RISKS ASSOCIATED WITH FEDERAL CONSTRUCTION PROJECTS

THESIS

Krishna R. Surajbally, Captain, USAF

AFIT/GEM/ENV/11-J01

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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Krishna R. Surajbally, B.S.

Captain, USAF

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Krishna R. Surajbally, B.S.

Captain, USAF

Approved:

Peter P. Feng, Lt Col, USAF, P.E., Ph.D. (Chairman)	6 JUNE 2011 Date
William E. Sitzabee, Lt Col, USAF, P.E., Ph.D. (Member)	6 June 2011 Date
Adedeji B. Badiru, Ph.D., PE, PMP, FIIE (Member)	6 June 2011 Date

Abstract

The rise in terrorism, corporate espionage, cyber attacks, and federal fiscal constraints play an important role in the federal construction process. The risks associated with these occurrences are studied to aid in the risk management of the military construction process. This paper presents the status of research into these areas to identify how methods, policies, applications, and information obtained from case studies can be used by stakeholders to manage risk in the United States Air Force construction process.

The author reviewed research on risk associated with four essential components of the military construction process – Critical Infrastructure, Information Technology, Contracts, and Cost in the construction and related industry. This study focused on the methodology, management policy, areas of application, and case studies research of the construction and related industry.

Keywords: Risk Assessment, Risk Analysis, Risk Management, Construction, Critical Infrastructure, Information Technology, Contract, Cost, Threat, Vulnerability, Consequence

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RISKS ASSOCIATED WITH FEDERAL CONSTRUCTION PROJECTS

I. Introduction

Background

Risk.

Risk is an inherent aspect of any operation and it must be considered during the planning and execution of military construction (MILCON). Roper (2008) defines risk as "the potential for damage or loss of an asset." It is a function of threat, vulnerability, and consequence (Volpe Center, 2003). In order to identify risk, a risk analysis is performed to evaluate combinations of threats and vulnerabilities to determine the probability for loss consequences. Risk management is the process of using the information from a risk analysis to make decisions on addressing risks. The primary method to manage risk is to implement mitigation measures to reduce the probability of the risk occurring or to accept the consequences of the risk occurring. The concept of risk is based on a subjective scale and is rated terms of relative risk where the probability of risk occurring varies according to changes in the risk components.

In construction, risk and its components affect key aspects of the construction process—Critical Infrastructure (CI), Information Technology (IT), Contracts, and Cost. These components are interrelated and combine to form the overall construction process. However, individually they are subjected to specific risks.

Critical Infrastructure.

CI refers to the wide array of physical assets, such as facilities, electric power

systems, telecommunications, utilities, logistics networks, and any other systems or sub-systems that is essential for an organization to function (Gorman et al., 2003.)

Information Technology.

The definition of IT in this study refers to the hardware, software, networks, computer systems, and supporting facilities that is used to gather, process, store, and distribution information. Although there are specific software and processes for IT in construction, IT-related risks are similar in other industries.

Contracts.

Contracts are legal agreements between parties in which a promise is made for the performance of an obligation, which is legally recognized (Ansley et al., 2009). For United States Air Force (USAF) MILCON, it is the agreement between an Architecture, Engineering, and Construction (AEC) firm and the contracting agent for the USAF. In this study, the United States Army Corps of Engineers (USACE) performs the contracting and project management function for the USAF.

Cost.

The cost of a project plays a crucial role in federal construction since there are specific rules for commitment and obligation of federal funds. This research involves MILCON projects, which are capital improvement projects that cost $750,000 or more (AFI 32-1022) and must be approved by United States Congress.

Research Questions

This thesis will investigate the risks associated with federal construction. The construction industry is very diverse with many types of risks. The details of some of

these risks are not known and this research intends to determine these details by seeking answers to the following questions:

1. What are the risk associated with the integration of CI, IT, contracts, and cost in construction project?
2. What are the factors that cause risk in these areas?
3. How can these factors be identified?
4. Can the risk in these areas be mitigated?
5. What is the cost to mitigate the risk?
6. What is the cost of not mitigating the risk?

Scope

This research will study the risks in federal construction by focusing on the USAF MILCON process. The research will concentrate on the design-build method of project delivery where all projects are designated MILCON and where the USACE perform contracting and project managing function for the USAF. A significant portion of this research will study the specific risks involved in the implementation of a new design process in the USAF. Since constructing techniques and processes are similar to non-federal construction, the research will also investigate non-federal construction.

Approach

The research for this thesis was completed in two major phases. The first phase involved an extensive literature review and the second phase involved a risk analysis of

the implementation of a new design process in the USAF. The risk analysis was done using knowledge gained from the literature review.

The literature review was done by separating the four major components of the MILCON process--CI, IT, Contract, and Cost, and determining the status of research of risk in these areas. All studies were sorted into methodologies, management policies, areas of application, and case studies. The risk analysis studied the risk associated with the implementation of Building Information Modeling (BIM). BIM is a design process that is being implemented by federal agencies including the USAF.

Preview

This thesis follows the scholarly article format. The chapters contain articles and details on how the articles were developed. Chapter I provides an overview of risk and its components along with details on the research structure. Chapter II is an extensive literature review of risk research involving construction. Chapter III is a research paper of a risk analysis of the implementation of BIM in the USAF. Chapter IV provides a summary of the research, the status of the research questions, and areas that would benefit from further research.

II. Literature Review of Risk in Construction

Critical Infrastructure

Critical Infrastructure (CI) covers a wide range of entities and includes facilities, networks, utilities, logistics systems, cyber systems, communication processes, and geographical nodes (Gorman et al., 2003). This research focuses on CI as it relates to construction, repair, or maintenance that occurs on federal installations and work done on behalf of the United States Government by the Architecture, Engineering, and Construction (AEC) Industry. Since the AEC performs the work in large nonfederal CI projects, research on the AEC operations is also reviewed. A summary table is presented at the end of each section.

Methodology.

The majority of research of risk in CI involved the methods, tools, frameworks, and models used to study risk assessment and risk management. Busuttil and Warren (2003) presented the *fourth generation* step-wise security risk analysis methodology for application in Critical Information Infrastructure Protection (CIIP). The methodology demonstrated effectiveness in mid-level applications and the authors suggests that it will be more effective in high-level infrastructure. Sholander et al. (2006) and Ball et al. (2005) presented models for risk assessment based on the treatment of a CI as a system. Sholander et al. (2006) developed a risk assessment model to analyze integrated CIs that contained physical and cyber elements. The study found that risk analysis requires integration of consequence and vulnerability estimates to determine the potential CI

impact. Ball et al. (2005) conducted an integrated review of approaches to modeling, simulation, and analysis of Critical Infrastructure Systems (CIS) as employed by the Institute for Complex Additive System Analysis (ICASA). The review help produced a process for CIS application of control tools to determine vulnerability based on the relationship among inputs, parameters, states, and outputs.

Ulieru and Worthington (2006) developed an Adaptive Risk Management System (ARMS) model based on a holonic structure to identify, prevent, and response to threat to CIs. The authors stated that the model had the capability to learn, respond, and adapt to new threats.

Bagheri et al. (2007) used the Agent-based Interdependency Modeling and Simulation (AIMS) simulation architecture to study interdependencies among CIs. The authors claimed that the study provided a better understanding of CI behavior by analyzing the services provided by the CI and their sub-systems.

Several other methods were developed to investigate specific aspects of risk in CI. Bagheri and Ghorbani (2007) studied the adaptive socio-technical systems of CIs using the Astrolabe Methodology which focused on deviation of a system from its original goals. The study allowed risks to be properly classified so analysts can make appropriate mitigation strategies.

Crowther (2008) and Setola et al. (2009) used Input-Output Inoperability Model (IIM) to study CI risk. Setola et al. (2009) used this model to assess dependencies and interdependencies of CIs. The model was effectiveness was demonstrated in a case study of Italian CI sectors. Crowther (2008) used the decomposition of the IIM to investigate decentralized risk management for strategic preparedness. The study provided insights

into the decentralized risk management process in the context of preparedness costs and economic resilience.

Guikema (2008) studied risk analysis of CI caused by natural disaster using statistical learning theory by making use of large datasets from complex CI. The study concluded that statistical learning theory methods can be used for real-time monitoring of infrastructure systems to detect abnormal behavior.

Vugrin et al. (2010) used optimal recovery sequencing to assess CI resilience. The researchers formulated a bi-level optimization problem for infrastructure network problem to identify recovery nodes and sequences. The application was tested on a national railroad model and a supply chain for Army munitions production.

Table 1 Summary of research on Methods in CI Risks

Author (Year)	Research Method	Synopsis
Busuttil and Warren (2003)	Step-wise security risk analysis	Demonstrated effectiveness in mid-level CI applications
Ball et al. (2005)	CI studied as a system	Determine vulnerability based on input, parameters, states, and outputs
Uilieru and Worthington (2006)	Adaptive Risk Management System	Authors stated that the model had the capability to learn, respond, and adapt to new threats
Sholander et al. (2006)	CI studied as a system	Integration of consequence and vulnerability can determine CI impact estimate
Bagheri et al. (2007)	Agent-based Interdependency Modeling and Simulation	Provided a better understanding of CI behavior
Bagheri and Ghorbani (2007)	Astrolabe Methodology	Allowed for risks to be properly classified so analysts can make appropriate mitigation strategies
Crowther (2008)	Input-Output Inoperability Model	Provided insights into decentralized risk management based on preparedness costs and economic resilience
Guikema (2008)	Statistical learning theory	Developed real-time monitoring of infrastructure systems to detect abnormal behavior
Setola et al. (2009)	Input-Output Inoperability Model	Demonstrated dependencies and interdependencies of CIs
Vugrin et al. (2010)	Optimal recovery sequencing	Identify recovery nodes and sequences

Management Policy.

