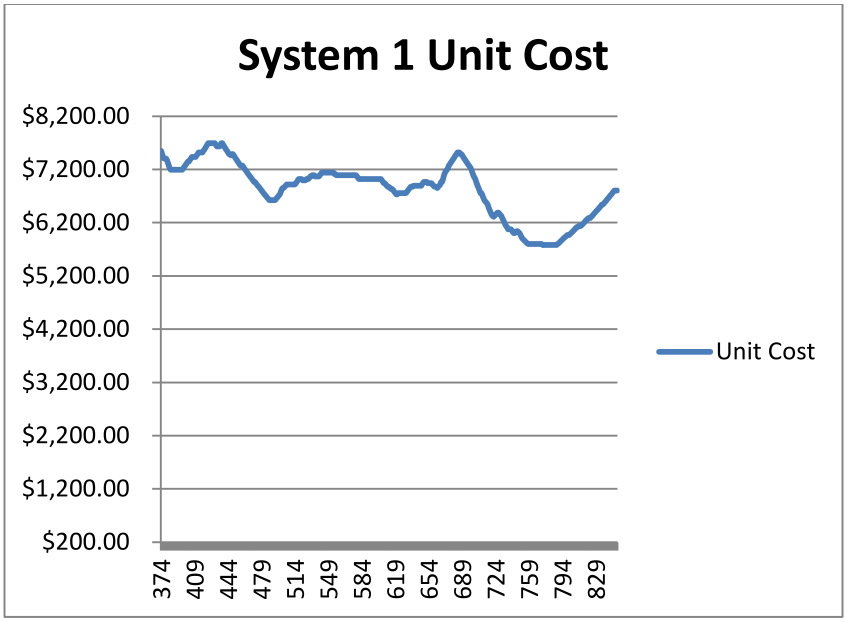


Figure 14. System 1 Unit Cost

2. System 2

The unit cost for System 2 (Figure 15) over the observed timeframe shows a positive trend (unit cost going down) throughout the observed period. This indicates strength in benefit returns for System 2.

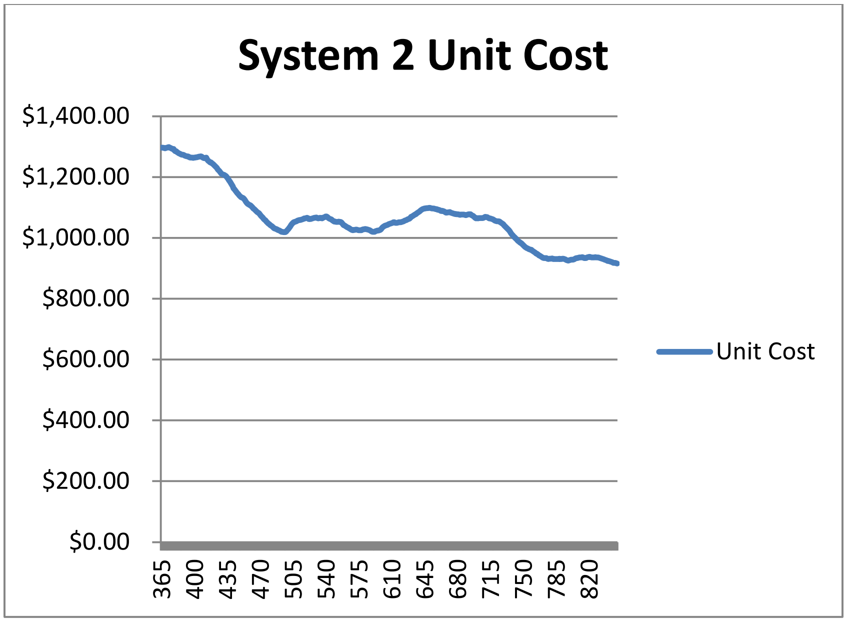


Figure 15. System 2 Unit Cost

The increments tell a different story. System 2.1 (Figure 16) actually shows a positive trend for the majority of the observed period, however the unit cost is so high that it indicates a system that costs more than the benefits received warrants and therefore should be a system considered for shut down or replacement. Unlike System 2.1 (Figure 16), System 2.2 (Figure 17) definitely shows a negative trend and indicates a system that once was efficient but has since become a system that does not warrant the cost and should be replaced. System 2.3 (Figure 18) shows a positive trend and outweighs all the other System 2 increments.