Management policy is a critical factor in risk management and several studies presented various aspects of management and how decisions affect risk in CI. Several government research studies (Wimbish and Sterling, 2003; Moteff, 2005; and D'Agostino, 2008) outlined risk analysis and management of the national critical infrastructure. Wimbish and Sterling (2003) outlined the function of the National Infrastructure Simulation and Analysis Center (NISAC). The NISAC educates strategic

leaders on the national infrastructure and how it is affected by government policies and action. Moteff (2005) studied how risk management and Critical Information Protection (CIP) functions under the Homeland Security Act of 2002. D'Agostino (2008) presented findings to the Government Accountability Office that Department of Defense risk analysis had omitted several high sensitive assets related to CI.

Other researchers studied types of management; Le Grand et al. (2004) and Caldeira et al. (2010) studied the interdependencies of large CIs and how policy-based management is used in vulnerability assessment and CIP. Le Grand et al. (2004) study formulated security policies that can be implemented under the policy-based management in CIs. Caldeira et al. (2010) focused on the quality of information exchange between interconnected CIs.

Table 2 Summary of research on Management Policies in CI Risks

Author (Year)	Management Policy	Synopsis
Wimbish and Sterling (2003)	The function of the National Infrastructure Simulation and Analysis Center	Educates strategic leaders on the national infrastructure
Le Grand et al. (2004)	Policy-based management	Formulated security policies
Moteff (2005)	CRS Report to Congress	Assessing, Integrating, and Managing Threats, Vulnerabilities, and Consequences
D'Agostino (2008)	GOA: Defense Critical Infrastructure	Department of Defense risk analysis had omitted several high sensitive assets related to CI had the capability to learn, respond, and adapt to new threats
Caldeira et al. (2010)	Policy-based management	Policies can enhance risk indicators accuracy

Areas of Application.

The overwhelming amount of research in the areas of application of risk involved dependencies and interdependencies among CIs. Researchers conducted studies on the various aspects of interdependencies with the focus being on the effect of impact of one CI on other interconnected CIs.

Conrad et al. (2006) developed a model to quantify the interdependencies of CIs for evaluation of vulnerability compensation plans. The study involved assignment of estimates to sub-system component of infrastructure and applied an aggregate scale to the CI using system dynamics. The authors concluded that telecommunication has significant impact across all affected CIs.

Daidone et al. (2008) investigated redundant architecture for Critical Information Protection (CIP). The study investigated information flow among infrastructure sub-systems to determine specific dependencies and availabilities. The author concluded that the parameters chosen for the detection of impacts were crucial in determining the dependability and availability of the CI system.

A study of CI survival from natural disaster was done by Mao (2009). The study investigated the factors that reduce vulnerability in interdependency. Interdependency and control strategy, identification of cascading pathways, and design models to simulate disaster were factors that can develop strategies for emergencies.

Interdependency was also studied by Becker et al. (2010). The authors presented an integrated 3-D model of multiple CI and networks to analyze risk and interdependencies. The authors claimed that the model will support risk analysis and the planning of emergency response actions.

Owusu et al. (2010) also studied the linkage of risk propagation in CI due to dependency, interdependency, and multi-interdependency. The authors developed a binary relationship for interdependency and showed the ripple effect of an impact of a CI and helped produce a method to estimate the value of risk impact.

Table 3 Summary of research on Areas of Application in CI Risk

Author (Year)	Area of Application	Synopsis
Conrad et al. (2006)	Interdependencies vulnerability compensation plans	Telecommunication sub-systems have a significant impact on CI interdependencies
Daidone et al. (2008)	Interdependencies redundant architecture	Parameters chosen for the detection of CI impacts were crucial in determining dependability and availability
Mao (2009)	Interdependencies vulnerability factors	Interdependency and control strategy, identification of cascading pathways, and design models to simulate disaster can develop strategies for emergencies
Becker et al. (2010)	Interdependencies risk analysis	Developed an integrated 3-D model of multiple CI to support risk analysis and the planning of emergency response actions
Owusu et al. (2010)	Interdependency risk propagation	Produce a method to estimate the value of risk impact caused by the ripple effect of a CI

Case Studies.

Case studies into CIs cover a wide area of application including telecommunication, construction security, and consequence of dam breakage. Gorman et al. (2003) conducted a study of national data carriers and the repercussions of targeted attacks. The study focused on data networks and the spatial implications of their susceptibility to these attacks. The authors stated that any analysis for security and economic impact must include regional and distance variables.

The tradeoff between risk and cost for CI at a construction site layout was studied by Said and El-Rayes (2009). The researchers proposed a framework for the planning and security of the site by using four phases—risk identification and system modeling, security lighting optimization, security-cost optimization, and performance evaluation. The study concluded that cost optimization involved balancing cost minimization and risk minimization.

Needham et al. (2010) described the consequence estimation for CI risk management used for a dam failure. The authors focused on the process of dam breakage flooding modeling conducted by the USACE. The study revealed that the USACE method for dam failure analysis and consequence estimation was scalable and could be updated and refined to support detailed assessment where results can be available in a few days.

Table 4 Summary of Case Studies of CI Risks

Author (Year)	Case	Synopsis
Gorman et al. (2003)	National data carriers targeted attacks	Analysis for security and economic impact must include regional and distance variables
Said and El-Rayes (2009)	Risk and cost tradeoffs for CI construction site layout	Cost optimization involves balancing cost minimization and risk minimization
Needham et al. (2010)	USACE dam failure flooding analysis	USACE method was scalable and could be refined to support detailed assessment and produce results in days

Information Technology Risk

Since IT is comprised of hardware, software, processes, and networks, it application in construction will face similar risk as in other industry. This consideration can be used to evaluate research of risk in various industries since similar IT type risk will exist in the construction industry. A summary table is presented at the end of each section.

Methodology.

Several researchers studied IT risk by using a combination of several methods. Rainer et al. (1991) studied a combination of qualitative and quantitative risk analysis methods. The quantitative methods include annualized loss expectancy, Livermore Risk Analysis Methodology, and Stochastic Dominance while the qualitative methods include scenario analysis, fuzzy metrics, and questionnaire. The authors concluded that the combination of risk methods was more flexible and covered a wider range of IT than a single method.

Other research involved the study of the component of risk. Rainer et al. (1991) used a four-step framework for IT risk management—risk identification, risk analysis, risk-reducing measures, and risk monitoring. The authors stated that the study should help organizations be more aware of IT dependence, the internal and external sources of threats, and be able to implement mitigation measures.

Some research studied the risk assessment and risk management methods used in other industries for application in IT. Oren (2008) investigated how risk assessment methods from the nuclear, aerospace, and chemical industries can be applied to IT. The

study involved applying probabilistic risk assessment in a service-oriented environment to determine the reliability, availability, and expected cost over time. Nikolic et al. (2009) researched methods from risk assessment used in occupational health for possible application to IT. The study focused on IT modification in the occupational health workplace and application with the aim to identify and evaluate threats, vulnerabilities, and safety characteristics. The author concluded IT risk assessment methods used in occupational health sector can be used in other IT areas.

Karadsheh (2010) presented a framework for integrating knowledge management and risk management for IT projects. The framework provided the ability to develop remedial project management actions to address IT project failures.

Table 5 Summary of research on Methods in IT Risks

Author (Year)	Methodology	Synopsis
Rainer et al. (1991)	Combination of qualitative and quantitative methods	Combination of risk methods was more flexible and covered a wider range of IT than a single method
Oren (2008)	Benchmarking IT risk management from other industries	Determine the reliability, availability, and expected cost over time
Nikolic et al. (2009)	Using risk assessment methods from occupational health area	IT risk assessment methods used in occupational health sector can be used in other IT system area
Karadsheh (2010)	Integrating Knowledge Management with Risk Management	Provided the ability to develop remedial project management actions to address IT project failures

Management Policy.

The evolving nature of IT requires policies to be regularly reviewed and updated. The United States Chief Information Officer (CIO) and DoD CIO is the responsible

office for IT in the federal government and the DoD respectively. The USAF CIO follows the policies and guidelines from these two agencies. Since IT applications will be the same for private and federal construction, any policy that affect it use will impact USAF construction.

Studies into management policies concerning risk in IT cover a wide range of research from management decisions, outsourcing, and legal issues. Researchers investigated the risks of outsourcing IT and improving IT critical infrastructure through the Trade Practices Law. Bahli (2001) proposed a model to define and measure IT outsourcing risk. The model was developed using transaction cost and IT outsourcing literature. The author stated that the model provided a systematic understanding of IT outsourcing risk and provided a tool for the assessment of those risks. Winn (2004) investigated the implementation of laws to require investing in cyber security in order to protect IT and CI. The authors conducted a legal review of factors that affect Critical Infrastructure Information Systems and recommends that the government reform the applicable laws to provide incentives to increase investment in cyber security.

Kutsch and Hall (2005) studied how specific risk management decisions can determine why IT project fails. The study sought to determine what causes IT managers behavior to IT to be different from what might be expected. The researcher found that some project managers tend to deny, avoid, ignore, and delay dealing with risk. In another study, Kutsch and Hall (2009) studied the degree of use of risk management and barriers that prevented IT managers from using risk management. The study concluded that in some situations, risk management was not applied because of problems with cost justification.

Obagbuwa and Chidiebere (2009) investigated the use of IT as a tool to leverage efficiency in risk management. The authors studied corporate governance of Boards of Directors and corporate officers to determine how IT affects specific roles in risk management. The study concluded that accessibility to reliable information is critical to decision making.

Table 6 Summary of research on Management Policies in IT Risks

Author (Year)	Management Policy	Synopsis
Bahli (2001)	Outsourcing Risk	Provided a systematic understanding of IT outsourcing risk and a tool for risk assessment
Winn (2004)	Review laws affecting Critical Infrastructure Information Systems	Recommends that the government reform the applicable law to provide incentives to increase investment in cyber security
Kutsch and Hall (2005)	Managers' decisions in risk management	Some project managers tend to deny, avoid, ignore, and delay dealing with risk
Kutsch and Hall (2009)	Barriers in risk management	Risk management may not be applied because of problems with cost justification
Obagbuwa and Chidiebere (2009)	Use of IT to leverage efficiency in risk management	Accessibility to reliable information is critical to decision making.

Areas of Application.

IT can be applied in almost all industries and since the function of IT operation is similar in all applications, the research areas selected are those that involve risk similar to that found in construction.

Ginzberg and Moulton (1990) stated that the concept of IT risk was too narrow and a broader approach was needed. The authors studied the range of IT risk in organizations by first identifying risks with the greatest impact and then expanding the

scope to covered the lower level risks. The study concluded that management will have to choose which risk they want to minimize based on the cost of risk minimization and the cost of consequence minimization.

Bandyopadhyay et al. (1999) examined the risk management needed for organizations that invested up to a third of their budget in IT. The author stated that IT risk management must be a major concern for the organizations' executives and recommended a framework for integrated risk management be used. The framework included risk identification, risk analysis, risk-reducing measures, and risk monitoring.

IT risk in project portfolio management was studied by Drake and Byrd (2006). Although business processes is different from construction process, the risk in IT application is similar where it is used in the management of construction projects folders. The authors identified five types of risk in the study—strategic alignment risk, organization and management risk, culture and climate risk, project relation risk, and financial risk.

Table 7 Summary of research on Areas of Application in IT Risks

Author (Year)	Area of Application	Synopsis
Ginzberg and Moulton (1990)	Range of risk in an organization	Risks chosen minimization is based on the cost of risk minimization and the cost of consequence minimization
Bandyopadhyay et al. (1999)	Risk management framework for large IT budget organizations	Integrated risk management framework based on risk identification, risk analysis, risk-reducing measures, and risk monitoring
Drake and Byrd (2006)	IT risk in project portfolio management	Identified five types of risk—strategic alignment risk, organization and management risk, culture and climate risk, project relation risk, and financial risk

Case Studies.

A review of case studies involving IT risk revealed that research in other field represents similar risk as in construction applications. Tolone et al. (2008) applied a system of systems approach to combine various systems in an Integrated Model Evaluation. The model was verified and validated in a Fortune 100 company where the risks from hardware, system software, business application, business processes, and business units were integrated.

Ronnback and Homlstrom (2008) investigated the role of IT in industry risk management by studying the operation of Smurfit Kappa Kraftliner, a paper fiber producing company. The researchers sought to determine the enabling and inhibiting effects of IT on the company's risk management. The study concluded that the company's risk management process had the effect of diffusing risk rather than containing it. The company had to continually invest more resources in the containing the increasing diffused risk.

Table 8 Summary of Case Studies in IT Risks

Author (Year)	Case	Synopsis
Tolone et al. (2008)	Verification and validation of a risk analysis model on Fortune 100 company	Integration of risks from hardware, system software, business application, business processes, and business units
Ronnback and Homlstrom (2008)	Risk management of Smurfit Kappa Kraftliner—a paper fiber producing company	The company's risk management process had the effect of diffusing risk rather than containing it

Contract

The governing directive for contracting in the federal and military construction is the Federal Acquisition Regulation (FAR). This regulation provides the legal framework for other regulation that deals with construction contracts. The United States Air Force (USAF) uses Air Force Instructions (AFIs), and Air Force Policy Directives (AFPD) to incorporate FAR requirements for construction within its control. AFPD, Installations and Facilities; AFI 32-1021, Planning and Programming Military Construction Projects; AFI 32-1022, Planning and Programming Non-Appropriated Fund Facility Construction Projects, and AFI 32-1023, Designing and Constructing Military Construction Projects are used in the contracting construction projects.

The AEC is a major party in the contract process and share risk with federal agencies in the construction contract. In addition, legal standards of contracts, the AEC must comply with federal policies. There are studies that examine the methods, management policies, and specific areas of application that involves the risks associated with construction contracts. Some research examines specific risks by conducting case studies. A summary table is presented at the end of each section.

Methodology.

In a comprehensive study of risk allocation in construction projects, Diepenbrock et al. (2002) examined methods of restricting liability or allocating risk to construction projects. The authors focused on design errors, unexpected site conditions, construction errors and delays, and the risks of payment. The authors concluded that contract enforceability from a legal perspective depends on the type of risk and the method of risk

allocation. From a practical standpoint, contracting parties must consider who is in the best position to bear the risk, which is based on having the best resource.

Tan and Thoen (2002) proposed a method based on Risk and Trust Management to negotiate and develop a contract. This method applies control mechanisms rules so contracting parties can amend existing contracting transaction to make it more appropriate to the respective risk and trust assessment.

Risk perception and Bayesian analysis of international construction contract risk was studied by Adams (2008). The research proposed that differing perceptions of risk by contracting parties affects the overall risk estimate of the contract terms. A Bayesian Analysis validated that risk perception of contracting parties from different socio-economic backgrounds affect contract risk estimates.

Lee et al. (2009) developed a method for using decision-analysis in contract risk-sharing. The authors used literature review, interviews, questionnaires, fuzzy evaluation, and current decisions models in their analysis. The research concluded that risk-sharing should be based on the fluctuation of the price of the project and the contracting authority should set rights and obligations with equal benefits to all parties.

Shane and Gransberg (2010) studied the coordination of contract design using the Construction Manager-at-Risk (CMR) in the project delivery. This method of contracting allowed direct collaboration between the designer and the builder. This collaboration was a major advantage and was found to reduce delivery time and project cost. Existing contracting terms must be modified to allow this contracting delivery method.

Table 9 Summary of research on Methods in Contract Risks

Author (Year)	Research Method	Synopsis
Diepenbrock et al. (2002)	Risk Allocation	Identified the contracting party who is best able to bear risk
Tan and Thoen (2002)	Risk and Trust Management	Contracting parties can amend contract transaction to the appropriate level of risk and trust
Adams (2008)	Risk Perception and Bayesian Analysis	Risk perception at lower levels affects the overall project risk
Lee et al. (2009)	Risk Sharing Decision Analysis	Contracting authority should share rights and obligations to all parties based on the change to the project cost
Shane and Gransberg (2010)	Construction Manager-at-Risk	Contract modification to allow collaboration between designer and builder can reduce delivery time and project cost

Management Policy.

In addition to policies created for contract requirements under the FAR, research have studied other management techniques and policies that involve risk in construction contracts. The Defense Contract Audit Agency use of risk analysis in contract planning was studied by Neuman (1979). The study focused on the risk associated with the priority of audits and the amount of time available to conduct the audit. To minimize the risk associated with the invested audit time, Neuman (1979) developed a system to balance audit priority and available audit time.

Dyson (2001) presented a comparative analysis of a sampling of risk management plans administered by the Defense Contract Management Agency (DCMA). The study focused on the DCMA's use of a five-step approach to risk management and the employment of IT in its Risk Assessment and Management Program (RAMP). The

author recommended that this program be implemented throughout the Department of Defense.

Friedlander (2003) researched the risk allocation in Design-Build construction projects by examining the legal aspects of the contract. The author analyzed the provisions of the contract and identified potential risks to the contracting parties. Friedlander (2003) concluded that the contract documents from organizations such as the Design-Build Institute of America and the American Institutes of Architects represent basic requirements of a construction contract because the practices evolved from the industry norms and standards.

Lloyd (2010) reviewed the inclusion of terms that contracting parties can use for misleading and deceptive claims under the Trade Practices Act 1974. Lloyd focused on the problematic nature of law governing the delay and change of scope of the contract. The study concludes that courts' decision indicates that parties should avoid deviating from the terms of the original contract since there is no relief under the Trade Practices Act.

Table 10 Summary of research on Management Policies in Contract Risks

Author (Year)	Management Policy	Synopsis
Neuman (1979)	Defense Contract Audit Agency use of risk analysis	Developed a system to balance audit priority and available audit time under DCAA
Dyson (2001)	Defense Contract Management Agency Risk Assessment and Management Program	The author recommended that this program be implemented throughout the Department of Defense
Friedlander (2003)	Legal aspects of Design-Build contract	Contracts developed from DBIA and AIA meet legal requirements
Lloyd (2010)	Review of the Trade Practice Act 1974	Parties should avoid deviating from the terms of the original contract since there is no relief under the Trade Practices Act.

Areas of Application.

Existing research shows that risk in contract cover a wide range of application in construction. Erikson and O'Connor (1979) investigated the assessment of risk between the owner and contractor in firm fixed-price construction contracts. The authors used utility theory to determine the cost effects of varying risk assignments and what type of techniques are used for contractually assigning risk.

Another area of application of research of risk in contract focused on community-controlled construction contracts. Randolph et al. (1987) evaluated the risk associated with construction contract development and applied it to the community of Lansing, Michigan, United States. The researchers collected and analyzed data from municipal contract documents. The analysis produced risk nomographs that management teams can use to determine the amount of effort needed to manage risk for a particular construction project.