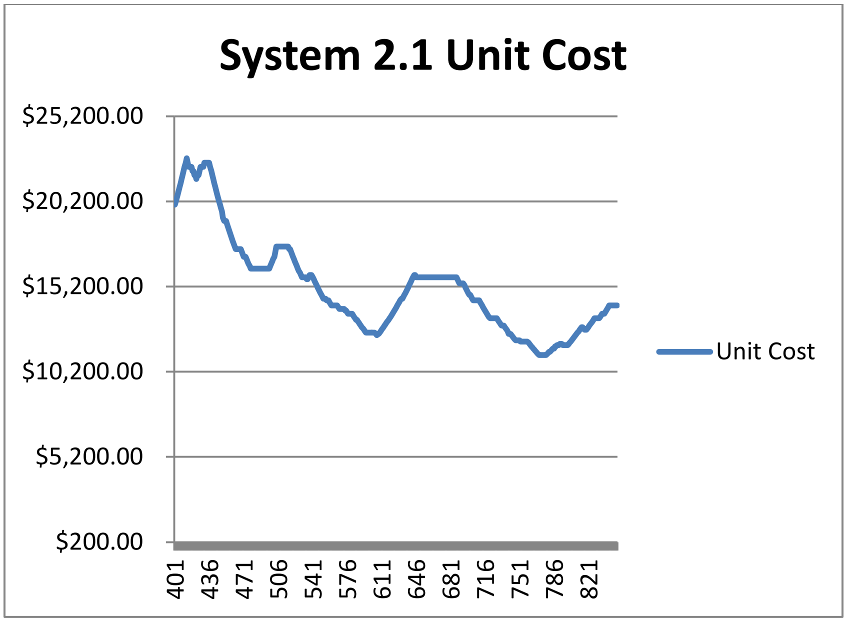


Figure 16. System 2.1 Unit Cost

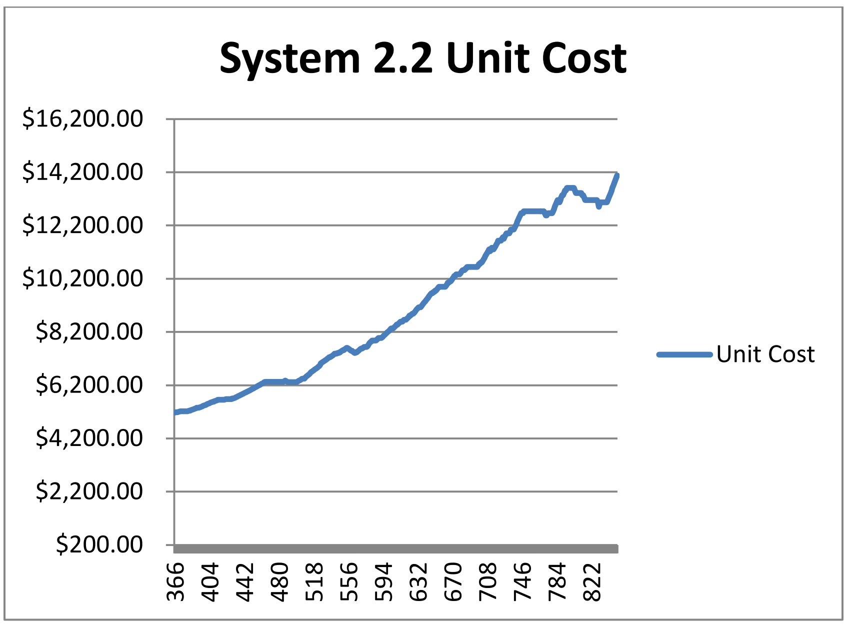


Figure 17. System 2.2 Unit Cost

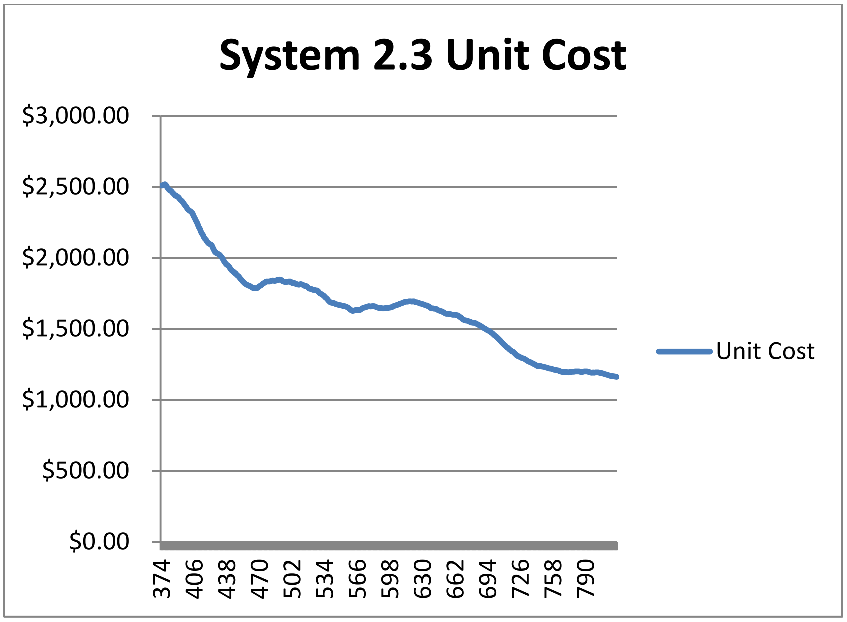


Figure 18. System 2.3 Unit Cost

3. System 3

The unit cost for System 3 (Figure 19) over the observed timeframe shows a positive trend (unit cost going down) throughout the observed period. The rapid decrease in unit cost is more in line with the market average indicating a maturing of the system and strength in benefit returns for System 3.

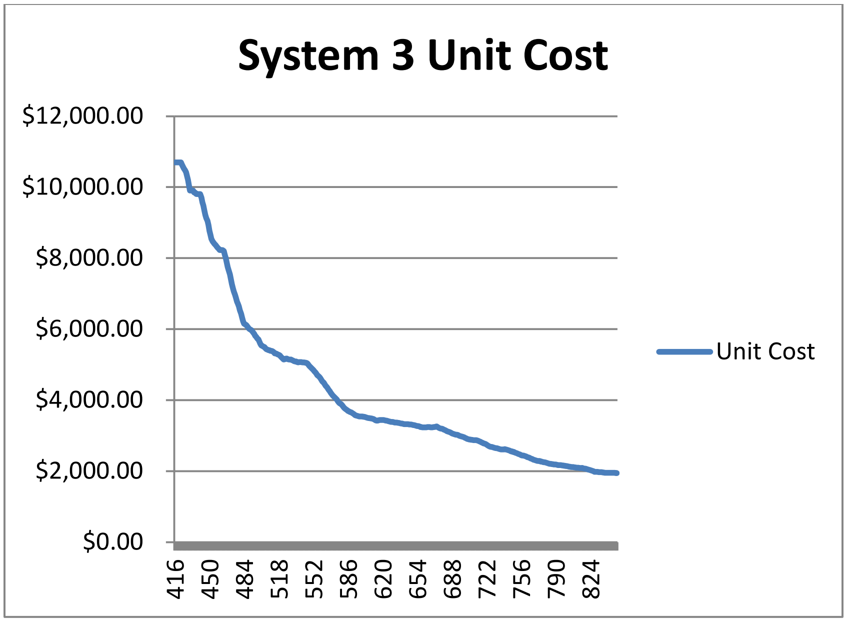
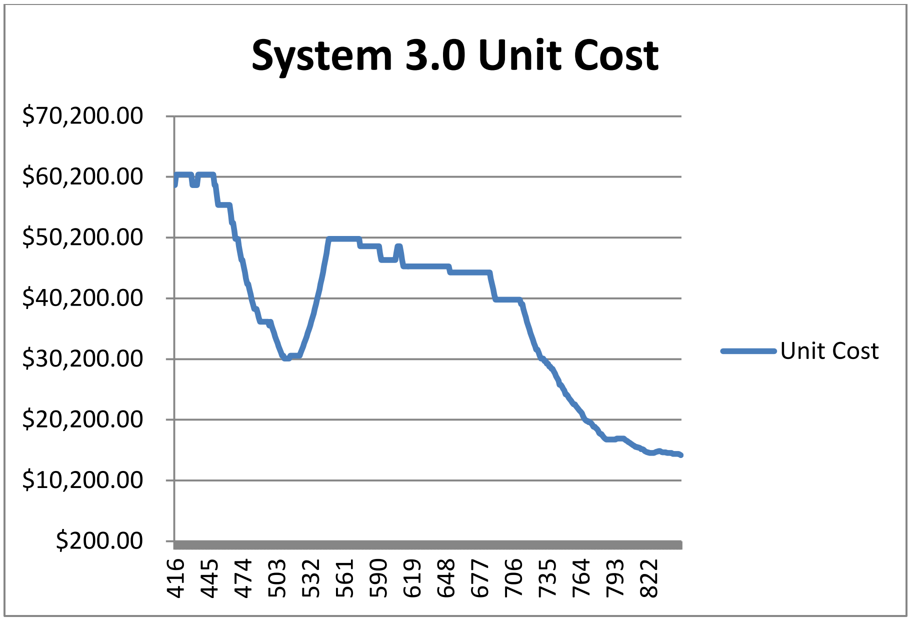


Figure 19. System 3 Unit Cost

Even though System 3.0 (Figure 20) shows a positive trend, its high unit cost indicates a system that does not warrant the costs and should be terminated as opposed to System 3.1 (Figure 21) whose unit cost is 84% lower than System 3.0. Incremental System 3.1 is the primary driver for System 3.



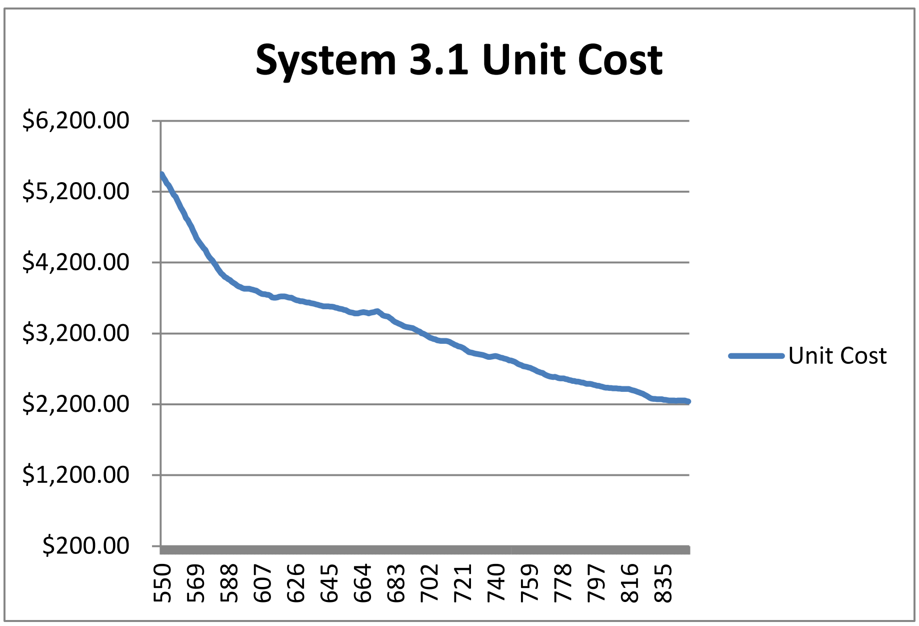


Figure 20. System 3.0 and 3.1 Unit Cost

4. System 4

System 4 (Figure 21) shows a negative trend to point 649 and then a positive trend for the remainder of the observation period. This would be an example of a system that requires further research. Unless it has a specific mission that it is meeting that it should be considered for improvement or termination as the amount of reports generated does not warrant the assumed cost.

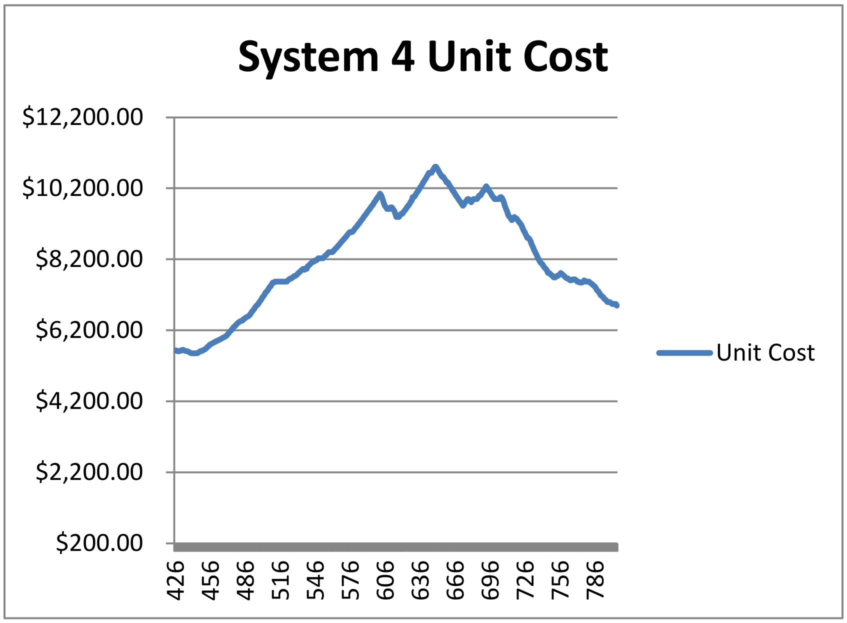


Figure 21. System 4 Unit Cost

5. System 5

Similar to System 4 (Figure 21), System 5 (Figure 22) is another example of a system that requires further research. Unless it has a specific mission that it is meeting that it should be considered for improvement or termination as the amount of reports generated does not warrant the high unit cost. The positive trend through the observed period only results in a low of over $8000 for its unit cost which is well above the market unit cost.