Other research into construction contract risk investigated the fixed price of housing construction contract. Birnie and Yates (1990) studied the uncertainty of the price of housing construction before contract negotiation. The research involved studying the risk associated with the Design-Build contract between owner and contractor. Birnie and Yates (1990) concluded that the owner can make decisions on the construction cost by considering the risk associated contract before negotiating a fixed price.

Adams (2008) studied the techniques for analyzing risk in construction contract in the United Kingdom. The study focused on the effectiveness of existing risk analysis and management techniques. Adams determined that current methods were not appropriate since they relied heavily on a single expert and did not address any individual perception or bias.

Table 11 Summary of research on Areas of Application in Contract Risks

Author (Year)	Area of Application	Synopsis
Erikson and O'Connor (1979)	Firm fixed-price construction contracts	Determined the cost effects of varying risk assignments and type of techniques are used for contractually assigning risk
Randolph et al. (1987)	Risk associated with construction contract development	Determine the amount of effort needed to manage risk for a particular construction project
Birnie and Yates (1990)	Housing construction before contract negotiation	Owner scan make decisions on construction cost by considering the risk associated contract before negotiating a fixed price
Adams (2008)	Techniques for analyzing risk in construction contract in the United Kingdom	Current methods were not appropriate since they relied heavily on a single expert and did not address any individual perception or bias

Case Studies.

Chapman and Cooper (1985) studied the risk analysis used by a consortium of engineering consulting firms for a turn-key electric power project. The case study focused on the individual sources of risk and their combined effect. The combined risk along with the project cash-flow model was used to determine the range of the overall project cost. Mitigation measures based on the cost associated with risk were implemented in the contract.

McClelland (1996) investigated the risk allocation techniques used by forty-four owners who obtained construction services. The author focused on the specific contract clauses and the varying risk allocation used by the different contractors. The study concluded that the variation of risk allocation was due to unclear language and interpretation of the contract and project documents.

Chang (2009) researched the risk associated with a tunnel construction contract. The unpredictable nature of risk in this type of construction and the accompanying hazards and accidents frequently produced contract disputes. Chang (2009) proposed a modification of the current contract process to develop an optimal risk sharing technique from a contract administration perspective. The risk sharing techniques was used to reduce contractual disputes, mitigate risk, and lower cost of damages and losses.

Table 12 Summary of Case Studies of Contract Risks

Author (Year)	Case	Synopsis
Chapman and Cooper (1985)	Turn-key electric power project	Mitigation measures based on the cost associated with risk were implemented in the contract
McClelland (1996)	Owners using construction services	Variation of risk allocation was due to unclear language and interpretation of the contract and project documents
Chang (2009)	Tunnel construction contract	Risk sharing techniques was used to reduce contractual disputes, mitigate risk, and lower cost of damages and losses

Cost Risk

Since cost is an overriding factor in all aspects of construction and plays a critical role in risk through mitigation cost and consequential cost, there is a wide range of research on various aspects of cost in risk. A summary table is presented at the end of each section.

Methodology.

A widely used methodology to study risk cost involved the application of statistical techniques. Balci and Sargent (1981) developed a model for cost-risk analysis based on Hotelling's two-sample T^2 test. This method was used to construct the relationship among project risk, cost, and data when simulation involves statistical hypothesis testing.

Hulett (2002) developed a cost-risk estimation using Monte Carlo simulation to determine more accurate total cost estimates. The study revealed that the model was

more accurate than tradition methods since data used tradition methods of estimation were not certain.

One of the most widely used techniques for studying cost and risk involves some form of fuzzy decisions framework. Baloi and Price (2003) used fuzzy decision framework to model global risk factors. The model was based on an evaluation of decision-making technologies and management science techniques. The authors indicated that the model was viable for global risk factors.

Dikmen et al. (2007) used fuzzy risk assessment to rate cost overruns in international construction projects. Dikmen et al. (2007) created a computerized system for an international construction company and successfully tested it with real data during the bidding stage of a construction contract. Rohman et al. (2008) presented a methodology and computer model based on risk analysis and fuzzy expert system to estimate contingency cost for a project. The model incorporated contractors' experience and judgment and was validated using data from four projects. Chan et al. (2011) also developed a fuzzy risk assessment for use in construction projects with guaranteed maximum price and target cost contracts. Chan et al. (2011) identified key risk factors from empirical questionnaires and categorized them into groups. The authors suggested that the model provide a strong platform to measure, evaluate, and mitigate risk level based on the objective evidence rather than subject judgment.

Stuparu et al. (2010) studied probability distribution in cost-risk analysis to identify the most probable threat to an organization. The study produced a risk analysis process for the foundation of recovery planning.

In another research, Clark and Hamilton (2007) investigated the use of Crystal Ball Software for cost-risk analysis in government cost estimations. The research showed that the software was effective in accomplishing cost-risk analysis based on life cycle costs.

Table 13 Summary of research on Methods in Cost Risk

Author (Year)	Research Method	Synopsis
Balci and Sargent (1981)	Hotelling's two-sample T^2 test	Constructed the relationship among project risk, cost, and data when simulation involves statistical hypothesis testing
Hulett (2002)	Cost-risk estimation using Monte Carlo simulation	Developed a model that was more accurate than tradition methods since data used tradition methods of estimation were not certain
Baloi and Price (2003)	Fuzzy decision framework	Developed framework to model global risk factors
Clark and Hamilton (2007)	Crystal Ball Software for cost-risk analysis	Software was effective in accomplishing cost-risk analysis based on life cycle costs
Dikmen et al. (2007)	Fuzzy risk management	Rated cost overruns in international construction projects
Rohman et al. (2008)	Fuzzy expert system	Incorporated contractors' experience and judgment to estimate contingency cost for a project
Stuparu et al. (2010)	Probability distribution in cost-risk analysis	Produced a risk analysis process for the foundation of recovery planning
Chan et al. (2011)	Fuzzy risk management	Developed a model to provide a strong platform to measure, evaluate, and mitigate risk level based on the objective evidence rather than subject judgment

Management Policy.

The prevailing management policy for risk cost in construction is published by the DoD and the USAF. These policies provide guidance for cost-risk in USAF operations to

include construction. Lurie et al. (1993) authored *A Handbook of Cost Risk Analysis Methods* for the Institute of Defense Analysis (IDA). The handbook was intended to be a guide for IDA analysts working for the DoD and other government agencies. Goldberg and Weber (1998) authored *The Evaluation of Risk Analysis and Cost Management (RACM) Model* also for the IDA. Goldberg and Weber (1998) recommended the RACM Model be used to supplement the risk analysis and management program in the defense industry.

Nibley and Dyer (2000) studied the issues in risk analysis and cost containment involved in the procurement of major construction projects by international governments. The authors' research focused on the most significant risk involved in the contracting of major construction projects by national governments. The study revealed the risk that government and contractors faced in international construction.

Covert (2005) created a presentation for the DoD Cost Analysis Symposium, which outline current status of cost risk analysis in the DoD and recommended particular areas for budget allocation.

Table 14 Summary of research on Management Policies in Cost Risk

Author (Year)	Management Policy	Synopsis
Lurie et al. (1993)	A Handbook of Cost Risk Analysis Methods	Intended to be a guide for IDA analysts working for the DoD and other government agencies
Goldberg and Weber (1998)	Evaluation of Risk Analysis and Cost Management (RACM) Model	Recommended the RACM Model be used to supplement the risk analysis and management program in the defense industry
Dyer (2000)	Contracting of major construction projects by national government	Revealed the risk that government and contractors faced in international construction
Covert (2005)	Presentation to the DoD Cost Analysis Symposium	Outlined current status of cost risk analysis in the DoD and recommended particular areas for budget allocation

Areas of Application.

A review of existing research reveal that the main areas of application for risk cost studies involved contingency, evaluation of services, estimating and forecasting, and total contract cost.

Cooper et al. (1985) and Touran (2003) studied contingency as it relates to risk cost. Cooper et al. (1985) research involved an independent check of reliability of project estimates and the adequacy of contingency allowance. Touran studied the random nature of construction change orders and incorporated uncertainties of project cost to calculate project contingency.

Ellis and Wood (2001) investigated the risk management services provided by engineering consultants for construction projects in the United Kingdom. The study involved examining the Risk Management (RM) Services performed throughout the

organization. The authors discovered that (RM) services typically translated risk as a cost and the client must determine how to apply the cost of risk to the overall project cost.

Abdou et al. (2004) reviewed the different approaches of modeling risk in cost estimating and forecasting that is used in construction. The review presented an understanding of the sources of risk and uncertainty by identifying and classifying the risk. The project owner can then choose the best method from the project parameters and related historical data.

Uncertainty in construction was studied by Odeyinka et al. (2006) to assess risk impacts on the overall construction cost. The authors found that the major uncertainty risk factors were caused by financial, political, and physical conditions.

Table 15 Summary of research on Areas of Application in Cost Risks

Author (Year)	Area of Application	Synopsis
Cooper et al. (1985)	Project Contingency	Independent check of reliability of project estimates and the adequacy of contingency allowance
Ellis and Wood (2001)	Risk management services	RM services typically translated risk as a cost and the client must determine how to apply the cost of risk to the overall project cost
Touran (2003)	Construction change orders	Incorporated uncertainties of project cost to calculate project contingency
Abdou et al. (2004)	Cost estimating and forecasting	Owner can then choose the best risk management method from the project parameters and related historical data
Odeyinka et al. (2006)	Uncertainty in construction	Major uncertainty risk factors were caused by financial, political, and physical conditions

Case Studies.