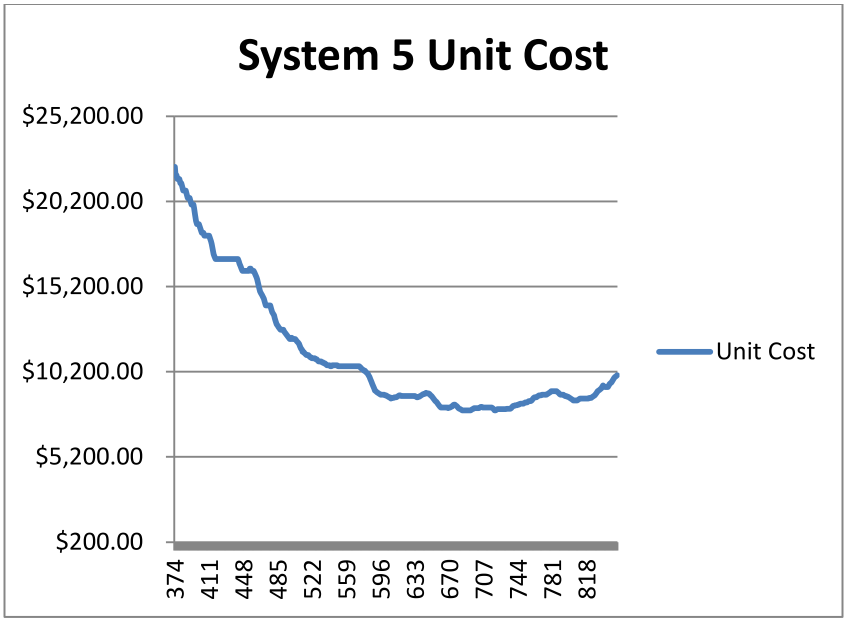


Figure 22. System 5 Unit Cost

6. Market

Figure 23 is the graphical representation of all the systems. The market (all systems) line shows a positive trend with the latest reading being $2500. Only two systems get under that average, Systems 2 and 3. Systems 1, 4, and 5 would require further research to determine what is driving their unit cost to be above average however since those three systems have unit costs 3x the market unit cost, they should be reviewed with the purpose of removing them.

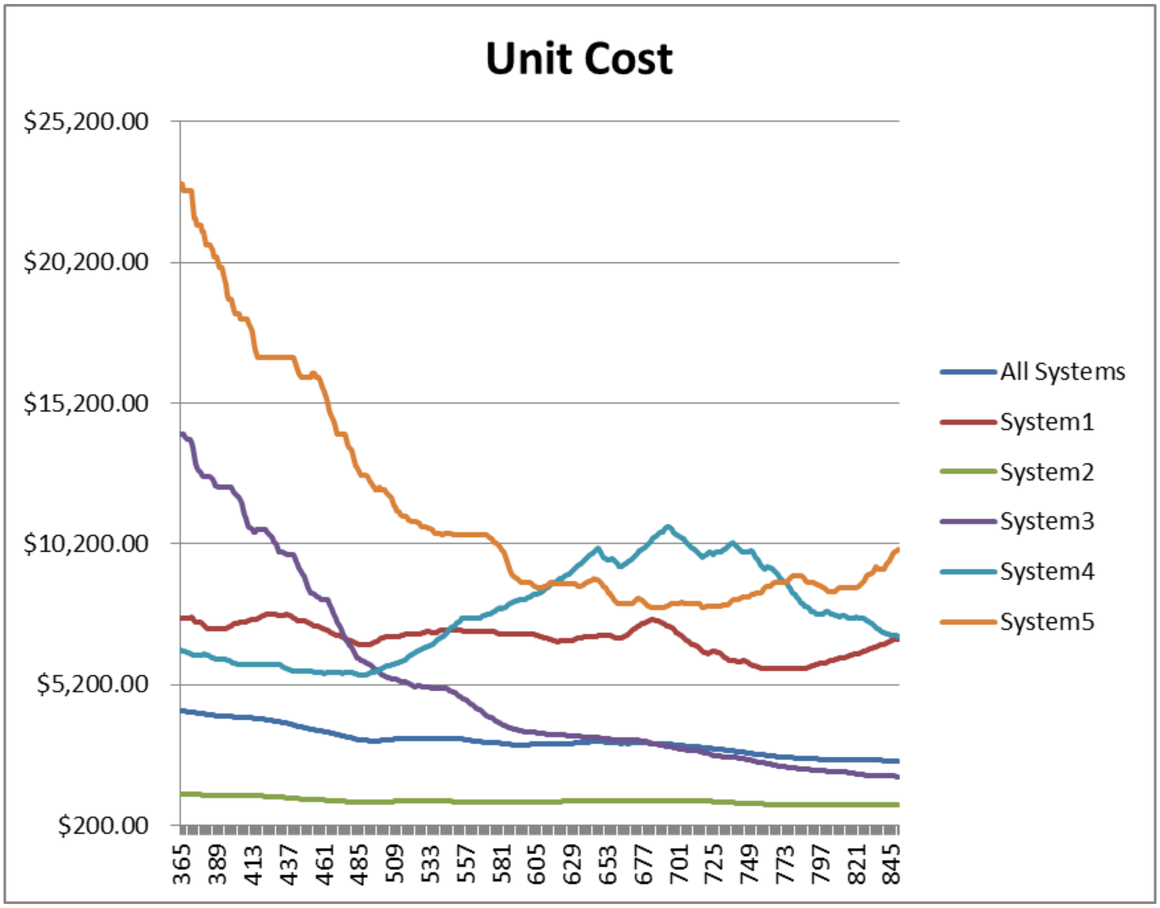


Figure 23. Market Unit Cost Comparisons

C. GARCH

The GARCH forecasted volatility charts are located in Appendix A. The following table (Table 1) provides a summary of the results.