Vidalis (2005) studied the relationship between cost, quality, and risk in Portland concrete pavement construction. The research involved studying the current process that contractors use for bidding on concrete pavement construction projects. The study revealed that a computer program can be created to incorporate risk and probability to achieve overall quality target for the project. The contractor can then balance the risk involved in project quality and bidding price.

Creedy (2006) investigated risk factors leading to cost overruns in the delivery of highway construction projects. The author analyzed completed highway projects that had cost overruns to determine the how the initial budget was wrong and to identify the risk associated with the overruns. The case study indicated that there is a reciprocal relationship between the project budget size and the percentage of cost overruns that the client can use to determine more accurate cost estimates.

Table 16 Summary of Case Studies of Cost Risks

Author (Year)	Case	Synopsis
Vidalis (2005)	Portland concrete pavement construction	Incorporated risk and probability to achieve overall quality target so the contractor can balance the risk involved in project quality and bidding price.
Creedy (2006)	Risk factors leading to cost overruns in the delivery of highway construction projects	There is a reciprocal relationship between the project budget size and the percentage of cost overruns that the client can use to determine more accurate cost estimates

Summary

The research in risks associated with construction covers a wide range of studies of risk analysis and risk management. The research provides valuable information that can be directly applied to federal construction since the construction process is the similar. Non-federal construction is almost identical to federal construction since the building science used by the AEC Industry is applied to all construction. Therefore the risks associated with any type of construction will also be similar and the research methods and areas of application used in the study of risk can be seamlessly applied to federal construction.

The main difference in non-federal and federal construction from the literature review involves management policies. Federal construction is governed by US Government regulations and for the USAF; there are also DoD and USAF guidelines. These policies are in addition to the standards building codes and practices that are the norm in the construction industry.

Federal construction also has additional factors that must be considered for risk management. The four major components of USAF construction--CI, IT, contract, and cost have unique requirements. The majority of USAF construction can be considered a CIs since it is a system or subsystem of a CI. The IT requirements are more stringent because it operates within a secured network. The contract is covered by the FAR and is managed by the USACE on behalf of the USAF. The cost is fixed and must be approved by the US Congress.

The range of research into risk management in construction provides studies that can be applied to federal construction but because of some unique requirements, there are some limitations of applicability to MILCON.

III. Scholarly Article

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Mission Assurance Implications for Federal Construction by Building Information Modeling Implementation

Abstract

The increasing use of Building Information Modeling in the commercial sector has affected construction in the federal sector. The Architecture, Engineering, and Construction Industry perform design and construction for federal agencies and using Building Information Modeling will impact the federal construction process. Building Information Modeling is a design process that operates in an information technology environment. It contains dynamic and interactive features that allow for greater efficiency in the design and construction of a facility. However, the use of Building Information Modeling in federal construction does present some degree of risk because of these features. The authors identified potential security risks associated with its implementation by studying the United States Air Force Military Construction process. As risks were identified, mitigation measures were recommended. Federal agencies involved in construction must be cognizant of these risks and their related costs

Key words: Building Information Modeling, Military Construction, Federal Construction, Mission Assurance, Critical Infrastructure, Risk

Introduction

As the use of Information Technology (IT) in construction becomes more widespread in the Architecture, Engineering, and Construction (AEC) industry, it will impact federal construction (Suermann, 2009). Most communication between AEC firms and federal agencies are done electronically; these communications include solicitation, proposals, contract documents, and project designs. Solicitation is done by advertising project requirements on the website https://www.fbo.gov/ (Federal Business Opportunities, 2011). AEC firms interested in the project must register for access to the site and can submit their proposal electronically. When an AEC firm is selected for a project, electronic exchange of contract documents between the AEC firm and federal agencies begin (USACE, 2010). This communication grows to include the project design drawings, bill of material, schedules, cost estimates, personnel information, and other construction information. The security of these sensitive communications relies heavily on the IT infrastructure and security protocols (Information Assurance Technology Analysis Center, 2009).

Since Building Information Modeling (BIM) is considered the next generation of design technology (Eastman et al., 2008), its functionality depends on the robustness of the IT system that supports it (Furneaux and Kivits, 2008). BIM will also be affected by existing IT infrastructure and security protocols. The consequences of compromised BIM data will be more significant than conventional design since BIM contains much more details of the project in a single model. These details include a 3-dimensional (3D) model of the facility, bill of material, schedules, cost information, and interactive design

attributes. The risks associated with facility design using BIM is of greater concern to federal agencies like the Department of Defense, who invests a significant amount of money on critical infrastructure, which is expected to be secure and not prone to security breaches.

The Department of Defense Military Construction (MILCON) Budget represents a large amount of construction business for the AEC Industry with an annual average of over $15 billion for the past 10 years (Office of the Undersecretary of Defense, 2010). AEC firms attempt to be most efficient in their construction process to be competitive for federal construction projects. At the same time, federal agencies seek to obtain the best value for the Government when awarding contracts for construction projects (USACE, 2010). BIM offers a method to effectively design a facility while maximizing work performance during construction (Eastman et al., 2008). For these reasons, the AEC Industry and federal agencies, including the United States Air Force (USAF) and United States Army Corps of Engineers (USACE), are currently implementing policies to require the use of BIM in the design and construction of federal facilities (Air Force Center for Engineering and the Environment, 2010). BIM offers the ability to design a 3D model of a facility that exists in a dynamic, interactive environment. BIM models are very detailed and show every aspect of the facility (Eastman et al., 2008). The power of BIM to produce precise and accurate design details poses a security risk to the federal construction process by allowing details not available in conventional 2-dimensional (2D) design to be made public. The concern is greater if the facility is one that handles confidential or classified information such as embassies and intelligence operations (Public Law, 2002).

This paper examines the potential risk to mission assurance involved in implementing BIM in the federal construction process. The study will focus on the MILCON program used by the USAF where the USACE performs the contracting and project management function for military services. The USACE coordinates with the selected AEC firm to execute the construction of the facility on behalf of the USAF (Furneaux and Kivits, 2008).

What is BIM?

BIM is a design process that produces an informational model of a facility; BIM is not considered a product (Eastman et al., 2008). The model is "a computable representation of the physical and functional characteristics of a facility" (Eastman et al., 2008) and is made up of objects represented by graphical lines, shapes, and symbols. The objects contain attributes with specific properties such as product information, solid or void spaces, material specification, and space orientation. These objects allow the model to be conceptual in nature or detailed enough for construction. BIM also provides tools for selecting, extracting, and editing the objects' characteristics. The ability to select and manipulate objects in the model allows for the viewing of specific sections of the model from different orientations. The selected objects remain consistent in size and location in all views. This consistency eliminates these types of errors that occur in 2D modeling.

BIM also defines objects parametrically so that they serve as parameters in relation to other objects. This feature allows for universal editing of an object's property; if a change is made in one object, parametric-related objects would automatically change based on the properties programmed in the original objects (Eastman et al., 2008). Any

change is updated in the entire model; these changes can be as complex as material specification or simple as paint color.

The properties of objects in BIM are also computable, which allows for cost estimation, creation of bills of material, and clash detection before any construction begins. The computability feature can also be used to analyze energy use, lighting, acoustics, heating, and other features that will exist when the facility is complete. These capabilities allow for better collaboration during the design process whereby owners and the AEC firm can explore configuration possibilities. Since BIM exists in an dynamic and interactive environment, designers, engineers, contractors, and subcontractors can view the model in real time and determine how changes would affect their part of the construction.

The current process of facility design uses 2D drawings, which are created by computer-aided design (CAD) software. These techniques produce an electronic 2D drawing that can be transmitted electronically or printed on paper (Eastman et al., 2008). The use of conventional design methods do present some risk, because it contains information needed to construct a facility. However, the risk is considered low since multiple sets of drawings are required to produce a complete model.

The conventional design exists in electronic or paper format and is not as easily visualized as in a 3D model. Although the 2D design process creates and represents all the information needed for the facility, this information exists in separate and distinct drawings. It is difficult to conceptualize a facility and its component systems from a set of 2D drawings. The 2D modeling process does not have the ability to select or deselect various attributes of the design. Designers and engineers incorporate changes in 2D

design by editing paper copies and submitting them to the design owner or CAD operator for revision.

The capabilities of BIM may affect the way in which the federal construction process works, so its implementation must be considered at all steps in the construction process. The USAF MILCON process includes Requirements, Programming, Funding, Solicitation, AEC Evaluation, Award, Project Validation, Design and Construction, and Project Management (USACE, 2010; AFI 32-1023, 2010). Risks can be identified by studying these steps.

MILCON Process

Figure 1 shows the major steps of the MILCON process, which are broadly classified into three phases for this study: the Conception Phase, the Planning Phase, and the Execution Phase. The areas of control for the USAF, the USACE, and AEC are shown on the horizontal tracks. These three entities play specific roles in the construction of federal facilities and must follow federal contracting and construction requirements. The USAF, as the main customer, is involved in all aspects of the MILCON process. The USACE becomes involved once the project is funded, and the AEC firm is involved in the Solicitation, Project Validation, and Design-Build Steps (USACE, 2010; AFI 32-1023, 2010).

Figure 1 also shows the steps of the MILCON process where BIM is used; these steps are highlighted by hatch marks and only these steps will be evaluated and given a risk rating. As risks are identified, the corresponding ratings are determined by using the levels of Threat, Vulnerability, and Consequence for that particular step.

Conception Phase.

The Conception Phase consists of the Requirements, Programming, and Funding Steps. BIM is not used in these steps.