System	Forecasted Volatility	Notes
1	12.95%	
2	7.81%	
2.0	20.72%	
2.1	17%	Decreasing over time
2.2	16.00%	Slightly increasing over time
2.3	10.67%	
3	721%	skewed by System 3.0
3.0	41.77%	
3.1	21.09%	
4	19.59%	
5	21.53%	
Market	7.38%	

Table 1. Forecasted Volatility

As expected the overall market volatility and forecasted volatility was lower with all of the data points smoothing out the results. Unexpectedly, that was not the case with System 3 where the rapid change and combination of System 3.0 and 3.1 resulted in even more volatility. As with the unit cost, the forecasted volatility measurements point to System 2, specifically incremental System 2.3 as the system of choice.

In the financial sector, the inverse relation between volatility and stock market returns is well known (Lee & Rye, 2013); the data shows that this trend also holds in returns in information systems. The higher volatility systems were also the lower performing systems, although the volatility should be measured on an incremental system basis to separate the underperforming systems from the performing systems.

D. BETA

The regression analysis results are located in Appendix B. The following table (Table 2) provides the beta for each system.

System	Beta
1	0.0098
2	0.0153
2.0	-0.0533
2.1	0.0969
2.2	0.1176
2.3	0.6040
3	0.2321
3.0	0.0461
3.1	0.2099
4	0.1485
5	0.0808

Table 2. System Betas

The analysis suggests that beta may be a better indicator of successful systems assuming that the overall market of systems is improving which is the case for this analysis. Using unit cost as a primary factor in ranking systems then Systems 2.3 and 3.1 are the top performers, which correlates to the higher beta levels. It could also be useful in determining the systems that should be reviewed for termination with the lowest three betas being Systems 2.0, 1, and 3.0 which were identified in the average returns and unit cost sections as the underperforming systems.

V. CONCLUSION

One of the first steps is to ensure that you are measuring precisely the intended values (Yang & Melitski, 2007). Management needs to embrace business models that assist in identifying those measures including agility capacity (Guertin et. al., 2012). Whether those metrics are internal versus external factors, efficiency versus effectiveness, interagency collaboration, vertical and horizontal integration, or distinct strategic value (Yang & Melitski, 2007), volatility measurements assist in the effort by measuring the deviations of those metrics. Development, clarification, measurement, and evaluation of all competing strategic values are paramount to ensure a successful IT system implementation (Yang & Melitski, 2007). The volatility measurements aids in metric evaluation providing the additional information needed to compare systems and make better decisions.

Demonstrating the competing values of IT systems allows the IT managers to make appropriate comparisons; however, care should be taken in generalizing the results as other factors may affect those values (Yang & Melitski, 2007). Volatility measurements take consideration of all factors and give a baseline from which the IT manager can make decisions across systems. The primary factors in determining volatility in IT systems are the amount of users, interoperability of the systems, and the volume of data collection. Metrics are important for decision makers as they can be used to establish goals to improve efficiency and effectiveness, are measureable, and are used to assess the effectiveness of the organization and its leadership (Kasunic, 2002). The volatility measurements allow systems to be compared appropriately to determine the gains over prior iterations along with aiding in determining which options to exercise for future systems. The additional capabilities provided by volatility measurements will go a long way in strengthening IT investments and the performance review of those systems.

A. LIMITATIONS

The DoD IEAs engages stakeholders to determine IT transformation including portfolio assembly and implementation (DoD CIO, 2012). Volatility measurements have shown to be a mechanism by which those stakeholders can optimize the portfolio assembly and implementation of information systems. However, there are limitations for this particular research. Human rationality and intervention are the most valuable component of portfolio assembly (Long, 2010). First, the incremental systems could potentially skew the data as the number of assets available for the different systems could have changed and resulted in the shifting of benefits from one incremental system to another. Second, most of these systems are brought into theatres for use by larger assets such U.S. Navy vessels whose numbers and operational schedule could greatly affect the returns of those systems. Third, the unit cost data only takes into account system cost. The fourth limitation is that this research assumes that all reports are created equal.

B. RESEARCH QUESTIONS

The first research question, do volatility measurements provide a capability to forecast future performance of the system, is answered yes. The forecasted volatility measurements do provide a forecast of future performance as shown through the GARCH data. The lower forecasted volatility systems are the higher performing systems, which in this research was System 2.3.

The second research question, do volatility measurements provide timing options for the implementation of incremental or new information systems, is not conclusive. The period of observation was just over two years which is not enough observations to make a conclusion. The two year timeframe was the extent of the data within the database analyzed. There is promise that volatility measurements will provide the information for the timing of options as more data is gathered. For example, the ability to determine learning curve with each system ranged from 5 to 11 months (System 2 and 3, respectively), would point to an option at month 12 to ensure that the learning curve was passed and the system will provide expected returns.

The third research question, can beta be determined within a portfolio of systems based on volatility measurements, is yes. The regression analysis results that provide the beta data are located in Appendix B with the table of beta results in the data chapter. However, future research of the use of beta as it applies to information systems is needed. In the financial industry, beta is used to reduce volatility/risk of a portfolio while maintaining a desired return. Having market data of only five systems spanning just over a two year timeframe is a limiting factor for this research.

C. FUTURE RESEARCH

There are five identified areas of future research with most being in the classified realm. The first is expanding the analysis based on the number of physical systems in the U.S. Navy and the returns they generate. Normalizing the data based on those numbers could result in systems that appear underperforming to be providing substantial results. The second is similar to the first possibility, but concentrating on the number of U.S. Navy vessels and their operational schedules. The operational schedule is a major factor in the return of these systems. The third area identified for future research is the use of actual cost data to provide unit cost. The costs in this research are assumed from annual budget submissions as actual cost data would push the research to a classified category. This future research opportunity can also be combined with previous research from Rios, Nelson, Lambeth, and Clapp and provide the ROI via the KVA methodology. The fourth future research area is the weighing of SIGINT reports to determine which reports are worth more or less than others. And finally, the fifth future research area is the use of beta as it applies to information systems. Previous research by Nelson, as well as this research, shows that beta can be derived but actually showing the use of the beta as it relates to information systems needs to be verified.

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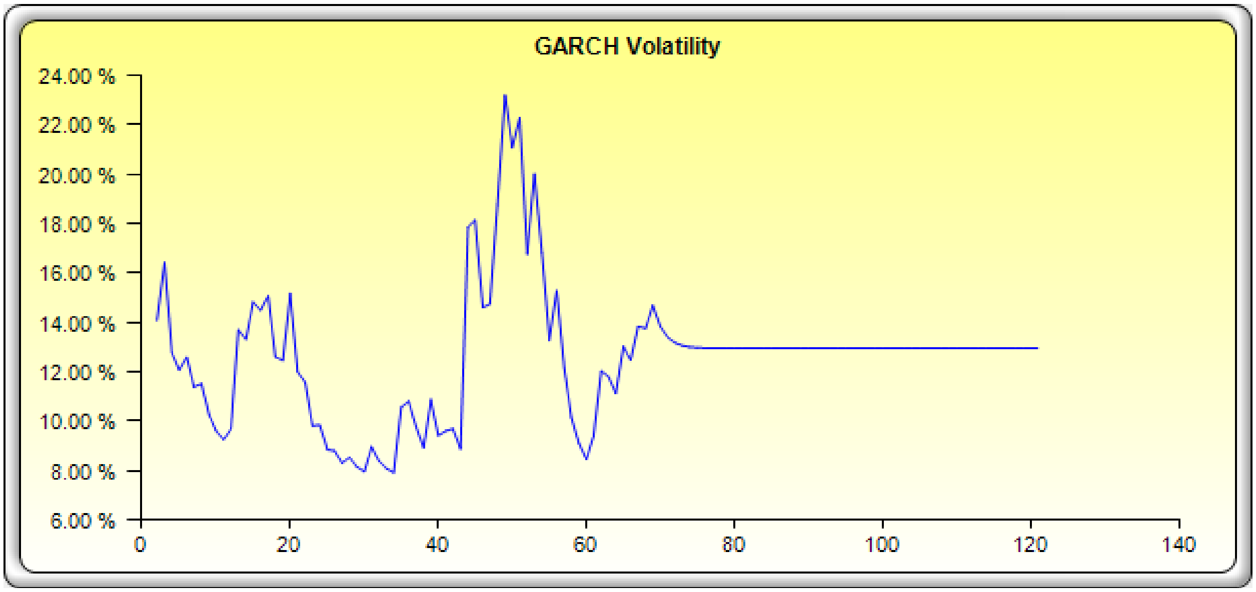
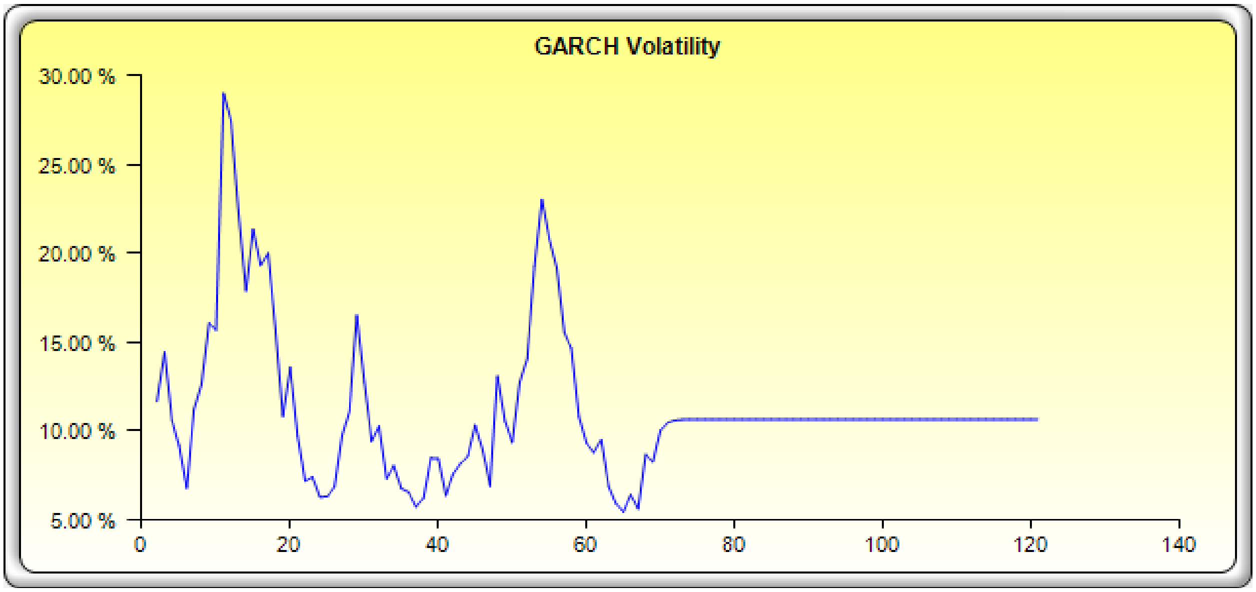
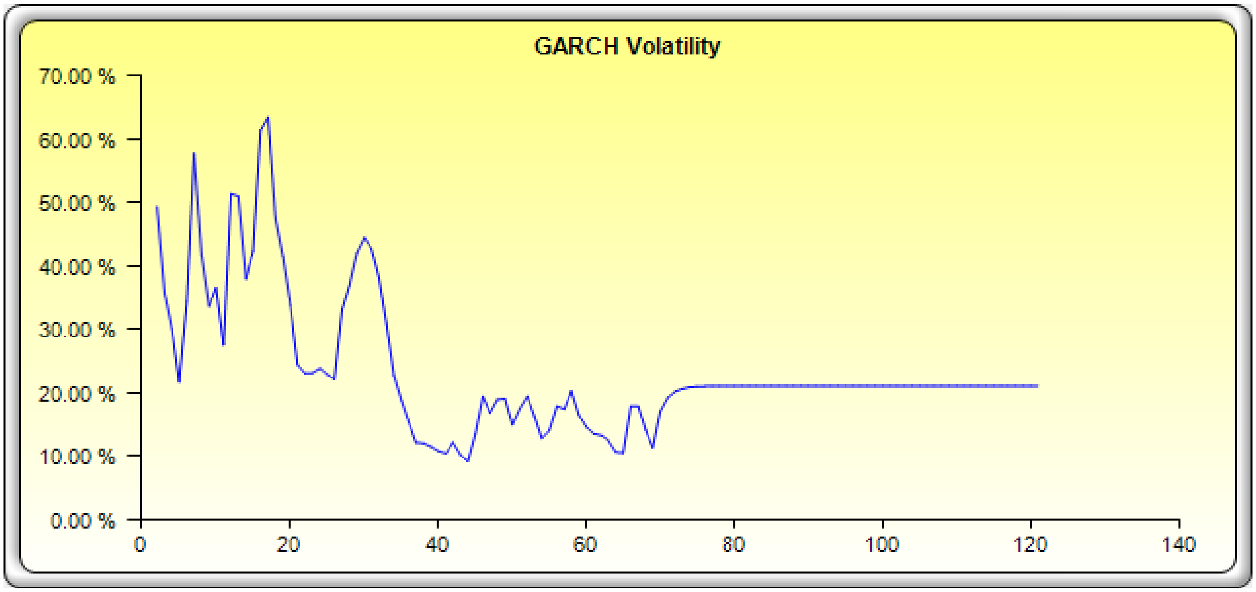
APPENDIX A. GARCH VOLATILITY FORECAST RESULTS