Requirements: Translates a need or request for a facility into quantifiable requirement documents.

Programming: Develops justification for the facility request and seeks approval.

Funding: All MILCON projects must be approved by the United States Congress (USACE, 2010; AFI 32-1023, 2010). For this reason, the project request is vetted and prioritized at several levels before it can be funded. After Funding, the project moves to the Planning Phase.

Planning Phase.

The Planning Phase includes the Solicitation, AEC Evaluation, and Award Steps. In this Phase, BIM is only used in the Solicitation and the AEC Evaluation steps.

Solicitation: Advertises the project and requests bids from interested AEC firms.

AEC Evaluation: Representatives from the USAF and the USACE evaluate bids from the AEC firms and selects the bid that is deemed the best value to the US Government.

Award: Announces which AEC firm was selected for the project. The AEC firm signs a contract with the Government, through the USACE, for the design and construction of the facility.

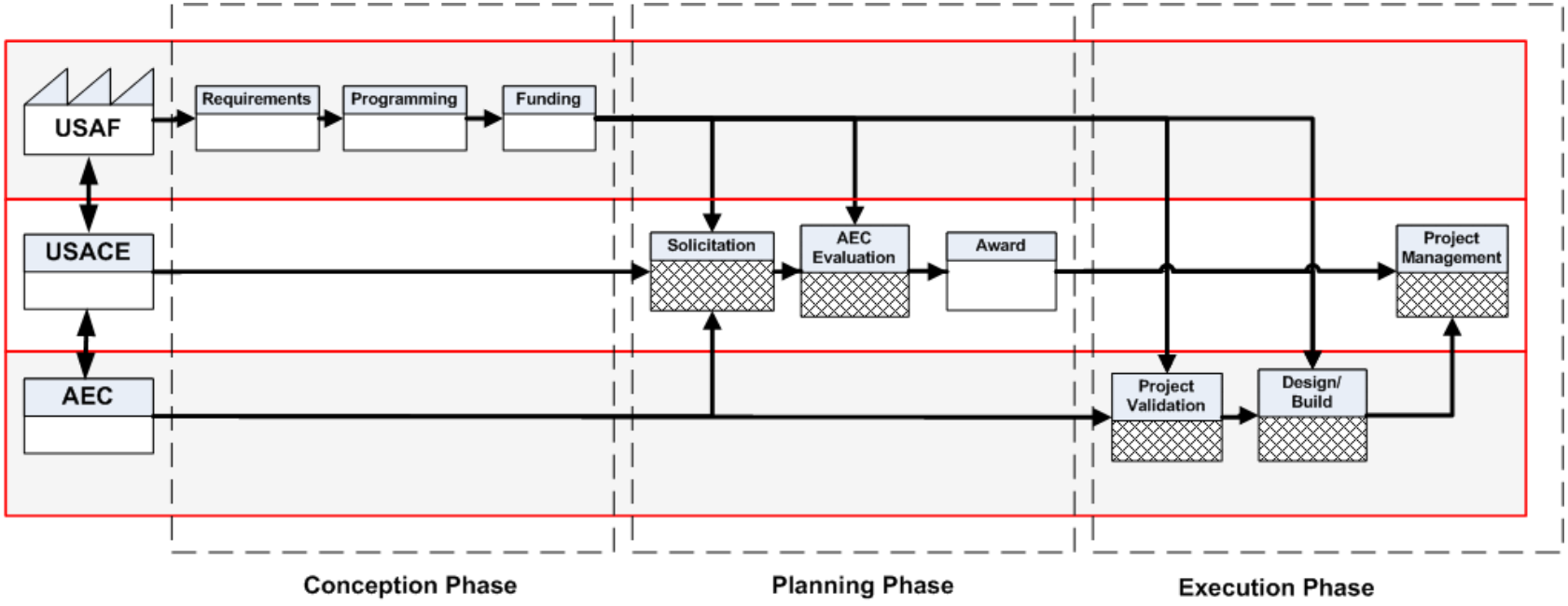

Figure 1 MILCON Process Flow and Areas of Control

Execution Phase.

The Execution Phase consists of Project Validation, Design-Build, and Project Management Steps. Extensive BIM use occurs in this phase of the MILCON process.

Project Validation: Details of the project and contract requirements are coordinated among the USAF, the USACE, and the AEC firm.

Design-Build: The facility design begins and certain type of construction, such as site preparation, may start. The design may go through several iterations before a final design is approved.

Project Management: USACE manages all aspects of the construction and coordinates with the USAFE to resolve any issues.

Risk

The risk of using BIM in federal construction occurs at several key steps in the process. The risk is determined by the factors involved at these steps or by the entity controlling the steps or a combination of factors and control. The risk of compromise of the facility design can be due to the IT requirements of BIM within an agency or communication between agencies. Risk also arises from contractual requirements of the federal acquisition process, which requires communication of design information that introduces additional risk (USACE, 2010; AFI 32-1023, 2010). The risk involved in using BIM in the MILCON process will vary for each phase of the MILCON process and will also vary from one agency to another. From a security perspective, the USAF and USACE primary concern is the compromise of the design and construction of the facility.

However, the AEC firms may be more concerned with protecting their design and bid details from their competitors.

BIM is not involved in the MILCON process until interested AEC firms submit proposals for the construction project. From this point, the risks involved in using BIM begin. However, until the Government selects an AEC firm, the risk rests mainly on the AEC firm submitting the proposal. Personnel representing the Government must be aware of the risks presented by BIM use at this point and ensure security measures are in place. The risks associated with the steps under the USAF control are minimal since BIM is not used in these steps. The risk associated with the steps under the USACE and USAF is higher, because the Solicitation, AEC Review, and Award Steps require the use of BIM. After the contract is awarded, the risk factors become more significant since BIM becomes a major part of the construction process and is most critical at the design phase where it is used extensively.

Risk is an integration of threat, vulnerability, and consequence:

> "*Threat* is a measure of the likelihood that a specific type of attack will be initiated against a specific target.
> *Vulnerability* is a measure of the likelihood that various types of safeguards against threat scenarios will fail.
> *Consequence* is the magnitude of the negative effects if the attack is successful" (Volpe Center, 2003).

The Volpe Center represents this relationship with the following formula (Volpe Center, 2003):

$$Risk = Threat \times Vulnerability \times Consequence \qquad (1)$$

Recent research has shown that there are limitations to this formula when considering terrorists attacks and that risk is a function of its three components (Cox, 2008):

$$Risk = f\,(Threat, Vulnerability, Consequence) \qquad (2)$$

However, the depth of research needed to study this concept is beyond the scope of this paper and the authors used a modified version of Formula (1):

$$Risk = Threat + Vulnerability + Consequence \qquad (3)$$

The risk for each step in the MILCON process is evaluated using this formula where values are assigned to the probability of occurrence of the Threat, Vulnerability, and Consequence based on the Likert Scale (Trochim, 2006). The values and ratings are shown in Table 17. The cumulative value obtained from the formula is then used to determine a value for the risk and its corresponding rating. These values and ratings are also based on Likert Scaling and are shown in Table 18.

Table 17 Rating for risk and its components

Possibility of Occurrence *Threat, Vulnerability, Consequence*			**RISK** *Threat + Vulnerability + Consequence*	
Possibility	**Value**	**Rating**	**RISK Value**	**Risk Rating**
Very Unlikely	1	Very Low	1 - 3	Very Low
Unlikely	2	Low	4 - 6	Low
Possible	3	Medium	7 - 9	Medium
Likely	4	High	10 - 12	High
Very Likely	5	Very High	13 - 15	Very High

Interception of design.

Threat: Since BIM exists in an electronic format, there is the possibility that it may be intercepted during transmittal.

Vulnerability: The use of electronic communication makes any transmission vulnerable to interception. The degree of vulnerability will depend on the network security of each user; the vulnerability will be based on the weakest security system.

Consequence: The consequence of interception can range from loss of confidentiality of the design and contract information to deliberate sabotage of the BIM model. These situations may arise from competition among contractors or acts by terrorist groups.

Recommended Mitigation Measures: AEC firms should employ electronic security protocols to reduce the chances of the design being intercepted. The communication link should be secured to deny unauthorized access to the BIM server. Personnel who evaluate bids must employ strict control over the BIM information to avoid compromising any bids.

Unauthorized distribution.

Threat: Unauthorized Distribution may allow a facility design to reach unintended or unauthorized people or groups.

Vulnerability: Distribution to unapproved or unknown parties may occur because of the ease of sending data electronically. This distribution may occur inadvertently or deliberately.

Consequence: Unauthorized distribution can result in the loss of confidentiality of design and contracting information. Since unauthorized or unintended recipients may not be identified, the facility information is deemed compromised.

Recommended Mitigation Measures: A distribution list of people authorized to send and receive BIM information should be created and updated periodically. The

number of people on this list should be kept at a minimum and only include people who need to send and receive BIM information. The information itself should be encrypted so that in the event unauthorized parties receive it, they will not be able to access it.

Unauthorized Access to BIM Design.

Threat: Unauthorized access is a widespread threat, because it can occur anywhere the design exists and may result in unauthorized distribution and changes to the existing design.

Table 18 Risk associated with BIM use

	MILCON Process Steps Using BIM				
RISK	***Solicitation***	***AEC Evaluation***	***Project Validation***	***Design-Build***	***Project Management***
A. Unauthorized Interception	Threat = 2 → L Vulnerability = 2 → L Consequence = 2 → L RISK = 6 → LOW	Threat = 2 → L Vulnerability = 3 → M Consequence = 3 → M RISK = 8 → MEDIUM	Threat = 2 → L Vulnerability = 2 → L Consequence = 2 → L RISK = 6 → LOW	Threat = 4 → H Vulnerability = 5 → VH Consequence = 4 → H RISK = 13 → VERY HIGH	Threat = 4 → H Vulnerability = 4 → H Consequence = 2 → L RISK = 10 → HIGH
B. Unauthorized Distribution	Threat = 2 → L Vulnerability = 2 → L Consequence = 2 → L RISK = 6 → LOW	Threat = 2 → L Vulnerability = 3 → M Consequence = 3 → M RISK = 8 → MEDIUM	Threat = 2 → L Vulnerability = 3 → M Consequence = 3 → M RISK = 8 → MEDIUM	Threat = 4 → H Vulnerability = 5 → VH Consequence = 4 → H RISK = 13 → VERY HIGH	Threat = 4 → H Vulnerability = 4 → H Consequence = 2 → L RISK = 10 → HIGH
C. Unauthorized Access	Threat = 2 → L Vulnerability = 2 → L Consequence = 3 → M RISK = 7 → MEDIUM	Threat = 2 → L Vulnerability = 2 → L Consequence = 3 → M RISK = 7 → MEDIUM	Threat = 2 → L Vulnerability = 3 → M Consequence = 2 → L RISK = 7 → MEDIUM	Threat = 4 → H Vulnerability = 4 → H Consequence = 4 → H RISK = 12 → HIGH	Threat = 2 → L Vulnerability = 2 → L Consequence = 2 → L RISK = 6 → LOW
D. Unauthorized Alteration	Threat = 3 → M Vulnerability = 3 → M Consequence = 4 → H RISK = 10 → HIGH	Threat = 3 → M Vulnerability = 3 → M Consequence = 3 → M RISK = 9 → MEDIUM	Threat = 2 → L Vulnerability = 3 → M Consequence = 2 → L RISK = 7 → MEDIUM	Threat = 4 → H Vulnerability = 4 → H Consequence = 4 → H RISK = 12 → HIGH	Threat = 2 → L Vulnerability = 2 → L Consequence = 2 → L RISK = 6 → LOW
E. Multiple Designs	Threat = 3 → M Vulnerability = 3 → M Consequence = 4 → H RISK = 10 → HIGH	Threat = 3 → M Vulnerability = 3 → M Consequence = 3 → M RISK = 9 → MEDIUM	Threat = 2 → L Vulnerability = 3 → M Consequence = 2 → L RISK = 7 → MEDIUM	Threat = 5 → VH Vulnerability = 5 → VH Consequence = 5 → VH RISK = 15 → VERY HIGH	Threat = 5 → VH Vulnerability = 5 → VH Consequence = 5 → VH RISK = 15 → VERY HIGH
F. Server Compromise	Threat = 4 → H Vulnerability = 4 → H Consequence = 5 → VH RISK = 13 → VERY HIGH	Threat = 2 → L Vulnerability = 2 → L Consequence = 2 → L RISK = 6 → LOW	Threat = 2 → L Vulnerability = 2 → L Consequence = 2 → L RISK = 6 → LOW	Threat = 5 → VH Vulnerability = 4 → H Consequence = 5 → VH RISK =14 → VERY HIGH	Threat = 4 → H Vulnerability = 3 → M Consequence = 3 → L RISK = 10 → HIGH
G. Alteration Errors	Threat = 3 → M Vulnerability = 3 → M Consequence = 4 → H RISK = 10 → HIGH	Threat = 2 → L Vulnerability = 2 → L Consequence = 2 → L RISK = 6 → LOW	Threat = 2 → L Vulnerability = 2 → L Consequence = 2 → L RISK = 6 → LOW	Threat = 5 → VH Vulnerability = 5 → VH Consequence = 5 → VH RISK = 15 → VERY HIGH	Threat = 3 → M Vulnerability = 3 → M Consequence = 3 → M RISK = 9 → MEDIUM
H. Management Errors	Threat = 2 → L Vulnerability = 2 → L Consequence = 2 → L RISK = 6 → LOW	Threat = 2 → L Vulnerability = 2 → L Consequence = 2 → L RISK = 6 → LOW	Threat = 4 → H Vulnerability = 4 → H Consequence = 4 → H RISK = 12 → HIGH	Threat = 5 → VH Vulnerability = 4 → H Consequence = 5 → VH RISK =14 → VERY HIGH	Threat = 4 → H Vulnerability = 4 → H Consequence = 5 → VH RISK = 13→ VERY HIGH

Vulnerability: Unauthorized access to the design is possible if adequate security protocols are not in place. The degree of vulnerability depends on the security of the locations where the design information is kept.

Consequence: Unauthorized access can compromise the design and contracting information. Unauthorized distribution and design changes may occur and not be discovered.

Recommended Mitigation Measures: The layers of security that protect BIM information must be in place and evaluated frequently. Since all access points must meet the required security level, there should be security protocol agreement at the initial meeting of the USAF, USACE, and the AEC firm.

Unauthorized Alteration of Design.

Threat: Unknown or unauthorized changes in the design can occur without detection. This may be inadvertent or deliberate.

Vulnerability: Once there is access to the BIM information, anyone who has the knowledge can make changes to the BIM design. The degree of vulnerability is based on the vulnerability of access to the design.

Consequence: Unknown or unauthorized changes in the design can ultimately result in a design and facility that was not originally conceived or approved. However, any significant alteration will eventually be discovered so the effect will not be substantial.

Recommended Mitigation Measures: A design team should be designated. This team can produce read-only designs for people who do not need to make design changes. The design team should be the only body authorized to makes changes to the design.

Additionally, there should be a log to record who accessed the design and document any changes that were made. A backup system should be installed to memorialize several past designs in case changes need to be undone.

Multiple Designs.

Threat: Since BIM operates in a dynamic and multi-user environment, there will be multiple users making design alteration within their purview. This will result in multiple versions of the design and there will need to be a process to incorporate all changes and resolved any clashes.

Vulnerability: Multiple versions of the design is very common since there are multiple users contributing to the model. Designers will focus on their specialty leading to multiple version of the design.

Consequence: Each construction specialty will edit their parts of the design resulting in numerous versions. With multiple designs, there will be some degree of confusion and unnecessary work to incorporate all the different versions in a single model. This can lead to construction clashes and the unnecessary performance of work based on the wrong design.

Recommended Mitigation Measures: Individual design changes must be discouraged or prevented. The project team must approve any changes to the original BIM design. Additionally, the person who makes the final decision and approves all changes must be identified. The project team should designate a design entity that is responsible for control the master copy of the BIM design. This entity should approve and perform any changes to the design. The legal status of who "owns" the design must also be resolved to prevent any litigation that may arise after construction (Furneaux and

Kivits, 2008). The possibility exists that individuals who make changes to the design may stake some claim to the final design.

Server Compromise.

Threat: Since BIM exists and functions on an electronic platform, this platform must be networked to allow for collaboration and coordination of multiple users. The facility design is susceptible to compromise if there is uncontrolled access to this platform.

Vulnerability: In order for BIM to be dynamic and interactive, it must operate on a server to allow multiple users. With multiple users accessing the BIM design, the chance for compromise by alteration, distribution, or destruction increases.

Consequence: The compromise of the BIM server can result in the alteration and distribution of the facility design. The design can also be damage, destroyed, or deleted.

Recommended Mitigation Measures: The BIM server can be protected by having effective IT infrastructure and security protocols in place. Additionally, personnel must be trained and vetted to ensure they know how to operate the system and can be trusted.

Alteration Errors.

Threat: Revisions and edits presented by the three agencies may result in a design containing errors and may affect the construction of the facility.

Vulnerability: With a relatively large amount of people from three different agencies making or suggesting numerous changes and updates to the design, there is the possibility that errors may be included. These errors may go unnoticed since there are multiple people working on the design.

Consequence: Alteration errors will produce a facility design that contains flaws. If these inaccurate changes are not detected, the construction process and the actual facility or it composite sections may be also be flawed.

Recommended Mitigation Measures: The three agencies must designate a 'design team' to coordinate all alteration and edits to the design. This team should be responsible for compiling, tracking, and performing all edits.

Management Errors.

Threat: With three separate agencies involved in federal construction, there is the possibility that there will be conflicting directions from different personnel. This can result in duplication of effect, errors in design, and possible legal claims.

Vulnerability: Numerous inputs from different agencies can result in errors. The more input there is the greater there is the chance for error.

Consequence: Management errors will result in design flaws and possibly flaws in the facility itself. Additionally, since there are legal contractual requirements for federal personnel, the AEC firm can file claims against the Government for following unauthorized directions.

Recommended Mitigation Measures: The project team must identify who the key decision-makers are and what their level of responsibility and authority is. These decision-makers should coordinate all requirements with their agencies before making presentations to the other agencies.

Risk and Cost

The amount of risk the project team is willing to accept affects the project cost. Figure 2 shows a relationship of risk planning and cost using three curves. Curves 1 and Curve 2 work in concert with each other. If a project team plans for a high degree of risk, initial cost for mitigation measures will be high and if a risk event occurs, there will be low consequential cost. Conversely, if a project team plans for a low degree of risk and a risk event occurs, there will be high consequential cost since fewer mitigation measures are in place. Curve 3 is the combination of costs from Curve 1 and Curve 2. The intersection of Curve 1 and Curve 2 lies within the best value region of total risk costs. Management Teams should balance Curve 3 with other project costs.