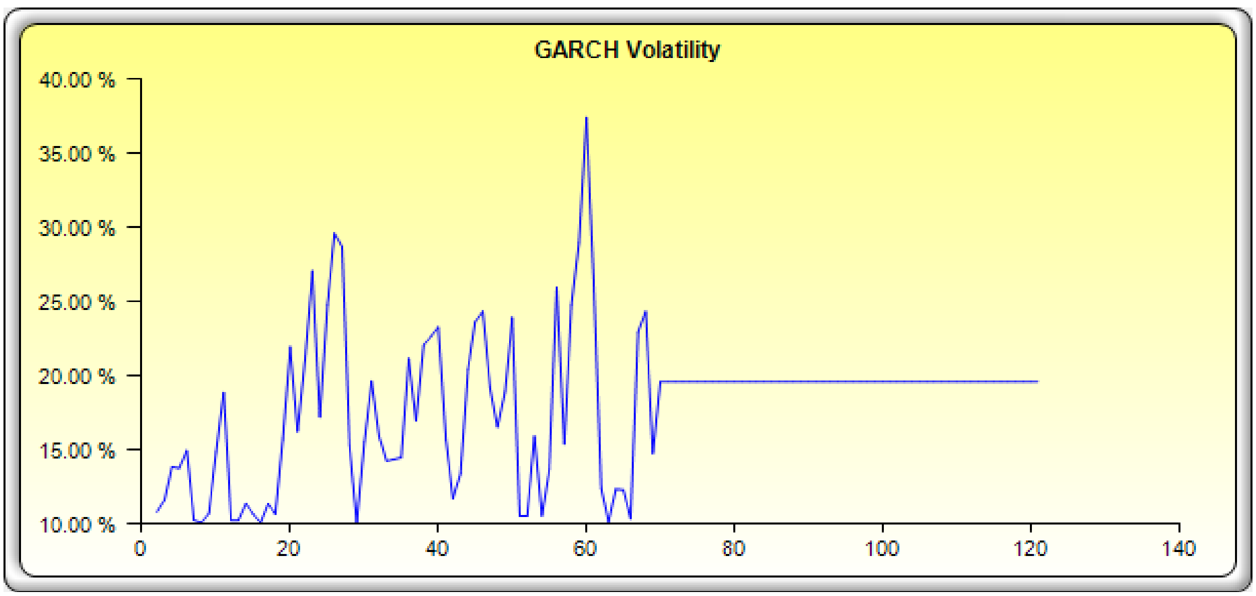
This is the volatility for System 1 with a forecasted volatility of 12.95%.



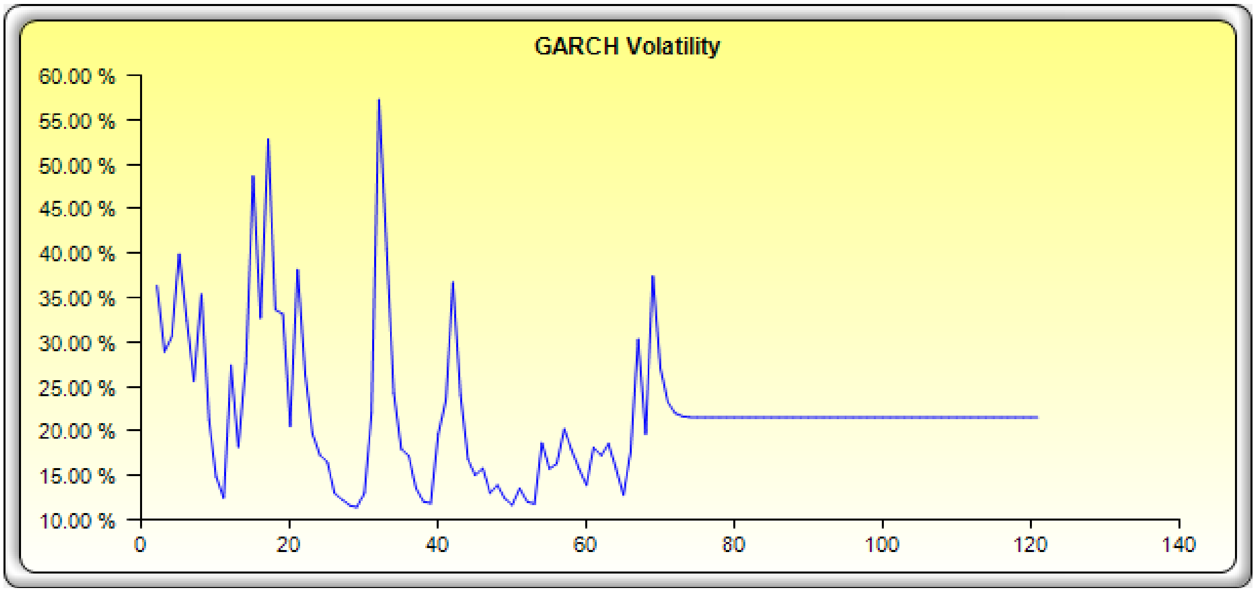
This is the volatility for incremental System 2.3 with a forecasted volatility of 10.67%.



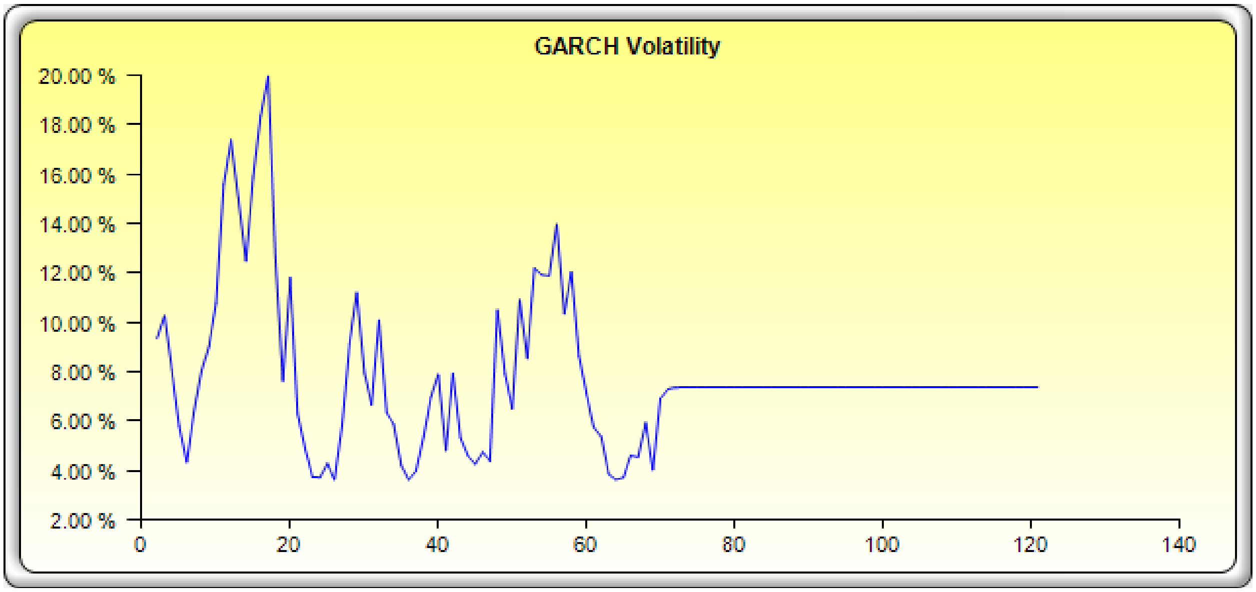
This is the volatility for System 3.1 with a forecasted volatility of 21.09%.



This is the volatility for System 4 with a forecasted volatility of 19.59%.



This is the volatility for System 5 with a forecasted volatility of 21.53%.



This is the volatility for all the systems with a forecasted volatility of 7.38%.

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APPENDIX B. REGRESSION ANALYSIS RESULTS

System 1

Regression Results		
	Intercept	System 1
Coefficients	0.0548	0.0098
Standard Error	0.0082	0.0045
t-Statistic	6.6990	2.1594
p-Value	0.0000	0.0344
Lower 5%	0.0385	0.0007
Upper 95%	0.0712	0.0189

System 2

Regression Results		
	Intercept	System 2
Coefficients	0.0486	0.0153
Standard Error	0.0090	0.0077
t-Statistic	5.3697	1.9894
p-Value	0.0000	0.0507
Lower 5%	0.0305	-0.0001
Upper 95%	0.0666	0.0307

System 2.3

Regression Results		
	Intercept	System 2.3
Coefficients	0.0042	0.6040
Standard Error	0.0048	0.0172
t-Statistic	0.8784	35.1954
p-Value	0.3802	0.0000
Lower 5%	-0.0052	0.5703
Upper 95%	0.0137	0.6377

System 3

Regression Results		
	Intercept	System 3
Coefficients	0.0151	0.2321
Standard Error	0.0089	0.0159
t-Statistic	1.7056	14.6275
p-Value	0.0888	0.0000
Lower 5%	-0.0023	0.2009
Upper 95%	0.0326	0.2633

System 3.1

Regression Results		
	Intercept	System3.1
Coefficients	0.0282	0.2099
Standard Error	0.0097	0.0236
t-Statistic	2.9111	8.8904
p-Value	0.0039	0.0000
Lower 5%	0.0091	0.1634
Upper 95%	0.0472	0.2563

System 4

Regression Results		
	Intercept	System 4
Coefficients	0.1118	0.1485
Standard Error	0.0070	0.0154
t-Statistic	16.0066	9.6403
p-Value	0.0000	0.0000
Lower 5%	0.0981	0.1182
Upper 95%	0.1256	0.1788

System 5

Regression Results		
	Intercept	System 5
Coefficients	0.0961	0.0808
Standard Error	0.0070	0.0127
t-Statistic	13.7019	6.3619
p-Value	0.0000	0.0000
Lower 5%	0.0823	0.0558
Upper 95%	0.1099	0.1057

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