This concept can be shown by considering Risk D - Unauthorized Alteration: an unwanted change to the design may go undetected and cause other aspects of the design to be flawed. Once the mistake is discovered, it will take additional man-hours and time to correct the flaw. The mitigation cost in this example will be to invest in backup systems to record the design at various stages and hire additional personnel to control design inputs. The consequential cost is the time and man-hours spent on tracing the change and correcting design errors caused by it. The project team must decide what risks and cost they are willing to accept.

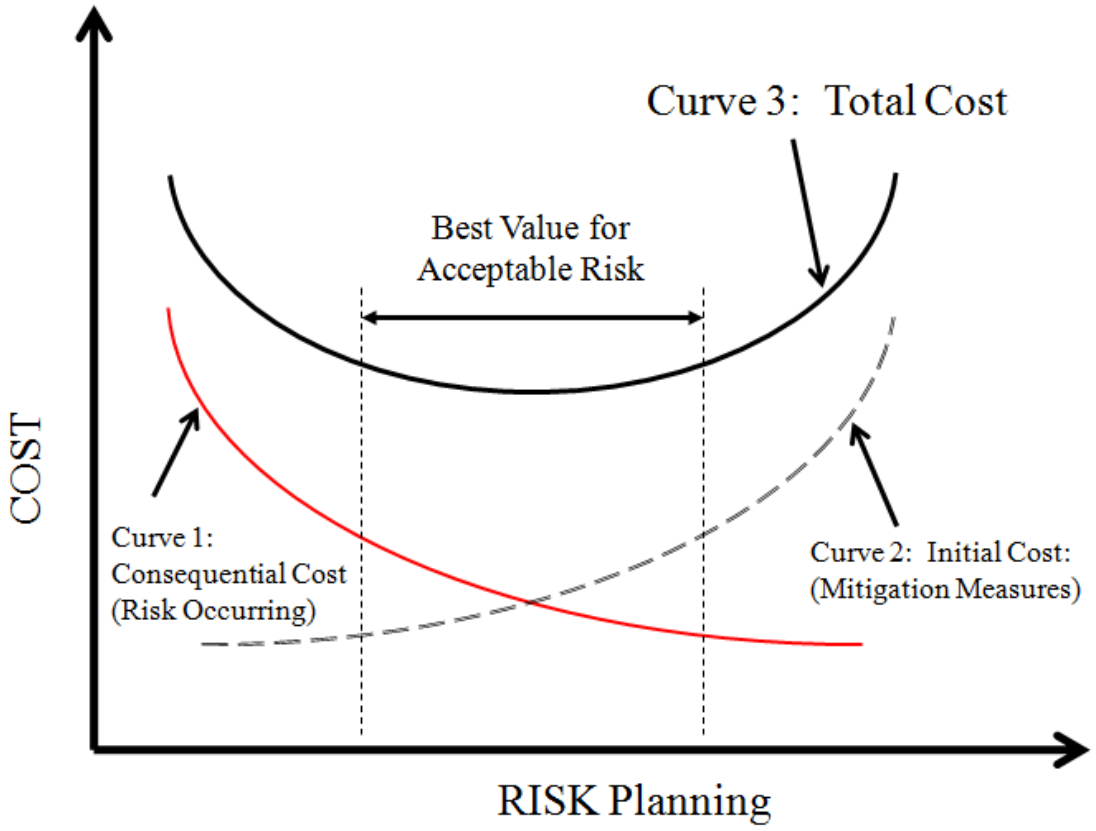

Figure 2 Relationship between cost and risk (Bea, 2009)

Conclusion

The AEC have advocated the benefits of BIM and federal agencies have begun to formulate policies for its implementation. Federal construction will be impacted by this implementation since BIM design involves changing certain procedures that are used in current construction process using 2D design. While BIM has tremendous benefits in the production and collaboration of a facility design, there are some risks associated with its use. Some of the features that make it more efficient than conventional design are the same features that produce vulnerabilities. These risks are especially important for

federal construction when critical infrastructure is involved and greater security is needed. The vulnerability in each step of the process that involves BIM must be analyzed to identify and mitigate any potential risk. The project team and the facility owner must decide how much risk they are willing to undertake and how much money they are willing to mitigate risks. They must balance these costs and risk throughout the project since each phase presents different levels of risk. On the surface, it may appear that the majority of risks associated with BIM seem IT related; however, the federal construction process has unique requirements that must be considered when using BIM. The authors understand that this paper is an initial assessment of the risks associated with BIM implementation; however, it provides a framework for further investigation by other federal agencies.

References

The references of this article are combined with the thesis.

IV. Conclusion

Overview

This chapter summarizes the results and findings of the research. The literature review provided a large and comprehensive background on the methods used in the study of risk analysis and risk management. The majority of these methods were based on the management and governing policies for the particular operation for the risk. The risk management decisions for the given process were based on the information gathered from the risk analysis and the policies governing the operation. The majority of studies indicated that risk management must consider the integration of the components of risk--threats, vulnerabilities, and consequences; in the methods, management, and application of risk. This integration was seen in the case studies. The literature review also revealed there was a strong relationship among the four major components of MILCON. This relationship was very close for the CI and IT, where IT was sometimes considered a CI on its own. In addition, contract and cost were closely linked since a contract is created for the performance of work based on an agreed cost.

The risk analysis of BIM implementation showed the significant role that IT plays in the MILCON process. The analysis also revealed that although most of the risks are IT-related, there are other risks involving the federal construction process. The BIM implementation risk analysis also showed the importance of the cost of risk in a construction project where the cost of mitigating a risk was compared to the consequential cost of a risk occurring. The analysis indicated that the project

management team must consider the total risk cost for the project and balance this risk cost between mitigation measures and the cost of the consequences of the risk occurring. The study recommends a best value region for risk cost based on the total project cost as shown in Figure 2.

Significance of Research

The finding in this research shows that risk analysis and risk management is an important factor in construction and knowledge gained from risk research can be incorporated into the federal construction process. The literature review provides a starting point for further detailed research into the specific areas of risk in construction. This literature review can be used as a database of research into construction risk and aid in raising questions and suggesting areas for further investigation.

The risk analysis of BIM implementation identified the specific risks, the severity, the consequences, and possible mitigation measures. It provides a framework for other investigations into the specific threats, vulnerabilities, consequences, and mitigation measures presented. As BIM is implemented by other federal agencies, this research can provided an overview of some of the risk involved so stakeholders will have information to make risk management decisions.

Future Research

The research presented in this thesis can be used as a source of reference for further study of risk into the specific areas of concern for an organization. Although there are several existing methods for conducting risk analysis, further research to other

methods with specific application to federal construction will be beneficial. A central area of focus is the development of a more robust model to analysis undefined threats such, terrorism and natural disasters. In addition, a quantitative risk formula will remove some of the bias and limit personal perspective from risk management decisions. Areas that warrant further studies include:

- Quantitative risk formula
- Risk analysis methods for terrorism and natural disaster
- Policy for AEC risk management for federal construction
- Status of risk management by other federal agencies
- Interaction of BIM with other IT processes, such as GIS and contracting documents
- The cost of BIM implementation: software, additional hardware, network configuration, maintenance, training, value to USAF

Summary

Risk is an inherent aspect of any project or operation and it must be considered during the design and construction of USAF facilities and infrastructure. A risk analysis of an operation helps determine the threats, vulnerabilities, and consequences for a particular process. An integrated view of these components of risk is used in risk management where decision-makers balance the cost of risk mitigation and cost of risk consequences.

The risk analysis of BIM implementation shows there are significant IT-related risks in using BIM. By knowing and understanding the specific threats, its significance,

and its cost, management can choose to mitigate the risk or accept the consequences. An operation can be made safer by investing a large amount of money in mitigation measures; the project management team must balance how much money to spend and how much risk to accept.

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Vita

Captain Krishna R. Surajbally graduated from St. Stephen's College High School in Princes Town, Trinidad. He later enlisted in the United States Air Force and was assigned to MacDill AFB, Florida. He then attended University of South Florida, Tampa, where he also enrolled in the AFROTC program at Detachment 158. On December 2001, he graduated with a Bachelors of Science degree in Industrial Engineering and was commissioned as a Second Lieutenant.

After commissioning, Capt Surajbally was assigned to Minot AFB, North Dakota and then to Hurlburt Field AFB, Florida. During his assignments, he served in various positions in the Civil Engineering career field and was deployed on several occasions to support operations in Saudi Arabia, Iraq, Afghanistan, and Kyrgyzstan. In August 2009, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology to pursue a Master of Science degree in Engineering Management. He will be assigned to Head Quarters Air Education and Training Command upon graduating.

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1. Type of Product:	2. Operating System/Version:	3. New Product or Replacement:	4. Type of File:
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Four (4) files	Not Applicable	700 MB
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27. Abstract:

The rise in terrorism, corporate espionage, cyber attacks, and federal fiscal constraints play an important role in the federal construction process. The risks associated with these occurrences are studied to aid in the risk management of the military construction process. This paper presents the status of research into these areas to identify how methods, policies, applications, and information obtained from case studies can be used by stakeholders to manage risk in the United States Air Force construction process.
The author reviewed research on risk associated with four essential components of the military construction process -- Critical Infrastructure, Information Technology, Contracts, and Cost in the construction and related industry. This study focused on the methodology, management policy, areas of application, and case studies research of the construction and related industry.

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Peter Feng, Lt Col, USAF
(937) 255-3636 ext 4648
peter.feng@afit.edu

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Air Force Center for Engineering and the Environment
Kelly AFB, TX 78241 patrick.suermann@us.af.mil
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